Click Here

Brand of computer products RadeonTop: LogoBottom: The most recent flagship model, the AMD Radeon RX 7900 XTXRelease date1 April 2000; 25 years ago (2000-04-01) by ATI TechnologiesManufactured byATI TechnologiesAMDSamsungTSMCDesigned byATI (2000–2006)AMD (2006–present)Models2000–02: Radeon 7000, 8000, 9000 series 2004–05: Radeon X300-X600, X700, X800, X1000 series2007–13: Radeon HD 2000, HD 3000, HD 4000, HD 5000, HD 6000, HD 7000, HD 8000 series2013–present: Radeon R5/R7/R9 200, R5/R7/R9 300, RX 400, RX 500, RX Vega, RX 5000, RX 6000, RX 7000, RX 9000 seriesTransistors R100 30M 180 nm R200 60M 150 nm R360 117M 150 nm R481 160M 130 nm RV410 120M 110 nm R580 384M 80 nm R600 700M 80 nm RV670 666M 55 nm RV790 959M 55 nm Cypress 2,154M 40 nm Cayman 2,640M 40 nm Tahiti 4,313M 28 nm Hawaii 6,200M 28 nm Fiji 8,900M 28 nm Polaris 5,700M 14 nm Vega 12,500M 14 nm Vega II 13,230M 7 nm Navi 10,300M 7 nm Navi 2X 26,800M 7 nm Navi 3X 58,000M 5 nm Navi 4X 53,900M 4 nm Fabrication process180 nm to 4 nmHistoryPredecessorRage Radeon (/ˈreɪdiɒn/) is a brand of computer products, including graphics processing units, random-access memory, RAM disk software, and solid-state drives, produced by Radeon Technologies Group, a division of AMD.[1] The brand was launched in 2000 by ATI Technologies, which was acquired by AMD in 2006 for US$5.4 billion. Radeon Graphics is the successor to the Rage line. Four different families of microarchitectures can be roughly distinguished, the fixed-pipeline family, the unified shader model-families of TeraScale, Graphics Core Next, and RDNA. ATI/AMD have developed different technologies, such as TruForm, HyperMemory, HyperZ, XGP, Eyefinity for multi-monitor setups, PowerPlay for power-saving, CrossFire (for multi-GPU) or Hybrid Graphics. A range of SIP blocks is also to be found on certain models in the Radeon products line: Unified Video Decoder, Video Coding Engine and TrueAudio. The brand was previously only known as "ATI Radeon" until August 2010, when it was renamed to increase AMD's brand awareness on a global scale.[2] Products up to and including the HD 5000 series are branded as ATI Radeon, while the HD 6000 series and beyond use the new AMD Radeon branding.[3] On 11 September 2015, AMD's GPU business was split into a separate unit known as Radeon Technologies Group, with Raja Koduri as Senior Vice President and chief architect.[1][4] AMD does not distribute Radeon cards directly to consumers (though some exceptions can be found).[5] Instead, it sells Radeon GPUs to third-party manufacturers, who build and sell the Radeon-based video cards to the OEM and retail channels. Manufacturers of the Radeon cards—some of whom also make motherboards—include ASRock, Asus, Biostar, Club 3D, Diamond, Force3D, Gainward, Gigabyte, HIS, PowerColor, Sapphire, VisionTek, and XFX. Generations timeline Fixed-pipeline family TeraScale-family Graphics Core Next-family RDNA-family 2000Radeon R1002001Radeon R2002002Radeon R30020032004Radeon R4002005Radeon R50020062007Radeon R600Radeon RV6702008Radeon R7002009Evergreen2010Northern Islands20112012Southern Islands2013Sea Islands20142015Volcanic Islands2016Arctic Islands2017PolarisVega20182019Navi2020Navi 2X20212022Navi 3X Early generations were identified with a number and major/minor alphabetic prefix. Later generations were assigned code names. New or heavily redesigned architectures have a prefix of R (e.g., R300 or R600) while slight modifications are indicated by the RV prefix (e.g., RV370 or RV635). The first derivative architecture, RV200, did not follow the scheme used by later parts. Main article: Radeon R100 series The Radeon, first introduced in 2000, was ATI's first graphics processor to be fully DirectX 7 compliant. R100 brought with it large gains in bandwidth and fill-rate efficiency through the new HyperZ technology. The RV200 was a die-shrink of the former R100 with some core logic tweaks for clockspeed, introduced in 2002. The only release in this generation was the Radeon 7500, which introduced little in the way of new features but offered substantial performance improvements over its predecessors. Main article: Radeon R200 series ATI's second generation Radeon included a sophisticated pixel shader architecture. This chipset implemented Microsoft's pixel shader 1.4 specification for the first time. Its performance relative to competitors was widely perceived as weak, and subsequent revisions of this generation were cancelled to focus on development of the next generation. Main article: Radeon R300 series The R300 was the first GPU to fully support Microsoft's DirectX 9.0 technology upon its release in 2001. It incorporated fully programmable pixel and vertex shaders. About a year later, the architecture was revised to allow for higher frequencies, more efficient memory access, and several other improvements in the R350 family. A budget line of RV350 products was based on this refreshed design with some elements disabled or removed. Models using the new PCI Express interface were introduced in 2004. Using 110-nm and 130-nm manufacturing technologies under the X300 and X600 names, respectively, the RV370 and RV380 graphics processors were used extensively by consumer PC manufacturers. While heavily based upon the previous generation, this line included extensions to the Shader Model 2 feature-set. Shader Model 2b, the specification ATI and Microsoft defined with this generation, offered somewhat more shader program flexibility. ATI's DirectX 9.0c series of graphics cards, with complete shader Model 3.0 support. Launched in October 2005, this series brought a number of enhancements including the floating point render target technology necessary for HDR rendering with anti-aliasing. Main article: TeraScale (microarchitecture) Main articles: Radeon HD 2000 series and Radeon HD 3000 series ATI's first series of GPUs to replace the old fixed-pipeline and implement unified shader model. Subsequent revisions tuned the design for higher performance and energy efficiency, resulting in the ATI Mobility Radeon HD series for mobile computers. Main article: Radeon HD 4000 series Based on the R600 architecture. Mostly a bolstered with many more stream processors, with improvements to power consumption and GDDR5 support for the high-end RV770 and RV740(HD4770) chips. It arrived in late June 2008. The HD 4850 and HD 4870 have 800 stream processors and GDDR3 and GDDR5 memory, respectively. The 4890 was a refresh of 4870 with the same amount of stream processors yet higher clock rates due to refinements. The 4870x2 has 1600 stream processors and GDDR5 memory on an effective 512-bit memory bus with 230.4 Gbit/s video memory bandwidth available. Main article: Radeon HD 5000 series The series was launched on 23 September 2009. It featured a 40 nm fabrication process for the entire product line (only the HD4770 (RV740) was built on this process previously), with more stream cores and compatibility with the next major version of the DirectX API, DirectX 11, which launched on 22 October 2009 along with Microsoft Windows 7. The Rxxx/RVxxx codename scheme was scrapped entirely. The initial launch consisted of only the 5870 and 5850 models. ATI released beta drivers that introduced full OpenGL 4.0 support on all variants of this series in March 2010.[6] Main article: Radeon HD 6000 series Radeon logo from 2011 to 2013 This is the first series to be marketed solely under the "AMD" brand. It features a 3rd generation 40 nm design, rebalancing the existing architecture with redesigned shaders to give it better performance. It was released first on 22 October 2010, in the form of the 6850 and 6870. 3D output is enabled with HDMI 1.4a and DisplayPort 1.2 outputs. Main article: Graphics Core Next AMD Radeon logo from 26 May 2016[7] – 27 October 2020 Main article: Radeon HD 7000 series "Southern Islands" was the first series to feature the new compute microarchitecture known as "Graphics Core Next"(GCN). GCN was used among the higher end cards, while the VLIW5 architecture utilized in the previous generation was used in the lower end, OEM products. However, the Radeon HD 7790 uses GCN 2, and was the first product in the series to be released by AMD on 9 January 2012. Main article: Radeon HD 8000 series The "Sea Islands" were OEM rebadges of the 7000 series, with only three products, code named Oland, available for general retail. The series, just like the "Southern Islands", used a mixture of VLIW5 models and GCN models for its desktop products. Main article: Radeon 200 series "Volcanic Islands" GPUs were introduced with the AMD Radeon RX 200 series, and were first released in late 2013.[8] The Radeon RX 200 line is mainly based on AMD's GCN architecture, with the lower end, OEM cards still using VLIW5. The majority of desktop products use GCN 1, while the R9 290x/290 & R7 260X/260 use GCN 2, and with only the R9 285 using the new GCN 3.[9] Main article: Radeon 300 series GPUs codenamed "Caribbean Islands"[10] were introduced with the AMD Radeon RX 300 series, released in 2015. This series was the first to solely use GCN based models, ranging from GCN 1st to GCN 3rd Gen, including the GCN 3-based Fiji-architecture models named Fury X, Fury, Nano and the Radeon Pro Duo. Main articles: Radeon 400 series and Radeon 500 series GPUs codenamed "Arctic Islands" were first introduced with the Radeon RX 400 series in June 2016 with the announcement of the RX 480.[11] These cards were the first to use the new Polaris chips which implements GCN 4th Gen on the 14 nm fab process. The RX 500 series released in April 2017 also uses Polaris chips.[12] Main article: Radeon RX Vega series Main article: RDNA (microarchitecture) Main article: Radeon RX 5000 series On 27 May 2019, at COMPUTEX 2019, AMD announced the new 'RDNA' graphics micro-architecture,[13] which is to succeed the Graphics Core Next micro-architecture. This is the basis for the Radeon RX 5700-series graphics cards, the first to be built under the codename 'Navi'. These cards feature GDDR6 SGRAM and support for PCI Express 4.0. Main article: Radeon RX 6000 series On 5 March 2020, AMD publicly announced its plan to release a "refresh" of the RDNA micro-architecture.[14] Dubbed as the RDNA 2 architecture, it was stated to succeed the first-gen RDNA micro-architecture and was initially scheduled for a release in Q4 2020. RDNA 2 was confirmed as the graphics microarchitecture featured in the Xbox Series X and Series S consoles[15] from Microsoft, and PlayStation 5[16] from Sony, with proprietary tweaks and different GPU configurations in each systems' implementation. AMD unveiled the Radeon RX 6000 series, its next-gen RDNA 2 graphics cards at an online event on 28 October 2020.[17][18] The lineup consists of the RX 6800, RX 6800 XT and RX 6900 XT.[19][20] The RX 6800 and 6800 XT launched on 18 November 2020, with the RX 6900 XT being released on 8 December 2020.[21] Further variants including a Radeon RX 6700 (XT) series based on Navi 22, launched on 18 March 2021, a Radeon RX 6600(XT) series based on Navi 23, launched on 11 August 2021 (that is the 6600XT release date, the RX 6600 launched on 13 October 2021), and a Radeon RX 6500(XT), launched on 19 January 2022.[22][23][24][25][26] Further information: ROCm and GPUOpen Some generations vary from their predecessors predominantly due to architectural improvements, while others were adapted primarily to new manufacturing processes with fewer functional changes. The table below summarizes the APIs supported in each Radeon generation (including pre-Radeon ATI GPUs). Also see AMD FireStream and AMD FirePro branded products. The following table shows the graphics and compute APIs support across ATI/AMD GPU microarchitectures. Note that this table include microarchitectures used in ATI products prior to Radeon, and a branding series might include older generation chips. [VisualEditor] viewtalkedit Chip series Microarchitecture Fab Supported APIs AMD support Year introduced Introduced with Rendering Computing / ROCm Vulkan[27] OpenGL[28] Direct3D HSA OpenCL Wonder Fixed-pipeline[a] 1000 nm800 nm — — — — — Ended 1986 Graphics Solutions Mach 800 nm600 nm 1991 Mach8 3D Rage 500 nm 1.0 1996 3D Rage Rage Pro 350 nm 1.1 6.0 1997 Rage Pro Rage 128 250 nm 1.2 1998 Rage 128 GL/VR R100 180 nm150 nm 1.3 7.0 2000 Radeon R200 Programmablepixel & vertexpipelines 150 nm 8.1 2001 Radeon 8500 R300 150 nm130 nm110 nm 2.0[b] 9.011 (FL 9_2) 2002 Radeon 9700 R420 130 nm110 nm 9.0b11 (FL 9_2) 2004 Radeon X800 R520 90 nm80 nm 9.0c11 (FL 9_3) 2005 Radeon X1800 R600 TeraScale 1 80 nm65 nm 3.3 10.011 (FL 10_0) ATI Stream 2007 Radeon HD 2900 XT RV670 55 nm 10.111 (FL 10_1) ATI Stream APP[29] Radeon HD 3850/3870 RV770 55 nm40 nm 1.0 2008 Radeon HD 4850/4870 Evergreen TeraScale 2 40 nm 4.5(Linux 4.2)[30][31][32][c] 11 (FL 11_0) 1.2 2009 Radeon HD 5850/5870 Northern Islands TeraScale 2TeraScale 3 2010 Radeon HD 6850/6870Radeon HD 6950/6970 Southern Islands GCN 1st gen 28 nm 1.0 4.6 11 (FL 11_1)12 (FL11_1) 1.22.0 possible 2012 Radeon HD 7950/7970 Sea Islands GCN 2nd gen 1.2 11 (FL 12_0)12 (FL 12_0) 2.0(1.2 in MacOS, Linux)2.1 Beta in Linux ROCm2.2 possible 2013 Radeon HD 7790 Volcanic Islands GCN 3rd gen 2014 Radeon R9 285 Arctic Islands GCN 4th gen 28 nm14 nm 1.2 1.3 (GCN 4) Supported 2016 Radeon RX 480 Polaris 2017 Radeon 520/530Radeon RX 530/550/570/580 Vega GCN 5th gen 14 nm7 nm 1.3 11 (FL 12_1)12 (FL 12_1) 2017 Radeon Vega Frontier Edition Navi RDNA 7 nm 2019 Radeon RX 5700 (XT) Navi 2X RDNA 2 7 nm6 nm 11 (FL 12_1)12 (FL 12_2) 2020 Radeon RX 6800 (XT) Navi 3X RDNA 3 6 nm5 nm 2022 Radeon RX 7900 XT(X) ^ Radeon 7000 Series has programmable pixel shaders, but do not fully comply with DirectX 8 or Pixel Shader 1.0. See article on R100's pixel shaders. ^ These series do not fully comply with OpenGL 2+ as the hardware does not support all types of non-power-of-two (NPOT) textures. ^ OpenGL 4+ compliance requires supporting FP64 shaders and these are emulated on some TeraScale chips using 32-bit hardware. [33][34][35] The following table shows features of AMD/ATI's GPUs (see also: List of AMD graphics processing units). [VisualEditor] viewtalkedit Name of GPU series Wonder Mach 3D Rage Rage Pro Rage 128 R100 R200 R300 R400 R500 R600 RV670 R700 Evergreen NorthernIslands SouthernIslands SeaIslands VolcanicIslands ArcticIslands/Polaris Vega Navi 1x Navi 2x Navi 3x Navi 4x Released 1986 1991 Apr1996 Mar1997 Aug1998 Apr2000 Aug2001 Sep2002 May2004 Oct2005 May2007 Nov2007 Jun2008 Sep2009 Oct2010 Dec2010 Jan2012 Sep2013 Jun2015 Jun 2016, Apr 2017, Aug 2019 Jun 2017, Feb 2019 Jul2019 Nov2020 Dec2022 Feb2025 Marketing Name Wonder Mach 3DRage RagePro Rage128 Radeon7000 Radeon8000 Radeon9000 RadeonX700/X800 RadeonX1000 RadeonHD 2000 RadeonHD 3000 RadeonHD 4000 RadeonHD 5000 RadeonHD 6000 RadeonHD 7000 Radeon200 Radeon300 Radeon400/500/600 RadeonRX Vega, Radeon VII RadeonRX 5000 RadeonRX 6000 RadeonRX 7000 RadeonRX 9000 AMD support Kind 2D 3D Instruction set architecture Not publicly known TeraScale instruction set GCN instruction set RDNA instruction set Microarchitecture Not publicly known GFX1 GFX2 TeraScale 1(VLIW5)(GFX3) TeraScale 2(VLIW5)(GFX4) TeraScale 2(VLIW5) up to 68xx(GFX4) TeraScale 3(VLIW4) in 69xx [36][37](GFX5) GCN 1stgen(GFX6) GCN 2ndgen(GFX7) GCN 3rdgen(GFX8) GCN 4thgen(GFX8) GCN 5thgen(GFX9) RDNA(GFX10.1) RDNA 2(GFX10.3) RDNA 3(GFX11) RDNA 4(GFX12) Type Fixed pipeline[a] Programmable pixel & vertex pipelines Unified shader model Direct3D — 5.0 6.0 7.0 8.1 9.011 (9_2) 9.0b11 (9_2) 9.0c11 (9_3) 10.011 (10_0) 10.111 (10_1) 11 (11_0) 11 (11_1)12 (11_1) 11 (12_0)12 (12_0) 11 (12_1)12 (12_1) 11 (12_1)12 (12_2) Shader model — 1.4 2.0+ 2.0b 3.0 4.0 4.1 5.0 5.1 5.16.5 6.7 6.8 OpenGL — 1.1 1.2 1.3 2.1[b][38] 3.3 4.5[39][40][41][c] 4.6 Vulkan — 1.1[c][d] 1.3[42] 1.4[43] OpenCL — Close to Metal 1.1 (not supported by Mesa) 1.2+ (on Linux: 1.1+ (no Image support on clover, with by rustiCL) with Mesa, 1.2+ on GCN 1.Gen) 2.0+ (Adrenalin driver on Win7+)(on Linux ROCM, Mesa 1.2+ (no Image support in clover, but in rustiCL with Mesa, 2.0+ and 3.0 with AMD drivers or AMD ROCm), 5th gen: 2.2 win 10+ and Linux RocM 5.0+ 2.2+ and 3.0 windows 8.1+ and Linux ROCM 5.0+ (Mesa rustiCL 1.2+ and 3.0 (2.1+ and 2.2+ wip))[44][45][46] HSA / ROCm — ? Video decoding ASIC — Avivo/UVD UVD+ UVD 2 UVD 2.2 UVD 3 UVD 4 UVD 4.2 UVD 5.0 or 6.0 UVD 6.3 UVD 7 [47][e] VCN 2.0 [47][e] VCN 3.0 [48] VCN 4.0 VCN 5.0 Video encoding ASIC — VCE 1.0 VCE 2.0 VCE 3.0 or 3.1 VCE 3.4 VCE 4.0 [47][e] Fluid Motion [f] ? Power saving ? PowerPlay PowerTune PowerTune & ZeroCore Power ? TrueAudio — Via dedicated DSP Via shaders FreeSync — 12 HDCP[g] — ? 1.4 2.2 2.3 [49] PlayReady[g] — 3.0 3.0 Supported displays[h] 1–2 2 2–6 ? 4 Max. resolution ? 2–6 ×2560×1600 2–6 ×4096×2160 @ 30 Hz 2–6 ×5120×2880 @ 60 Hz 3 ×7680×4320 @ 60 Hz [50] 7680×4320 @ 60 Hz PowerColor 7680x4320 @165 Hz 7680x4320 /drm/radeon[i] — /drm/amdgpu[i] — Optional [51] ^ The Radeon 100 Series has programmable pixel shaders, but do not fully comply with DirectX 8 or Pixel Shader 1.0. See article on R100's pixel shaders. ^ R300, R400 and R500 based cards do not fully comply with OpenGL 2+ as the hardware does not support all types of non-power of two (NPOT) textures. ^ a b OpenGL 4+ compliance requires supporting FP64 shaders and these are emulated on some TeraScale chips using 32-bit hardware. ^ Vulkan support is theoretically possible but has not been implemented in a stable driver. ^ a b c The UVD and VCE were replaced by the Video Core Next (VCN) ASIC in the Raven Ridge APU implementation of Vega. ^ Video processing for video frame rate interpolation technique. In Windows it works as a DirectShow filter in your player. In Linux, there is no support on the part of drivers and / or community. ^ a b To play protected video content, it also requires card, operating system, driver, and application support. A compatible HDCP display is also needed for this. HDCP is mandatory for the output of certain audio formats, placing additional constraints on the multimedia setup. ^ More displays may be supported with native DisplayPort connections, or splitting the maximum resolution between multiple monitors with active converters. ^ a b DRM (Direct Rendering Manager) is a component of the Linux kernel. AMDgpu is the Linux kernel module. Support in this table refers to the most current version. Main article: AMD Radeon Software On 24 November 2015, AMD released a new version of their graphics driver following the formation of the Radeon Technologies Group (RTG) to provide extensive software support for their graphics cards. This driver, labelled Radeon Software Crimson Edition, overhauls the UI with Qt, resulting in better responsiveness from a design and system perspective. It includes a new interface featuring a game manager, clocking tools, and sections for different technologies.[52] Unofficial modifications such as Omega drivers and DNA drivers were available. These drivers typically consist of mixtures of various driver file versions with some registry variables altered and are advertised as offering superior performance or image quality. They are, of course, unsupported, and as such, are not guaranteed to function correctly. Some of them also provide modified system files for hardware enthusiasts to run specific graphics cards outside of their specifications.[citation needed] AMD Catalyst was based on a proprietary binary blob. The unified kernel-mode driver (DRM/KMS) is utilized by Catalyst and by Mesa 3D.[53] amdkfd was mainlined into Linux kernel 3.19.[54] Radeon Software is being developed for Microsoft Windows and Linux. As of January 2019[update], other operating systems are not officially supported. This may be different for the Radeon Pro brand, which is based on identical hardware but features OpenGL-certified graphics device drivers. ATI previously offered driver updates for their retail and integrated Macintosh video cards and chipsets. ATI stopped support for Mac OS 9 after the Radeon R200 cards, making the last officially supported card the Radeon 9250. The Radeon R100 cards up to the Radeon 7200 can still be used with even older classic Mac OS versions such as System 7, although not all features are taken advantage of by the older operating system.[55] Ever since ATI's acquisition by AMD, ATI no longer supplies or supports drivers for classic Mac OS nor macOS. macOS drivers can be downloaded from Apple's support website, while classic Mac OS drivers can be obtained from 3rd party websites that host the older drivers for users to download. ATI used to provide a preference panel for use in macOS called ATI Displays which can be used both with retail and OEM versions of its cards. Though it gives more control over advanced features of the graphics chipset, ATI Displays has limited functionality compared to Catalyst for Windows or Linux. Main article: free and open-source "radeon" graphics device driverThe free and open-source for Direct Rendering Infrastructure has been under constant development by the Linux kernel developers, by 3rd party programming enthusiasts and by AMD employees. It is composed out of five parts: Linux kernel component DRM this part received dynamic re-clocking support in Linux kernel version 3.12 and its performance has become comparable to that of AMD Catalyst Linux kernel component KMS driver: basically the device driver for the display controller user-space component libDRM user-space component in Mesa 3D; currently most of these components are written conforming to the Gallium3D-specifications. all drivers in Mesa 3D with Version 10.x (last 10.6.7) are as of September 2014 limited to OpenGL version 3.3 and OpenGL ES 3.0. all drivers in Mesa 3D with Version 11.x (last 11.2.2) are as of Mai 2016 limited to OpenGL version 4.1 and OpenGL ES 3.0 or 3.1 (11.2+). all drivers in Mesa 3D with version 12.x (in June 2016) can support OpenGL version 4.3.[56] all drivers in Mesa 3D with Version 13.0.x (in November 2016) can support OpenGL 4.4 and unofficial 4.5. all drivers in Mesa 3D with Version 17.0.x (in January 2017) can support OpenGL 4.5 and OpenGL ES 3.2 Actual Hardware Support for different MESA versions see: glxinfo [57] AMD R600/700 since Mesa 10.1: OpenGL 3.3+, OpenGL ES 3.0+ (+: some more Features of higher Levels and Mesa Version) AMD R800/900 (Evergreen, Northern Islands): OpenGL 4.1+ (Mesa 13.0+), OpenGL ES 3.0+ (Mesa 10.3+) AMD GCN (Southern/Sea Islands and newer): OpenGL 4.5+ (Mesa 17.0+), OpenGL ES 3.2+ (Mesa 18.0+), Vulkan 1.0 (Mesa 17.0+), Vulkan 1.1 (GCN 2nd Gen+, Mesa 18.1+) a special and distinct 2D graphics device driver for X.Org Server, which is finally about to be replaced by Glamor OpenCL with GalliumCompute (previous Clover) is not full developed in 1.0, 1.1 and only parts of 1.2. Some OpenCL conformance tests were failed in 1.0 and 1.1, most in 1.2. ROCm is developed by AMD and Open Source. OpenCL 1.2 is full supported with OpenCL 2.0 language. Only CPU or GCN-Hardware with PCIe 3.0 is supported. So GCN 3rd Gen. or higher is here full usable for OpenCL 1.2 software. The free and open-source driver supports many of the features available in Radeon-branded cards and APUs, such as multi-monitor or hybrid graphics. The free and open-source drivers are primarily developed on Linux and for Linux. Being entirely free and open-source software, the free and open-source drivers can be ported to any existing operating system. Whether they have been, and to what extent depends entirely on the man-power available. Available support shall be referenced here. FreeBSD adopted DRI, and since Mesa 3D is not programmed for Linux, it should have identical support.[citation needed] MorphOS supports 2D and 3D acceleration for Radeon R100, R200 and R300 chipsets.[58] AmigaOS 4 supports Radeon R100, R200, R300,[59] R520 (X1000 series), R700 (HD 4000 series), HD 5000 (Evergreen) series, HD 6000 (Northern Islands) series and HD 7000 (Southern Islands) series.[60] The RadeonHD AmigaOS 4 driver has been developed by Hans de Ruiter[61] funded and owned by A-EON Technology Ltd. The older R100 and R200 "ATIRadeon" driver for AmigaOS, originally developed Forefront Technologies has been acquired by A-EON Technology Ltd in 2015. In the past ATI provided hardware and technical documentation to the Haiku Project to produce drivers with full 2D and video in/out support on older Radeon chipsets (up to R500) for Haiku. A new Radeon HD driver was developed with the unofficial and indirect guidance of AMD open source engineers and currently exists in recent Haiku versions. The new Radeon HD driver supports native mode setting on R600 through Southern Islands GPU's.[62] Current drivers are affected by LeftoverLocals [63] vulnerability referenced as GPU Memory Leaks by AMD.[64] This was supposed to be fixed at 2024 Q1 but it has been postponed several times and the current plan for desktop CPUs containing Radeon GPU and GPUs mitigation is set for 2025 Q2 leaving customers exposed to it for more than year. Other vendors facing this vulnerability such as Qualcom fixed this issue within a month. AMD (and its predecessor ATI) have released a series of embedded GPUs targeted toward medical, entertainment, and display devices. Model Released Shaders (Compute Units) FP power Single Precision Memory Memory band-with Memory clock OpenGL Version OpenCL Version DirectX Version Vulkan UVD Power Output E9550 (Polaris, GCN 4)[65] 2016-09-27 2304 (36 CU) 5834 GFLOPS 8 GB GDDR5 256 Bit 2000 MHz 4.5 2.0 12 1.1 6.3 95 Watt MXM-B E9260 (GCN 4)[66] 2016-09-27 896 (14 CU) 2150 GFLOPS 4 GB GDDR5 128 Bit 1750 MHz 4.5 2.0 12 1.1 6.3 50 W PCIe 3.0, MXM-A E9171 MCM (GCN 4)[67] 2017-10-03 512 (8 CU) 1248 GFLOPS 4 GB GDDR5 128 Bit 1500 MHz 4.5 2.0 12 1.1 6.3 40 W PCIe 3.0 x8 E9172 MXM (GCN 4)[68] 2017-10-03 512 (8 CU) 1248 GFLOPS 2 GB GDDR5 64 Bit 1500 MHz 4.5 2.0 12 1.1 6.3 35 W MXM-A 3.0 E9173 PCIe (GCN 4)[69] 2017-10-03 512 (8 CU) 1248 GFLOPS 2 GB GDDR5 64 Bit 1500 MHz 4.5 2.0 12 1.1 6.3 35 W PCIe 3.0 x8 E9174 MXM (GCN 4)[70] 2017-10-03 512 (8 CU) 1248 GFLOPS 4 GB GDDR5 128 Bit 1500 MHz 4.5 2.0 12 1.1 6.3 50 W MXM-A 3.0 E9175 PCIe (GCN 4)[71] 2017-10-03 512 (8 CU) 1248 GFLOPS 4 GB GDDR5 128 Bit 1500 MHz 4.5 2.0 12 1.1 6.3 50 W PCIe 3.0 x8 E8950 (GCN 3)[72] 2015-09-29 2048 (32 CU) 3010 GFLOPS 8 GB GDDR5 128 Bit 1500 MHz 4.5 2.0 12 1.1 4.2 95 W MXM-B E8870 (GCN 2)[73] 2015-09-29 768 (12 CU) 1536 GFLOPS 4 GB GDDR5 128 Bit 1500 MHz 4.5 2.0 12 1.1 4.2 75 W PCIe 3.0, MXM-B E8860 (GCN 1)[74][75][76] 2014-01-25 640 (10 CU) 800 GFLOPS 2 GB GDDR5 128 Bit 1125 MHz 4.5 1.2 12.0 1.0 3.1 37 W PCIe 3.0, MXM-B E6760 (Turks)[77][78] 2011-05-02 480 (6 CU) 576 GFLOPS 1 GB GDDR5 128 Bit 800 MHz 4.3 1.2 11 N/A 3.0 35 W PCIe 2.1, MXM-A, MCM E6465 (Caicos)[79][80] 2015-09-29 160 (2 CU) 192 GFLOPS 2 GB GDDR5 64 Bit 800 MHz 4.5 1.2 11.1 N/A 3.0 < 20 W PCIe 2.1, MXM-A, MCM E6460 (Caicos)[81][82] 2011-04-07 160 (2 CU) 192 GFLOPS 512 MB GDDR5 64 Bit 800 MHz 4.5 1.2 11.1 N/A 3.0 16 W PCIe 2.1, MXM-A, MCM E4690 (RV730)[83] 2009-06-01 320 (4 CU) 388 GFLOPS 512 MB GDDR3 128 Bit 700 MHz 3.3 1.0 10.1 N/A 2.2 30 W MXM-II E2400 (RV610)[84] 2006-07-28 40 (2 CU) 48 GFLOPS 128 MB GDDR3 64 Bit 700 MHz 3.3 ATI Stream 10.0 N/A 1.0 25 W MXM-II In August 2011, AMD expanded the Radeon name to include random access memory modules under the AMD Memory line. The initial releases included 3 types of 2GiB DDR3 SDRAM modules: Entertainment (1333 MHz, CL9 9-9), UltraPro Gaming (1600 MHz, CL11 11-11) and Enterprise (specs to be determined).[85] On May 8, 2013, AMD announced the release of Radeon RG2133 Gamer Series Memory.[86] Radeon R9 2400 Gamer Series Memory was released on January 16, 2014.[87][88] Dataram Corporation is manufacturing RAM for AMD.[89] On September 6, 2012, Dataram Corporation announced it has entered into a formal agreement with AMD to develop an AMD-branded version of Dataram's RAMDisk software under the name Radeon RAMDisk, targeting gaming enthusiasts seeking exponential improvements in game load times leading to an enhanced gaming experience.[90] The freeware version of Radeon RAMDisk software supports Windows Vista and later with minimum 4GiB memory, and supports maximum of 4GiB RAM disk[91] (6GiB if AMD Radeon Value, Entertainment, Performance Edition or Products installed, and Radeon RAMDisk is activated between 2012-10-10 and 2013-10-10[92]). Retail version supports RAM disk size between 5MiB to 64GiB.[93][94] Version 4.1 was released in May 8, 2013.[86] In 2014-04-02, Dataram Corporation announced it has signed an Agreement with Elysium Europe Ltd. to expand sales penetration in Europe, the Middle East and Africa. Under this Agreement, Elysium is authorized to sell AMD Radeon RAMDisk software. Elysium is focusing on etailers, retailers, system builders and distributors.[95] AMD planned to enter solid state drive market with the introduction of R7 models powered by Indilinx Barefoot 3 controller and Toshiba 19 nm MLC flash memory, and initially available in 120G, 240G, 480G capacities.[96][97] The R7 Series SSD was released on August 9, 2014, which included Toshiba's A19 MLC NAND flash memory, Indilinx Barefoot 3 M00 controller.[98] These components are the same as in the SSD OCZ Vector 150 model. AMD FirePro – brand for professional product line based on Radeon GPUs up to the AMD Radeon Rx 300 series AMD Radeon Pro – successor to FirePro and launched alongside the AMD Radeon 400 series AMD FireStream – brand for stream processing and GPGPU based on Radeon GPUs AMD Instinct – successor to FireStream AMD FireMV – brand for multi-monitor product line based on Radeon GPUs ^ a b "AMD creates graphics-focused Radeon Technologies Group, taps Raja Koduri for GPU czar". PC World. Archived from the original on 11 September 2015. Retrieved 11 September 2015. ^ "ATI to be re-branded as AMD". Arnnet.com.au. 30 August 2010. Archived from the original on 21 April 2012. Retrieved 30 December 2012. ^ "AMD Officially Drops ATI Brand from FirePro and Radeon Marking". Xbitlabs.com. 30 August 2010. Archived from the original on 20 September 2011. Retrieved 30 December 2012. ^ "Executive Biography - Raja Koduri". Archived from the original on 18 September 2017. Retrieved 10 September 2017. ^ 3 AAMD Archived 12 January 2021 at the Wayback Machine ^ "Ready, Willing and Able – AMD Supports OpenGL 3.3 and OpenGL 4.0 | AMD Developer Central Blogs". Blogs.amd.com. 25 March 2010. Retrieved 7 May 2010. [permanent dead link] ^ Worrel, Jon (28 May 2016). "AMD's Macau, China event NDA gets lifted 29 June". Fudzilla.com. Archived from the original on 1 November 2020. Retrieved 29 October 2020. ^ Pop, Sebastian (30 September 2013). "Launch Date Revealed for AMD Radeon R9 290X Hawaii Graphics Card". Softpedia. Archived from the original on 2 February 2022. Retrieved 4 October 2013. ^ "A Bit More On Graphics Core Next 1.1 - The AMD Radeon R9 290X Review". Archived from the original on 19 May 2014. Retrieved 22 May 2014. ^ "AMD officially introduces Radeon 300 'Caribbean Islands' series". videocardz.com. 18 June 2015. Archived from the original on 5 February 2022. Retrieved 5 June 2016. ^ Smith, Ryan (1 June 2016). "AMD Teases Radeon RX 480: Launching June 29th for 199". Anandtech.com. Archived from the original on 24 August 2016. Retrieved 1 June 2016. ^ "AMD launches Radeon RX 500 family of graphics cards". Neowin. Archived from the original on 3 February 2019. Retrieved 28 August 2017. ^ "AMD Announces Next-Generation Leadership Products at Computex 2019 Keynote". Archived from the original on 10 August 2019. Retrieved 27 May 2019. ^ "AMD to Introduce New Next-Gen RDNA GPUs in 2020, Not a Typical 'Refresh' of Navi". tomshardware.com. Tom's Hardware. 29 January 2020. Archived from the original on 26 August 2022. Retrieved 8 February 2020. ^ Smith, Ryan. "Microsoft Drops More Xbox Series X Tech Specs: Zen 2 + RDNA 2, 12 TFLOPs GPU, HDMI 2.1, & a Custom SSD". www.anandtech.com. Archived from the original on 6 November 2020. Retrieved 19 March 2020. ^ "Unveiling New Details of PlayStation 5: Hardware Technical Specs [UPDATED]". PlayStation.Blog. 18 March 2020. Archived from the original on 4 April 2020. Retrieved 19 March 2020. ^ Garreffa, Anthony (9 September 2020). "AMD to reveal next-gen Big Navi RDNA 2 graphics cards on October 28". TweakTown. Archived from the original on 10 September 2020. Retrieved 9 September 2020. ^ Lyles, Taylor (9 September 2020). "AMD's next-generation Zen 3 CPUs and Radeon RX 6000 'Big Navi' GPU will be revealed next month". The Verge. Archived from the original on 9 September 2020. Retrieved 10 September 2020. ^ "AMD Teases Radeon RX 6000 Card Performance Numbers: Aiming For 3080?". anandtech.com. AnandTech. 8 October 2020. Archived from the original on 8 October 2020. Retrieved 25 October 2020. ^ "AMD Announces Ryzen "Zen 3" and Radeon "RDNA2" Presentations for October: A New Journey Begins". anandtech.com. AnandTech. 9 September 2020. Archived from the original on 10 September 2020. Retrieved 25 October 2020. ^ Judd, Will (28 October 2020). "AMD unveils three Radeon 6000 graphics cards with ray tracing and RTX-beating performance". Eurogamer. Archived from the original on 10 September 2021. Retrieved 28 October 2020. ^ Hollister, Sean (3 March 2021). "AMD announces $479 Radeon RX 6700 XT, says it will have 'significantly more GPUs available'". The Verge. Archived from the original on 4 March 2021. Retrieved 4 March 2021. ^ Mujtaba, Hassan (30 November 2020). "AMD Radeon RX 6700 XT 'Navi 22 GPU' Custom Models Reportedly Boost Up To 2.95 GHz". Wccftech. Archived from the original on 6 December 2020. Retrieved 3 December 2020. ^ Tyson, Mark (3 December 2020). "AMD CEO keynote scheduled for CES 2020 on 12th January". HEXUS. Archived from the original on 3 December 2020. Retrieved 3 December 2020. ^ Cutress, Ian (12 January 2021). "AMD to Launch Mid-Range RDNA 2 Desktop Graphics in First Half 2021". AnandTech. Archived from the original on 12 January 2021. Retrieved 4 January 2021. ^ Smith, Ryan. "Launching Today: AMD's Radeon RX 6500 XT, Starring Navi 24". www.anandtech.com. Archived from the original on 10 February 2022. Retrieved 10 February 2022. ^ "Conformant Products - The Khronos Group Inc". The Khronos Group. Retrieved 6 June 2019. ^ "Conformant Products - The Khronos Group Inc". The Khronos Group. Retrieved 6 June 2019. ^ "GPU-Tech.org - Catalyst 11.10 WHQL - First official Battlefield 3 driver for Radeon cards". GPU-Tech.org. 31 October 2011. ^ "AMD Radeon Software Crimson Edition Beta". AMD. Retrieved 20 April 2018. ^ "Mesamatrix". mesamatrix.net. Retrieved 20 April 2018. ^ "RadeonFeature". X.Org Foundation. Retrieved 20 April 2018. ^ Wallossek, Igor; Woligroski, Don (21 December 2011). "Graphics Core Next: The Southern Islands Architecture". Tom's Hardware. Retrieved 26 July 2013. ^ Broekhuijsen, Niels (20 February 2013). "AMD Clarifies 2013 Radeon Plans". Tom's Hardware. Retrieved 26 July 2013. ^ "Radeon Vega Frontier Edition". AMD. 30 December 2022. Archived from the original on 27 June 2017. Retrieved 30 July 2017. ^ "AMD Radeon HD 6900 (AMD Cayman) series graphics cards". HWlab. hw-lab.com. 19 December 2010. Archived from the original on 23 August 2022. Retrieved 23 August 2022. New VLIW4 architecture of stream processors allowed to save area of each SIMD by 10%, while performing the same compared to previous VLIW5 architecture ^ "GPU Specs Database". TechPowerUp. Retrieved 23 August 2022. ^ "NPOT Texture (OpenGL Wiki)". Khronos Group. Retrieved 10 February 2021. ^ "AMD Radeon Software Crimson Edition Beta". AMD. Retrieved 20 April 2018. ^ "Mesamatrix". mesamatrix.net. Retrieved 22 April 2018. ^ "RadeonFeature". X.Org Foundation. Retrieved 20 April 2018. ^ "Conformant Products". Khronos Group. Retrieved 2 December 2024. ^ "radv: add Vulkan 1.4 support". Mesa. Retrieved 2 December 2024. ^ "AMD Radeon RX 6800 XT Specs". TechPowerUp. Retrieved 1 January 2021. ^ "AMD Launches The Radeon PRO W7500/W7600 RDNA3 GPUs". Phoronix. 3 August 2023. Retrieved 4 September 2023. ^ "AMD Radeon Pro 5600M Grafikkarte". TopCPU.net (in German). Retrieved 4 September 2023. ^ a b c Killian, Zak (22 March 2017). "AMD publishes patches for Vega support on Linux". Tech Report. Retrieved 23 March 2017. ^ Larabel, Michael (15 September 2020). "AMD Radeon Navi 2 / VCN 3.0 Supports AV1 Video Decoding". Phoronix. Retrieved 1 January 2021. ^ Edmonds, Rich (4 February 2022). "ASUS Dual RX 6600 GPU review: Rock-solid 1080p gaming with impressive thermals". Windows Central. Retrieved 1 November 2022. ^ "Radeon's next-generation Vega architecture" (PDF). Radeon Technologies Group (AMD). Archived from the original (PDF) on 6 September 2018. Retrieved 13 June 2017. ^ "AMDGPU". Retrieved 29 December 2023. ^ Introducing Radeon Software Crimson Edition Archived 7 May 2016 at the Wayback Machine ^ "AMD exploring new Linux driver Strategy". 8 October 2014. Archived from the original on 21 January 2015. Retrieved 21 January 2015. ^ Dave Airlie (26 November 2014). "Merge AMDKFD". freedesktop.org. Archived from the original on 25 December 2018. Retrieved 21 January 2015. ^ "System 7 Today – High Power 3D Video Cards". Main.system7today.com. Archived from the original on 14 May 2010. Retrieved 7 May 2010. ^ "The Mesa drivers matrix". mesamatrix.net. Archived from the original on 9 March 2022. Retrieved 31 May 2016. ^ "Mesa OpenGL Extensions and Capabilities". people.freedesktop.org. Archived from the original on 31 May 2016. Retrieved 31 May 2016. ^ "Supported hardware – MorphOS". Archived from the original on 5 March 2012. Retrieved 22 November 2008. ^ "AmigaOS 4.1 Hardware Compatibility List". Acube Systems. 25 November 2012. Archived from the original on 8 May 2014. Retrieved 8 May 2014. ^ "RadeonHD Version 1.0 Released". A-Eon Technology. 27 March 2014. Retrieved 8 May 2014. ^ "RadeonHD Driver". Archived from the original on 26 August 2022. Retrieved 25 January 2017. ^ "Haiku Radeon HD driver". Archived from the original on 21 September 2013. Retrieved 6 March 2013. ^ [1] ^ [2] ^ "AMD Radeon E9550 MXM Specs". Archived from the original on 26 August 2022. Retrieved 11 July 2017. ^ "AMD Radeon E9260 MXM Specs". Archived from the original on 26 August 2022. Retrieved 11 July 2017. ^ "AMD Radeon E9171 MCM Specs". Archived from the original on 26 August 2022. Retrieved 29 August 2018. ^ "AMD Radeon E9172 MXM Specs | TechPowerUp GPU Database". Techpowerup.com. 22 August 2022. Archived from the original on 26 August 2022. Retrieved 22 August 2022. ^ "AMD Radeon E9173 PCIe Specs | TechPowerUp GPU Database". Techpowerup.com. 22 August 2022. Archived from the original on 26 August 2022. Retrieved 22 August 2022. ^ "AMD Radeon E9174 MXM Specs | TechPowerUp GPU Database". Techpowerup.com. 22 August 2022. Archived from the original on 26 August 2022. Retrieved 22 August 2022. ^ "AMD Radeon E9175 PCIe Specs | TechPowerUp GPU Database". Techpowerup.com. 22 August 2022. Archived from the original on 26 August 2022. Retrieved 22 August 2022. ^ "AMD Radeon E8950 Specs | TechPowerUp GPU Database". Techpowerup.com. 22 August 2022. Archived from the original on 26 August 2022. Retrieved 22 August 2022. ^ "AMD Radeon E8870 Specs | TechPowerUp GPU Database". Techpowerup.com. 22 August 2022. Archived from the original on 26 August 2022. Retrieved 22 August 2022. ^ "AMD Radeon™ E8860 Embedded GPU" (PDF). AMD. Archived from the original (PDF) on 28 March 2019. Retrieved 11 April 2022. ^ "Grafikeinheit für Spielautomaten: Radeon E8860 mit GCN-Architektur". 27 February 2014. Archived from the original on 23 May 2017. Retrieved 11 July 2017. ^ "AMD Radeon E8860 Specs | TechPowerUp GPU Database". Archived from the original on 26 August 2022. Retrieved 11 July 2017. ^ Product brief Archived 9 December 2017 at the Wayback Machine ^ "AMD Radeon E6760 MXM Specs | TechPowerUp GPU Database". Archived from the original on 26 August 2022. Retrieved 11 July 2017. ^ AMD graphics lineup Archived 19 September 2017 at the Wayback Machine ^ "AMD Radeon E6465 Specs | TechPowerUp GPU Database". ^ "Product Brief: AMD Power-Efficient Embedded GPUs" (PDF). AMD. Archived (PDF) from the original on 20 July 2022. Retrieved 11 April 2022. ^ "AMD Radeon E6460 Specs | TechPowerUp GPU Database". ^ "ATI Radeon E4690 MXM Specs | TechPowerUp GPU Database". 14 July 2023. ^ "ATI Radeon E2400 Specs | TechPowerUp GPU Database". Techpowerup.com. 22 August 2022. Retrieved 22 August 2022. ^ "AMD Quietly Releases Radeon-Branded Memory Modules". Archived from the original on 22 September 2013. ^ a b "AMD Announces Memory Series Designed with Gamers in Mind – AMD Radeon RG2133 and upgraded AMD Radeon RAMDisk deliver lightning fast memory performance for PC gaming -". Archived from the original on 4 April 2015. Retrieved 10 September 2017. ^ "Dataram Unveils Radeon R9 2400 Gamer Series Memory, Joining AMD in Revolutionizing Computing and UltraHD Entertainment". Archived from the original on 9 August 2014. Retrieved 8 August 2014. ^ "Dataram Unveils Radeon R9 2400 Gamer Series Memory". Archived from the original on 9 August 2014. Retrieved 8 August 2014. ^ Unknown, Cristian (17 October 2012). "Dataram to Attend AMD Radeon ExtravaLANza". www.techpowerup.com. Retrieved 19 December 2023. ^ "Dataram Executes Agreement with AMD for Radeon RAMDisk". Archived from the original on 9 August 2014. Retrieved 8 August 2014. ^ AMD Radeon RAMDisk ^ "AMD Radeon RAMDisk 6GB- SOFTWARE DOWNLOAD PROMOTION" (PDF). Archived (PDF) from the original on 23 August 2014. Retrieved 8 August 2014. ^ "AMD Launches Radeon RAMDisk, Free 6GB Disks With AMD Memory". 11 October 2012. Archived from the original on 9 August 2014. Retrieved 8 August 2014. ^ "AMD Radeon RAMDisk For Desktops and Notebooks Quick Setup Guide" (PDF). Archived (PDF) from the original on 11 August 2014. Retrieved 8 August 2014. ^ "Dataram Signs Strategic Sales Agreement with Elysium Europe LTD to Expand Penetration of AMD Product". Archived from the original on 9 August 2014. Retrieved 8 August 2014. ^ "AMD readies Radeon line of SSDs". ZDNet. Archived from the original on 10 August 2014. Retrieved 8 August 2014. ^ "AMD Radeon R7 SSD Series Expected This Month – Rebranded OCZ?". 5 August 2014. Archived from the original on 15 January 2021. Retrieved 8 August 2014. ^ "AMD Expands Gaming Portfolio with New Radeon™ R7 Series Solid State Drives". Archived from the original on 14 February 2017. Retrieved 10 September 2017. Radeon Technologies Group pages: Radeon Graphics Cards AMD Radeon pages: AMD Graphics, Radeon Memory, Radeon RAMDisk X.Org driver for ATI/AMD Radeon DRI Wiki: ATI Radeon Rage3D: Support community for ATI hardware and drivers. News and discussion. Retrieved from " 2MOSFET technology node This article may be too technical for most readers to understand. Please help improve it to make it understandable to non-experts, without removing the technical details. (January 2020) (Learn how and when to remove this message) Semiconductordevicefabrication MOSFET scaling(process nodes) 020 µm – 1968 010 µm – 1971 006 µm – 1974 003 µm – 1977 1.5 µm – 1981 001 µm – 1984 800 nm – 1987 600 nm – 1990 350 nm – 1993 250 nm – 1996 180 nm – 1999 130 nm – 2001 090 nm – 2003 065 nm – 2005 045 nm – 2007 032 nm – 2009 028 nm – 2010 022 nm – 2012 014 nm – 2014 010 nm – 2016 007 nm – 2018 005 nm – 2020 003 nm – 2022 Future 002 nm ~ 2025 001 nm ~ 2027 Half-nodes Density CMOS Device (multi-gate) Moore's law Transistor count Semiconductor Industry Nanoelectronics vte This article may rely excessively on sources too closely associated with the subject, potentially preventing the article from being verifiable and neutral. Please help improve it by replacing them with more appropriate citations to reliable, independent sources. (September 2024) (Learn how and when to remove this message) In semiconductor manufacturing, the "7 nm" process is a term for the MOSFET technology node following the "10 nm" node, defined by the International Roadmap for Devices and Systems (IRDS), which was preceded by the International Technology Roadmap for Semiconductors (ITRS). It is based on FinFET (fin field-effect transistor) technology, a type of multi-gate MOSFET technology. As of 2021, the IRDS Lithography standard gives a table of dimensions for the "7 nm" node,[1] with examples given below: Calculated Value nm Minimum half pitch (DRAM, MPU metal) 18 Minimum half pitch (Flash, MPU fin, LGAA) 15 Minimum required overlay (OL) (DRAM, Flash, MPU) 3.6 Gate pitch 54 Gate length 20 The 2021 IRDS Lithography standard is a retrospective document, as the first volume production of a "7 nm" branded process was in 2016 with Taiwan Semiconductor Manufacturing Company's (TSMC) production of 256Mbit SRAM memory chips using a "7nm" process called N7.[2] Samsung started mass production of their "7nm" process (7LPP) devices in 2018.[3] These process nodes had the same approximate transistor density as Intel's "10 nm Enhanced Superfin" node, later rebranded "Intel 7."[4] Since at least 1997, the length scale of a process node has not referred to any particular dimension on the integrated circuits, such as gate length, metal pitch, or gate pitch, as new lithography processes no longer uniformly shrank all features on a chip. By the late 2010s, the length scale had become a commercial name[5] that indicated a new generation of process technologies, without any relation to physical properties.[6][7][8] Previous ITRS and IRDS standards had insufficient guidance on process node naming conventions to address the widely varying dimensions on a chip, leading to a divergence between how foundries branded their lithography and the actual dimensions their process nodes achieved. The first mainstream "7nm" mobile processor intended for mass market use, the Apple A12 Bionic, was announced at Apple's September 2018 event.[9] Although Huawei announced its own "7nm" processor before the Apple A12 Bionic, the Kirin 980 on August 31, 2018, the Apple A12 Bionic was released for public, mass market use to consumers before the Kirin 980. Both chips were manufactured by TSMC.[10] In 2019,[11] AMD released their "Rome" (EPYC 2) processors for servers and datacenters, which are based on TSMC's N7 node[12] and feature up to 64 cores and 128 threads. They also released their "Matisse" consumer desktop processors with up to 16 cores and 32 threads. However, the I/O die on the Rome multi-chip module (MCM) is fabricated with the GlobalFoundries' 14nm (14HP) process, while the Matisse's I/O die uses the GlobalFoundries' "12nm" (12LP+) process. The Radeon RX 5000 series is also based on TSMC's N7 process. This section is in list format but may read better as prose. You can help by converting this section, if appropriate. Editing help is available. (November 2021) In the early 2000s, researchers began demonstrating 7nm level MOSFETs , with an IBM team including Bruce Doris, Omer Dokumaci, Meikei Ieong, and Anda Mocuta successfully fabricating a 6nm silicon-on-insulator (SOI) MOSFET.[13][14] Shortly after, in 2003, NEC's researchers Hitoshi Wakabayashi and Shigeharu Yamagami advanced further by fabricating a 5nm MOSFET.[15][16] In July 2015, IBM announced that they had built the first functional transistors with "7nm" technology, using a silicon-germanium process.[17][18][19][20] With further development in February 2017, TSMC produced 256Mbit SRAM memory cells at with their "7nm" process, with a cell area of 0.027 square micrometers,[21] giving a square minimum feature size: F 2 = 0.027 n n 2 (0.07 n n) 2 = 550 {\displaystyle F^{2}={\cfrac {0.027nn^{2}}{(0.07nn)^{2}}}=550} This cumulated in TSMC starting volume of 7nm production in 2018.[2] This article is in list format but may read better as prose. You can help by converting this article, if appropriate. Editing help is available. (February 2024) In 2015, Intel expected that at the 7nm node, III–V semiconductors would have to be used in transistors, signaling a shift away from silicon.[22] In April 2016, TSMC announced that "7nm" trial production would begin in the first half of 2017.[23] In April 2017, TSMC began risk production of 256Mbit SRAM memory chips using a "7nm" (N7FF+) process,[2] with extreme ultraviolet lithography (EUV).[24] TSMC's "7nm" production plans, as of early 2017,[needs update] was to use deep ultraviolet (DUV) immersion lithography initially on this process node (N7FF), and transition from risk to commercial volume manufacturing from Q2 2017 to Q2 2018. Also, their later generation "7nm" (N7FF+) production was planned[needs update] to use EUV multiple patterning and have an estimated transition from risk to volume manufacturing between 2018 and 2019.[25] In September 2016, GlobalFoundries announced trial production in the second half of 2017 and risk production in early 2018, with test chips already running.[26] In February 2017, Intel announced Fab 42 in Chandler, Arizona, which was according to press releases at that time expected[needs update] to produce microprocessors using a "7nm" (Intel 4[27]) manufacturing process.[28] The company had not, at that time, published any expected values for feature lengths at this process node.[needs update] In April 2018, TSMC announced volume production of "7nm" (CLN7FF, N7) chips. In June 2018, the company announced mass production ramp up.[3] In May 2018, Samsung announced production of "7nm" (7LPP) chips for later that year. ASML Holding NV is their main supplier of EUV lithography machines.[29] In August 2018, GlobalFoundries announced it was stopping development of "7nm" chips, citing cost.[30] On October 28, 2018, Samsung announced their second generation "7nm" process (7LPP) had entered risk production and was at that time expected to have entered mass production by 2019.[needs update] On January 17, 2019, for the Q4 2018 earnings call, TSMC mentioned that different customers would have "different flavors" of second generation "7nm".[31][needs update] On April 16, 2019, TSMC announced their "6nm" process called (CLN6FF, N6), which was, according to a press release made on April 16, 2019, at that time expected to have been in mass products from 2021.[32][needs update] N6 was at that time expected to have used EUVL in up to 5 layers, compared to up to 4 layers in their N7+ process.[33] On July 28, 2019, TSMC announced their second gen "7nm" process called N7P, which was projected to have been DUV-based like their N7 process.[34] Since N7P was fully IP-compatible with the original "7nm", while N7+ (which uses EUV) was not, N7+ (announced earlier as "7nm+") was to have been a separate process from "7nm". N6 ("6nm"), another EUV-based process, was at that time planned to have been released later than even TSMC's "5nm" (N5) process, with the IP-compatibility with N7. At their Q1 2019 earnings call, TSMC reiterated their Q4 2018 statement[31] that N7+ was at that time expected to have generated less than $1 billion TWD in revenue in 2019.[35][needs update] On October 5, 2019, AMD announced their EPYC Roadmap, featuring Milan chips built using TSMC's N7+ process.[36][needs update] On October 7, 2019, TSMC announced they had started delivering N7+ products to market in high volume.[37][needs update] On July 26, 2021, Intel announced their new manufacturing roadmap, renaming all of their future process nodes.[27] Intel's "10nm" Enhanced SuperFin (10ESF), which was roughly equivalent to TSMC's N7 process, would thenceforth be known as "Intel 7", while their earlier "7nm" process would erstwhile be called "Intel 4".[27][38] As a result, Intel's first processors based on Intel 7 were at that time planned to have started shipping by the second half of 2022,[needs update] whereas Intel announced earlier that they were planning to have launched "7nm" processors in 2023.[39][needs update] In June 2018, AMD announced 7nm Radeon Instinct GPUs launching in the second half of 2018.[40] In August 2018, the company confirmed the release of the GPUs.[41] On August 21, 2018, Huawei announced their HiSilicon Kirin 980 SoC to be used in their Huawei Mate 20 and Mate 20 Pro built using TSMC's 7nm (N7) process.[needs update] On September 12, 2018, Apple announced their A12 Bionic chip used in iPhone XS and iPhone XR built using TSMC's 7nm (N7) process. The A12 processor became the first 7nm chip for mass market use as it released before the Huawei Mate 20.[42][43] On October 30, 2018, Apple announced their A12X Bionic chip used in iPad Pro built using TSMC's 7nm (N7) process.[44] On December 4, 2018, Qualcomm announced their Snapdragon 855 and 8cx built using TSMC's 7nm (N7) process.[45] The first mass product featuring the Snapdragon 855 was the Lenovo Z5 Pro GT, which was announced on December 18, 2018.[46] On May 29, 2019, MediaTek announced their 5G SoC built using a TSMC 7nm process.[47] On July 7, 2019, AMD officially launched their Ryzen 3000 series of central processing units, based on the TSMC 7nm process and Zen 2 microarchitecture. On August 6, 2019, Samsung announced their Exynos 9825 SoC, the first chip built using their 7LPP process. The Exynos 9825 is the first mass market chip built featuring EUVL.[48] On September 6, 2019, Huawei announced their HiSilicon Kirin 990 4G & 990 5G SoCs, built using TSMC's N7 and N7+ processes.[49] On September 10, 2019, Apple announced their A13 Bionic chip used in iPhone 11 and iPhone 11 Pro built using TSMC's 2nd gen N7P process.[50] 7nm (N7 nodes) manufacturing made up 36% of TSMC's revenue in the second quarter of 2020.[51] On August 17, 2020, IBM announced their Power10 processor.[50] On July 26, 2021, Intel announced that their Alder Lake processors would be manufactured using their newly rebranded "Intel 7" process, previously known as "10nm Enhanced SuperFin".[27] These processors were, at that time, expected based on press releases to have been planned to have been released in the second half of 2021.[needs update] The company earlier confirmed a 7nm, now called "Intel 4",[27] microprocessor family called Meteor Lake to be released in 2023.[52][53][needs update] Pitch splitting issues. Successive litho-etch patterning is subject to overlay errors as well as the CD errors from different exposures. Spacer patterning issues. Spacer patterning has excellent CD control for features directly patterned by the spacer, but the spaces between spacers may be split into core and gap populations. Overlay error impact on line cut. An overlay error on a cut hole exposure could distort the line ends (top) or infringe on an adjacent line (bottom). Two-bar EUV patterning issues. In EUV lithography, a pair of features may not have both features in focus at the same time; one will have different size from the other, and both will shift differently through focus as well. 7nm EUV stochastic failure probability. "7nm" features were expected to approach ~20nm width. The probability of EUV stochastic failure is measurably high for the commonly applied dose of 30 mJ/cm2. The "7nm" foundry node is expected to utilize any of or a combination of the following patterning technologies: pitch splitting, self-aligned patterning, and EUV lithography. Each of these technologies carries significant challenges in critical dimension (CD) control as well as pattern placement, all involving neighboring features. Pitch splitting involves splitting features that are too close together onto different masks, which are exposed successively, followed by litho-etch processing. Due to the use of different exposures, there is always the risk of overlay error between the two exposures, as well as different CDs resulting from the different exposures. Spacer patterning involves depositing a layer onto pre-patterned features, then etching back to form spacers on the sidewalls of those features, referred to as core features. After removing the core features, the spacers are used as an etch mask to define trenches in the underlying layer. While the spacer CD control is generally excellent, the trench CD may fall into one of two populations, due to the two possibilities of being located where a core feature was located or in the remaining gap. This is known as 'pitch walking'.[54] Generally, pitch = core CD + gap CD + 2 * spacer CD, but this does not guarantee core CD = gap CD. For FEOL features like gate or active area isolation (e.g. fins), the trench CD is not as critical as the spacer-defined CD, in which case, spacer patterning is actually the preferred patterning approach. When self-aligned quadruple patterning (SAQP) is used, there is a second spacer that is utilized, replacing the first one. In this case, the core CD is replaced by core CD – 2* 2nd spacer CD, and the gap CD is replaced by gap CD – 2 * 2nd spacer CD. Thus, some feature dimensions are strictly defined by the second spacer CD, while the remaining feature dimensions are defined by the core CD, core pitch, and first and second spacer CD's. The core CD and core pitch are defined by conventional lithography, while the spacer CDs are independent of lithography. This is actually expected to have less variation than pitch splitting, where an additional exposure defines its own CD, both directly and through overlay. Spacer-defined lines also require cutting. The cut spots may shift at exposure, resulting in distorted line ends or intrusions into adjacent lines. Self-aligned litho-etch-litho-etch (SALELE) has been implemented for "7nm" BEOL patterning.[55] Extreme ultraviolet lithography (also known as EUV or EUVL) is capable of resolving features below 20nm in conventional lithography style. However, the 3D reflective nature of the EUV mask results in new anomalies in the imaging. One particular nuisance is the two-bar effect, where a pair of identical bar-shaped features do not focus identically. One feature is essentially in the 'shadow' of the other. Consequently, the two features generally have different CDs which change through focus, and these features also shift position through focus.[56][57][58] This effect may be similar to what may be encountered with pitch splitting. A related issue is the difference of best focus among features of different pitches.[59] EUV also has issues with reliably printing all features in a large population; some contacts may be completely missing or lines bridged. These are known as stochastic printing failures.[60][61] The defect level is on the order of 1K/mm2.[62] The tip-to-tip gap is hard to control for EUV, largely due to the illumination constraint.[63] A separate exposure(s) for cutting lines is preferred. Attenuated phase shift masks have been used in production for 90 nm node for adequate focus windows for arbitrarily pitched contacts with the ArF laser wavelength (193nm),[64][65] whereas this resolution enhancement is not available for EUV.[66][67] At 2021 SPIE's EUV Lithography conference, it was reported by a TSMC customer that EUV contact yield was comparable to immersion multipatterning yield.[68] Due to these challenges, "7nm" poses unprecedented patterning difficulty in the back end of line (BEOL). The previous high-volume, long-lived foundry node (Samsung "10nm", TSMC "16nm") used pitch splitting for the tighter pitch metal layers.[69][70][71] Process Immersion (≥ 275 WPH)[72] EUV (1500 wafers/day)[73] Single-patterned layer:1 day completion by immersion 6000 wafers/day 1500 wafers/day Double-patterned layer:2 days completion by immersion 6000 wafers/2 days 3000 wafers/2 days Triple-patterned layer:3 days completion by immersion 6000 wafers/3 days 4500 wafers/3 days Quad-patterned layer:4 days completion by immersion 6000 wafers/4 days 6000 wafers/4 days Due to the immersion tools being faster presently, multipatterning is still used on most layers. On the layers requiring immersion quad-patterning, the layer completion throughput by EUV is comparable. On the other layers, immersion would be more productive at completing the layer even with multipatterning. The "7nm" metal patterning currently practiced by TSMC involves self-aligned double patterning (SADP) lines with cuts inserted within a cell on a separate mask as needed to reduce cell height.[74] However, self-aligned quad patterning (SAQP) is used to form the fin, the most important factor to performance.[75] Design rule checks also allow via multi-patterning to be avoided, and provide enough clearances for cuts that only one cut mask is needed.[75] This section's factual accuracy is disputed. Relevant discussion may be found on the talk page. Please help to ensure that disputed statements are reliably sourced. (September 2023) (Learn how and when to remove this message) The naming of process nodes by 4 different manufacturers (TSMC, Samsung, SMIC, Intel) is partially marketing-driven and not directly related to any measurable distance on a chip – for example TSMC's "7nm" node was previously similar in some key dimensions to Intel's planned first-iteration "10nm" node, before Intel released further iterations, culminating in "10nm Enhanced SuperFin", which was later renamed to "Intel 7" for marketing reasons.[76][77] Since EUV implementation at "7nm" is still limited, multipatterning still plays an important part in cost and yield; EUV adds extra considerations. The resolution for most critical layers is still determined by multiple patterning. For example, for Samsung's "7nm", even with EUV single-patterned 36nm pitch layers, 44nm pitch layers would still be quadruple patterned.[78] 7nm process nodes and process offerings Samsung TSMC Intel SMIC Process name 7LPP[79][80] 6LPP[81] N7[82] N7P[34] N7+[83] N6 Intel 7[27][disputed – discuss] (10nm)[84] N+1 (>7nm) N+2 (7nm) 7nm EUV Transistor density (MTr/mm2) 95.08–100.59[85][86] Unknown 91.2–96.5[87][88] 113.9[87] 114.2[32] 100.76–106.1[89][90] 60.41[91] 89[92] Unknown Unknown SRAM bit-cell size 0.0262 µm2[93] Unknown 0.027 µm2[93] Unknown Unknown 0.0312 µm2 Unknown Unknown Unknown Transistor gate pitch 54nm Unknown 57nm 54nm 66nm 63nm Unknown Transistor fin pitch 27nm Unknown N/A Unknown Unknown 34nm Un-known Unknown Unknown Transistor fin height Unknown Unknown N/A Unknown Unknown 53nm Unknown Unknown Unknown Minimum (metal) pitch 46nm Unknown 40nm 40nm[94] 44nm 42nm Unknown EUV implementation 36nm pitch metal;[78]20% of total layer set Unknown None, used self-aligned quad patterning (SAQP) instead 4 layers 5 layers None. Relied on SAQP heavily None None Yes (after N+2) EUV-limited wafer output 1500 wafers/day[73] Unknown N/A ~ 1000 wafers/day[95] Unknown N/A Unknown Unknown Unknown Multipatterning (≥ 2 masks on a layer) FinsGateVias (double-patterned)[96]Metal 1 (triple-patterned)[96]44nm pitch metal (quad-patterned)[78] Unknown FinsGateContacts/vias (quad-patterned)[97]Lowest 10 metal layers Same as N7, with reduction on 4 EUV layers Same as N7, with reduction on 5 EUV layers multipatterning with DUV multipatterning with DUV Unknown Release status 2018 risk production2019 production 2020 production 2017 risk production2018 production[2] 2019 production 2018 risk production[2]2019 production 2020 risk production2020 production 2021 production[27] April 2021 risk production, mass production unknown Late 2021 risk production, quietly produced since July 2021[98] Cancelled due to US embargo GlobalFoundries' "7nm" 7LP (Leading Performance) process would have offered 40% higher performance or 60%+ lower power with a 2x scaling in density and at a 30–45 + % lower cost per die over its "14nm" process. The Contacted Poly Pitch (CPP) would have been 56nm and the Minimum Metal Pitch (MMP) would have been 40nm, produced with Self-Aligned Double Patterning (SADP). A 6T SRAM cell would have been 0.269 square microns in size. GlobalFoundries planned to eventually use EUV lithography in an improved process called 7LP+.[99] GlobalFoundries later stopped all "7nm" and beyond process development.[100] Intel's new "Intel 7" process, previously known as "10nm Enhanced SuperFin" (10ESF), is based on its previous "10nm" node. The node will feature a 10–15% increase in performance per watt. Meanwhile, their old "7nm" process, now called "Intel 4", was at that time expected to have been released in 2023.[101][needs update] Few details about the "Intel 4" node had at that time been made public, although its transistor density had at that time been estimated to be at least 202 million transistors per square millimeter.[27][102][needs update] As of 2020, Intel had been experiencing problems with its "Intel 4" process to the point of outsourcing production of its Ponte Vecchio GPUs.[103][104][needs update] ^ "International Roadmap for Devices and Systems 2021 Update: Lithography" (PDF). International Roadmap for Devices and Systems. 7 April 2024. ^ a b c d e "7nm Technology". TSMC. Retrieved June 30, 2019. ^ a b Chen, Monica; Shen, Jessie (22 June 2018). "TSMC ramping up 7nm chip production". DigiTimes. Retrieved September 17, 2022. ^ Subramaniam, Vaidyanathan (27 July 2021). "Intel details new process innovations and node names, Alder Lake 10 nm Enhanced SuperFin is now Intel 7; Intel 20A is the 2 nm process for 2024". Notebook Check. ^ Morris, Kevin (July 23, 2020). "No More Nanometers: It's Time for New Node Naming". Electronic Engineering Journal. Retrieved September 17, 2022. ^ Shukla, Priyank. "A Brief History of Process Node Evolution". Design-Reuse. Retrieved July 9, 2019. ^ Hruska, Joel (June 23, 2014). "14nm, 7nm, 5nm: How low can CMOS go? It depends if you ask the engineers or the economists…". ExtremeTech. Retrieved September 17, 2022. ^ Pirzada, Usman (September 16, 2016). "Exclusive: Is Intel Really Starting To Lose Its Process Lead? 7nm Node Slated For Release in 2022". Wccftech. Retrieved September 17, 2022. ^ Shankland, Stephen (September 12, 2018). "Apple's A12 Bionic CPU for the new iPhone XS is ahead of the industry moving to 7nm chip manufacturing tech". CNET. Retrieved September 16, 2018. ^ Summers, N. (September 12, 2018). "Apple's A12 Bionic is the first 7-nanometer smartphone chip". Engadget. Retrieved September 20, 2018. ^ "AMD Launches Epyc Rome, First 7nm CPU". August 8, 2019. Archived from the original on 2019-08-15. ^ Smith, Ryan (July 26, 2018). "AMD "Rome" EPYC CPUs to Be Fabbed By TSMC". AnandTech. Retrieved 18 June 2019. ^ "IBM claims world's smallest silicon transistor – TheINQUIRER". Theinquirer.net. 2002-12-09. Archived from the original on May 31, 2011. Retrieved 7 December 2017. ^ Doris, Bruce B.; Dokumaci, Omer H.; Ieong, Meikei K.; Mocuta, Anda; Zhang, Ying; Kanarsky, Thomas S.; Roy, R. A. (December 2002). "Extreme scaling with ultra-thin Si channel MOSFETs". Digest. International Electron Devices Meeting. pp. 267–270. doi:10.1109/IEDM.2002.1175829. ISBN 0-7803-7462-2. S2CID 10151651. ^ "NEC test-produces world's smallest transistor". The Free Library. Retrieved December 7, 2017. ^ Wakabayashi, Hitoshi; Yamagami, Shigeharu; Ikezawa, Nobuyuki; Ogura, Atsushi; Narihiro, Mitsuru; Arai, K.; Ochiai, Y.; Takeuchi, K.; Yamamoto, T.; Mogami, T. (December 2003). "Sub-10-nm planar-bulk-CMOS devices using lateral junction control". IEEE International Electron Devices Meeting 2003. pp. 20.7.1–20.7.3. doi:10.1109/IEDM.2003.1269446. ISBN 0-7803-7872-5. S2CID 2100267. ^ Dignan, Larry. "IBM Research builds functional 7nm processor". ZDNet. ^ Markoff, John (July 9, 2015). "IBM Discloses Working Version of a Much Higher-Capacity Chip". The New York Times. ^ "Beyond silicon: IBM unveils world's first 7nm chip – Ars Technica". arstechnica.com. July 9, 2015. ^ "Seven Advancements for Beyond 7nm Chips". IBM Research Blog. February 27, 2017. ^ Chang, J.; Chen, Y.; Chan, W.; Singh, S. P.; Cheng, H.; Fujiwara, H.; Lin, J.; Lin, K.; Hung, J.; Lee, R.; Liao, H. (February 2017). "12.1 a 7nm 256Mb SRAM in high-k metal-gate FinFET technology with write-assist circuitry for low-VMIN applications". 2017 IEEE International Solid-State Circuits Conference (ISSCC). pp. 206–207. doi:10.1109/ISSCC.2017.7870333. ISBN 978-1-5090-3758-2. S2CID 19930825. ^ "Intel forges ahead to 10nm, will move away from silicon at 7nm". February 23, 2015. ^ Parish, Kevin (April 20, 2016). "Watch out Intel and Samsung: TSMC is gearing up for 7 nm processing with trial production". Digital Trends. Retrieved September 17, 2022. ^ "TSMC Tips 7+, 12, 22nm Nodes | EE Times". EETimes. Retrieved 2017-03-17. ^ Shilov, Anton (5 May 2017). "Samsung and TSMC Roadmaps: 8 and 6 nm Added, Looking at 22ULP and 12FFC". AnandTech. Retrieved September 17, 2022. ^ "GLOBALFOUNDRIES to Deliver Industry's Leading-Performance Offering of 7 nm FinFET Technology". GlobalFoundries (Press release). September 15, 2016. Retrieved April 8, 2017. ^ a b c d e f g h Cutress, Ian. "Intel's Process Roadmap to 2025: with 4nm, 3nm, 20A and 18A?!". www.anandtech.com. Retrieved 2021-07-27. ^ "Intel Supports American Innovation with $7 Billion Investment in Next-Generation Semiconductor Factory in Arizona". Intel Newsroom. February 8, 2017. Retrieved September 17, 2022. ^ King, Ian (May 22, 2018). "Samsung Says New 7-Nanometer Chip Production Starting This Year". Bloomberg. Retrieved September 17, 2022. ^ Dent, Steve (August 28, 2018). "Major AMD chip supplier will no longer make next-gen chips". Engadget. Retrieved September 17, 2022. ^ a b Q4 2018 TSMC earnings call transcript, January 17, 2019. ^ a b Schor, David (April 16, 2019). "TSMC Announces 6-Nanometer Process". WikiChip Fuse. Retrieved May 31, 2019. ^ Shilov, Anton (May 1, 2019). "TSMC: Most 7nm Clients Will Transition to 6nm". AnandTech. Retrieved May 31, 2019. ^ a b Schor, David (July 28, 2019). "TSMC Talks 7nm, 5nm, Yield, And Next-Gen 5G And HPC Packaging". WikiChip Fuse. Retrieved September 13, 2019. ^ C. C. Wei, TSMC Q1 2019 earnings call (April 18) transcript. ^ Alcorn, Paul (October 5, 2019). "AMD Dishes on Zen 3 and Zen 4 Architecture, Milan and Genoa Roadmap". Tom's Hardware. Retrieved October 8, 2019. ^ "TSMC's N7+ Technology is First EUV Process Delivering Customer Products to Market in High Volume | Planet 3DNow!" (in German). October 7, 2019. Retrieved 2019-10-08. ^ "Accelerating

Process Innovation" (PDF). Intel. July 26, 2021. ^ Jones, Ryan (March 27, 2021). "Ctrl+Alt+Delete: Why you should be excited for Intel's 7nm processor". Trusted Reviews. Retrieved March 30, 2021. ^ "Pushing Boundaries for CPUs and GPUs, AMD Shows Next-Generation of Ryzen, Radeon and EPYC Product Leadership at Computex 2018" (Press release). June 5, 2018. ^ Martin, Dylan (August 23, 2018). "AMD CTO: 'We Went All In' On 7nm CPUs". CRN. Retrieved September 17, 2022. ^ "Apple Announces 'iPhone Xs' and 'iPhone Xs Max' With Gold Color, Faster Face ID, and More". September 12, 2018. ^ Freedman, Andrew E. (September 12, 2018). "Apple Introduces 7nm A12 Bionic CPU for iPhone XS". Tom's Hardware. Retrieved September 12, 2018. ^ Axon, Samuel (November 7, 2018). "Apple walks Ars through the iPad Pro's A12X system on a chip". Ars Technica. Retrieved November 18, 2018. ^ Cutress, Ian (December 4, 2018). "Qualcomm Tech Summit, Day 1: Announcing 5G Partnerships and Snapdragon 855". AnandTech. Retrieved May 31, 2019. ^ Frumusanu, Andrei (December 18, 2018). "Lenovo First to a Snapdragon 855 Phone with Announcement of Z5 Pro GT". AnandTech. Retrieved May 31, 2019. ^ "MediaTek 5G". MediaTek. Retrieved May 31, 2019. ^ Siddiqui, Aamir (August 7, 2019). "Samsung announces Exynos 9825 prior to Galaxy Note 10 launch". XDA-Developers. Retrieved September 13, 2019. ^ Cutress, Ian. "Huawei Announces Kirin 990 and Kirin 990 5G: Dual SoC Approach, Integrated 5G Modem". AnandTech. Retrieved September 13, 2019. ^ a b "IBM Reveals Next-Generation IBM POWER10 Processor". IBM Newsroom. August 17, 2020. Retrieved August 17, 2020. ^ "TSMC Plots an Aggressive Course for 3nm Lithography and Beyond - ExtremeTech". ^ "Intel CEO Announces 'IDM 2.0' Strategy for Manufacturing, Innovation". Intel Newsroom. March 23, 2021. Retrieved September 17, 2022. ^ "Intel Unleashed: Engineering the Future (Replay)". Intel Newsroom. March 23, 2021. Retrieved September 17, 2022. ^ M. J. Maslow et al., Proc. SPIE 10587, 1058704 (2018). ^ SALELE Double Patterning for 7nm and 5nm Nodes ^ "IMEC EUVL 2018 Workshop" (PDF). ^ Y. Nakajima et al., EUVL Symposium 2007, Sapporo. ^ L. de Winter et al., Proc. SPIE 9661, 96610A (2015). ^ M. Burkhardt and A. Raghunathan, Proc. SPIE 9422, 94220X (2015). ^ P. De Bisschop and E. Hendrickx, Proc. SPIE 10583, 105831K (2018). ^ "EUV's Stochastic Valley of Death". linkedin.com. ^ S. Larivière et al., Proc. SPIE 10583, 105830U (2018). ^ E. van Setten et al., Proc. SPIE 9661. 96610G (2015). ^ C-H. Chang et al., Proc. SPIE 5377, 902 (2004). ^ T. Devoivre et al., MTDT 2002. ^ S-S. Yu et al., Proc. SPIE 8679, 86791L (2013). ^ A. Erdmann et al., Proc. SPIE 10583, 1058312 (2018). ^ Qi Li et al., Proc. SPIE 11609, 116090V (2021). ^ Jeong, W. C.; Ahn, J. H.; Bang, Y. S.; Yoon, Y. S.; Choi, J. Y.; Kim, Y. C.; Paek, S. W.; Ahn, S. W.; Kim, B. S.; Song, T. J.; Jung, J. H.; Do, J. H.; Lim, S. M.; Cho, H.-; Lee, J. H.; Kim, D. W.; Kang, S. B.; Ku, J.-; Kwon, S. D.; Jung, S.-; Yoon, J. S. (June 23, 2017). "10nm 2nd generation BEOL technology with optimized illumination and LELELELE". 2017 Symposium on VLSI Technology. pp. T144 – T145. doi:10.23919/VLSIT.2017.7998156. ISBN 978-4-86348-605-8. S2CID 43207918 – via IEEE Xplore. ^ "TSMC Symposium: "10nm is Ready for Design Starts at This Moment" – Industry Insights – Cadence Blogs – Cadence Community". community.cadence.com. ^ Wu, S.; Lin, C. Y.; Chiang, M. C.; Liaw, J. J.; Cheng, J. Y.; Yang, S. H.; Liang, M.; Miyashita, T.; Tsai, C. H.; Hsu, B. C.; Chen, H. Y.; Yamamoto, T.; Chang, S. Y.; Chang, V. S.; Chang, C. H.; Chen, J. H.; Chen, H. F.; Ting, K. C.; Wu, Y. K.; Pan, K. H.; Tsui, R. F.; Yao, C. H.; Chang, P. R.; Lien, H. M.; Lee, T. L.; Lee, H. M.; Chang, W.; Chang, T.; Chen, R.; Yeh, M.; Chen, C. C.; Chiu, Y. H.; Chen, Y. H.; Huang, H. C.; Lu, Y. C.; Chang, C. W.; Tsai, M. H.; Liu, C. C.; Chen, K. S.; Kuo, C. C.; Lin, H. T.; Jang, S. M.; Ku, Y. (December 23, 2013). "A 16nm FinFET CMOS technology for mobile SoC and computing applications". 2013 IEEE International Electron Devices Meeting. pp. 9.1.1–9.1.4. doi:10.1109/IEDM.2013.6724591. ISBN 978-1-4799-2306-9 – via IEEE Xplore. ^ "Products & services – Supplying the semiconductor industry". asml.com. ^ a b "Samsung Ramps 7nm EUV Chips". EETimes. October 17, 2018. ^ "7 nm lithography process – WikiChip". ^ a b "A Heuristic Approach to Fix Design Rule Check (DRC) Violations in ASIC Designs @7nm FinFET Technology". Design And Reuse. ^ Merrit, Rick (16 Jan 2017). "15 Views from a Silicon Summit". EETimes. Retrieved September 16, 2022. ^ Hill, Brandon (March 28, 2017). "Intel Details Cannonlake's Advanced 10nm FinFET Node, Claims Full Generation Lead Over Rivals". HotHardware. Archived from the original on June 12, 2018. Retrieved August 30, 2018. ^ a b c J. Kim et al., Proc. SPIE 10962, 1096204 (2019). ^ "VLSI 2018: Samsung's 2nd Gen 7nm, EUV Goes HVM". WikiChip. August 4, 2018. Retrieved September 16, 2022. ^ "Samsung Electronics Starts Production of EUV-based 7nm LPP Process". Samsung Newsroom. October 18, 2018. Retrieved September 16, 2022. ^ "Samsung Starts Mass Production at V1: A Dedicated EUV Fab for 7nm, 6nm, 5nm, 4nm, 3nm Nodes". ^ IEDM 2016 ^ "TSMC Goes Photon to Cloud". EETimes. October 4, 2018. ^ Bonshor, Gavin (20 October 2022). "Intel Core i9-13900K and i5-13600K Review: Raptor Lake Brings More Bite". AnandTech. Retrieved 28 September 2023. ^ "Can TSMC Maintain Their Process Technology Lead". July 18, 2023. ^ "Samsung 3nm GAAFET Enters Risk Production; Discusses Next-Gen Improvements". July 5, 2022. ^ a b Jones, Scotten (May 3, 2019). "TSMC and Samsung 5nm Comparison". Semiwiki. Retrieved 30 July 2019. ^ "N3E Replaces N3; Comes in Many Flavors". September 4, 2022. ^ Jones, Scotten (July 18, 2023), Can TSMC Maintain Their Process Technology Lead ^ "Intel's Process Roadmap to 2025: With 4nm, 3nm, 20A and 18A?!". ^ Schor, David (2022-06-19). "A Look At Intel 4 Process Technology". WikiChip Fuse. ^ SMIC Mass Produces 14nm Nodes, Advances To 5nm, 7nm, September 16, 2022 ^ a b "VLSI 2018: Samsung's 2nd Gen 7nm, EUV Goes HVM". WikiChip Fuse. 2018-08-04. Retrieved 2019-05-31. ^ Smith, Ryan (June 13, 2022). "Intel 4 Process Node In Detail: 2x Density Scaling, 20% Improved Performance". AnandTech. Retrieved September 17, 2022. ^ "TSMC Q1 2018 earnings call transcript, p.12" (PDF). Archived from the original (PDF) on October 14, 2018. Retrieved October 14, 2018. ^ a b W. C. Jeong et al., VLSI Technology 2017. ^ Dillinger, Tom (March 23, 2017). "Top 10 Updates from the TSMC Technology Symposium, Part II". SemiWiki. Retrieved September 16, 2022. ^ Paul Alcorn (21 July 2022). "China's SMIC Shipping 7nm Chips, Reportedly Copied TSMC's Tech". Tom's Hardware. ^ Jones, Scotten (July 8, 2017). "Exclusive – GLOBALFOUNDRIES discloses 7nm process detail". SemiWiki. Retrieved September 16, 2022. ^ Shilov, Anton; Cutress, Ian (August 27, 2018). "GlobalFoundries Stops All 7nm Development: Opts To Focus on Specialized Processes". AnandTech. Retrieved July 27, 2021. ^ "Intel: Sorry, But Our 7nm Chips Will Be Delayed to 2022, 2023". PCMAG. Retrieved 2021-07-27. ^ "7 nm lithography process – WikiChip". ^ "Intel's 7nm Process Six Months Behind Schedule – News". ^ "As 7nm schedule continues slipping, Intel contemplates 3rd-party fabs". July 24, 2020. 7 nm lithography process Preceded by10 nm MOSFET semiconductor device fabrication process Succeeded by5 nm Retrieved from " 3Broadband cellular network standard For other uses, see 5G (disambiguation). 3GPP logo of 5G Part of a series on theWireless network technologies Analog 0G1G (1.5G) Digital 2G (2.5G, 2.75G, 2.9G)3G (3.5G, 3.75G, 3.9G/3.95G)4G (4G/4.5G, 4.5G, 4.9G)5G (5.5G)6G Mobile telecommunicationsvte An Android phone, showing that it is connected to a 5G networkIn telecommunications, 5G is the "fifth generation" of cellular network technology, as the successor to the fourth generation (4G), and has been deployed by mobile operators worldwide since 2019. Compared to 4G, 5G networks offer not only higher download speeds, with a peak speed of 10 gigabits per second (Gbit/s),[a] but also substantially lower latency, enabling near-instantaneous communication through cellular base stations and antennae.[1] There is one global unified 5G standard: 5G New Radio (5G NR),[2] which has been developed by the 3rd Generation Partnership Project (3GPP) based on specifications defined by the International Telecommunication Union (ITU) under the IMT-2020 requirements.[3] The increased bandwidth of 5G over 4G allows them to connect more devices simultaneously and improving the quality of cellular data services in crowded areas.[4] These features make 5G particularly suited for applications requiring real-time data exchange, such as extended reality (XR), autonomous vehicles, remote surgery, and industrial automation. Additionally, the increased bandwidth is expected to drive the adoption of 5G as a general Internet service provider (ISP), particularly through fixed wireless access (FWA), competing with existing technologies such as cable Internet, while also facilitating new applications in the machine-to-machine communication and the Internet of Things (IoT), the latter of which may include diverse applications such as smart cities, connected infrastructure, industrial IoT, and automated manufacturing processes. Unlike 4G, which was primarily designed for mobile broadband, 5G can handle millions of IoT devices with stringent performance requirements, such as real-time sensor data processing and edge computing. 5G networks also extend beyond terrestrial infrastructure, incorporating non-terrestrial networks (NTN) such as satellites and high-altitude platforms, to provide global coverage, including remote and underserved areas. 5G deployment faces challenges such as significant infrastructure investment, spectrum allocation, security risks, and concerns about energy efficiency and environmental impact associated with the use of higher frequency bands. However, it is expected to drive advancements in sectors like healthcare, transportation, and entertainment. Mobile base station at Hatta city, UAE 5G networks are cellular networks,[5] in which the service area is divided into small geographical areas called cells. All 5G wireless devices in a cell communicate by radio waves with a cellular base station via fixed antennas, over frequencies assigned by the base station. The base stations, termed nodes, are connected to switching centers in the telephone network and routers for Internet access by high-bandwidth optical fiber or wireless backhaul connections. As in other cellular networks, a mobile device moving from one cell to another is automatically handed off seamlessly. The industry consortium setting standards for 5G, the 3rd Generation Partnership Project (3GPP), defines "5G" as any system using 5G NR (5G New Radio) software—a definition that came into general use by late 2018. 5G continues to use OFDM encoding. Several network operators use millimeter waves or mmWave called FR2 in 5G terminology, for additional capacity and higher throughputs. Millimeter waves have a shorter range than the lower frequency microwaves, therefore the cells are of a smaller size. Millimeter waves also have more trouble passing through building walls and humans. Millimeter-wave antennas are smaller than the large antennas used in previous cellular networks. The increased data rate is achieved partly by using additional higher-frequency radio waves in addition to the low- and medium-band frequencies used in previous cellular networks. For providing a wide range of services, 5G networks can operate in three frequency bands—low, medium or high. 5G can be implemented in low-band, mid-band or high-band millimeter-wave. Low-band 5G uses a similar frequency range to 4G smartphones, 600–900 MHz, which can potentially offer higher download speeds than 4G: 5–250 megabits per second (Mbit/s).[6][7] Low-band cell towers have a range and coverage area similar to 4G towers. Mid-band 5G uses microwaves of 1.7–4.7 GHz, allowing speeds of 100–900 Mbit/s, with each cell tower providing service up to several kilometers in radius. This level of service is the most widely deployed, and was deployed in many metropolitan areas in 2020. Some regions are not implementing the low band, making Mid-band the minimum service level. High-band 5G uses frequencies of 24–47 GHz, near the bottom of the millimeter wave band, although higher frequencies may be used in the future. It often achieves download speeds in the gigabit-per-second (Gbit/s) range, comparable to co-axial cable Internet service. However, millimeter waves (mmWave or mmW) have a more limited range, requiring many small cells.[8] They can be impeded or blocked by materials in walls or windows or pedestrians.[9][10] Due to their higher cost, plans are to deploy these cells only in dense urban environments and areas where crowds of people congregate such as sports stadiums and convention centers. The above speeds are those achieved in actual tests in 2020, and speeds are expected to increase during rollout.[6] The spectrum ranging from 24.25 to 29.5 GHz has been the most licensed and deployed 5G mmWave spectrum range in the world.[11] Rollout of 5G technology has led to debate over its security and relationship with Chinese vendors. It has also been the subject of health concerns and misinformation, including discredited conspiracy theories linking it to the COVID-19 pandemic. The ITU-R has defined three main application areas for the enhanced capabilities of 5G. They are Enhanced Mobile Broadband (eMBB), Ultra Reliable Low Latency Communications (URLLC), and Massive Machine Type Communications (mMTC).[12] Only eMBB is deployed in 2020; URLLC and mMTC are several years away in most locations.[13] Enhanced Mobile Broadband (eMBB) uses 5G as a progression from 4G LTE mobile broadband services, with faster connections, higher throughput, and more capacity. This will benefit areas of higher traffic such as stadiums, cities, and concert venues.[14] 'Ultra-Reliable Low-Latency Communications' (URLLC) refers to using the network for mission-critical applications that require uninterrupted and robust data exchange. Short-packet data transmission is used to meet both reliability and latency requirements of the wireless communication networks. Massive Machine-Type Communications (mMTC) would be used to connect to a large number of devices. 5G technology will connect some of the 50 billion connected IoT devices.[15] Most will use the less expensive Wi-Fi. Drones, transmitting via 4G or 5G, will aid in disaster recovery efforts, providing real-time data for emergency responders.[15] Most cars will have a 4G or 5G cellular connection for many services. Autonomous cars do not require 5G, as they have to be able to operate where they do not have a network connection.[16] However, most autonomous vehicles also feature tele-operations for mission accomplishment, and these greatly benefit from 5G technology.[17][18] The 5G Automotive Association has been promoting the C-V2X communication technology that will first be deployed in 4G. It provides for communication between vehicles and infrastructures.[19] A real time digital twin of the real object such as a turbine engine, aircraft, wind turbines, offshore platform and pipelines. 5G networks helps in building it due to the latency and throughput to capture near real-time IoT data and support digital twins. Mission-critical push-to-talk (MCPTT) and mission-critical video and data are expected to be furthered in 5G.[20] Fixed wireless connections will offer an alternative to fixed-line broadband (ADSL, VDSL, fiber optic, and DOCSIS connections) in some locations. Utilizing 5G technology, fixed wireless access (FWA) can deliver high-speed internet to homes and businesses without the need for extensive physical infrastructure. This approach is particularly beneficial in rural or underserved areas where traditional broadband deployment is too expensive or logistically challenging. 5G FWA can outperform older fixed-line technologies such as ADSL and VDSL in terms of speed and latency, making it suitable for bandwidth-intensive applications like streaming, gaming, and remote work.[21][22][23] Sony has tested the possibility of using local 5G networks to replace the SDI cables currently used in broadcast camcorders.[24] The 5G Broadcast tests started around 2020 (Orkney, Bavaria, Austria, Central Bohemia) based on FeMBMS (Further evolved multimedia broadcast multicast service).[25] The aim is to serve unlimited number of mobile or fixed devices with video (TV) and audio (radio) streams without these consuming any data flow or even being authenticated in a network. Main article: Voice over NR 5G networks, like 4G networks, do not natively support voice calls traditionally carried over circuit-switched technology. Instead, voice communication is transmitted over the IP network, similar to IPTV services. To address this, Voice over NR (VoNR) is implemented, allowing voice calls to be carried over the 5G network using the same packet-switched infrastructure as other IP-based services, such as video streaming and messaging. Similarly to how Voice over LTE (VoLTE) enables voice calls on 4G networks, VoNR (Vo5G) serves as the 5G equivalent for voice communication, but it requires a 5G standalone (SA) network to function.[26] This article possibly contains unsourced predictions, speculative material, or accounts of events that might not occur. Information must be verifiable and based on reliable published sources. Please help improve it by removing unsourced speculative content. (January 2022) (Learn how and when to remove this message) 5G is capable of delivering significantly faster data rates than 4G (5G is approximately 10 times faster than 4G),[27][28] with peak data rates of up to 20 gigabits per second (Gbps).[29] Furthermore, average 5G download speeds have been recorded at 186.3 Mbit/s in the U.S. by T-Mobile,[30] while South Korea, as of May 2022[update], leads globally with average speeds of 432 megabits per second (Mbps).[31][32] 5G networks are also designed to provide significantly more capacity than 4G networks, with a projected 100-fold increase in network capacity and efficiency.[33] The most widely used form of 5G, sub-6 GHz 5G (mid-band), is capable of delivering data rates ranging from 10 to 1,000 megabits per second (Mbps), with a much greater reach than mm Wave bands. C-Band (n77/n78) was deployed by various U.S. operators in 2022 in the sub-6 bands, although its deployment by Verizon and AT&T was delayed until early January 2022 due to safety concerns raised by the Federal Aviation Administration. The record for 5G speed in a deployed network is 5.9 Gbit/s as of 2023, but this was tested before the network was launched.[34] Low-band frequencies (such as n5) offer a greater coverage area for a given cell, but their data rates are lower than those of mid and high bands in the range of 5–250 megabits per second (Mbps).[7] In 5G, the ideal "air latency" is of the order of 8 to 12 milliseconds i.e., excluding delays due to HARQ retransmissions, handovers, etc. Retransmission latency and backhaul latency to the server must be added to the "air latency" for correct comparisons. Verizon reported the latency on its 5G early deployment is 30 ms.[35] Edge Servers close to the towers have the possibility to reduce round-trip time (RTT) latency to 14 milliseconds and the minimum jitter to 1.84 milliseconds.[36] Latency is much higher during handovers; ranging from 50 to 500 milliseconds depending on the type of handover[citation needed]. Reducing handover interruption time is an ongoing area of research and development; options include modifying the handover margin (offset) and the time-to-trigger (TTT). 5G uses an adaptive modulation and coding scheme (MCS) to keep the block error rate (BLER) extremely low. Whenever the error rate crosses a (very low) threshold the transmitter will switch to a lower MCS, which will be less error-prone. This way speed is sacrificed to ensure an almost zero error rate. The range of 5G depends on many factors: transmit power, frequency, and interference. For example, mmWave (e.g.: band n258) will have a lower range than mid-band (e.g.: band n78) which will have a lower range than low-band (e.g.: band n5) Given the marketing hype on what 5G can offer, simulators and drive tests are used by cellular service providers for the precise measurement of 5G performance. Initially, the term was associated with the International Telecommunication Union's IMT-2020 standard, which required a theoretical peak download speed of 20 gigabits per second and 10 gigabits per second upload speed, along with other requirements.[29] Then, the industry standards group 3GPP chose the 5G NR (New Radio) standard together with LTE as their proposal for submission to the IMT-2020 standard.[37][38] 5G NR can include lower frequencies (FR1), below 6 GHz, and higher frequencies (FR2), above 24 GHz.[39] However, the speed and latency in early FR1 deployments, using 5G NR software on 4G hardware (non-standalone), are only slightly better than new 4G systems, estimated at 15 to 50% better.[40][41] The standard documents are organized by 3rd Generation Partnership Project (3GPP),[42][43] with its system architecture defined in TS 23.501.[44] The packet protocol for mobility management (establishing connection and moving between base stations) and session management (connecting to networks and network slices) is described in TS 24.501.[45] Specifications of key data structures are found in TS 23.003.[46] DECT NR+ is a related, non-cellular standard of 5G based on DECT-2020 specifications based on a mesh network.[47][48] Further information: Fronthaul and Common Public Radio Interface IEEE covers several areas of 5G with a core focus on wireline sections between the Remote Radio Head (RRH) and Base Band Unit (BBU). The 1914.1 standards focus on network architecture and dividing the connection between the RRU and BBU into two key sections. Radio Unit (RU) to the Distributor Unit (DU) being the NGFI-I (Next Generation Fronthaul Interface) and the DU to the Central Unit (CU) being the NGFI-II interface allowing a more diverse and cost-effective network. NGFI-I and NGFI-II have defined performance values which should be compiled to ensure different traffic types defined by the ITU are capable of being carried.[page needed] The IEEE 1914.3 standard is creating a new Ethernet frame format capable of carrying IQ data in a much more efficient way depending on the functional split utilized. This is based on the 3GPP definition of functional splits.[page needed] Main article: 5G NR 5G NR (5G New Radio) is the de facto air interface developed for 5G networks.[49] It is the global standard for 3GPP 5G networks.[50] The study of 5G NR within 3GPP started in 2015, and the first specification was made available by the end of 2017. While the 3GPP standardization process was ongoing, the industry had already begun efforts to implement infrastructure compliant with the draft standard, with the first large-scale commercial launch of 5G NR having occurred at the end of 2018. Since 2019, many operators have deployed 5G NR networks and handset manufacturers have developed 5G NR enabled handsets.[51] 5Gi is an alternative 5G variant developed in India. It was developed in a joint collaboration between IIT Madras, IIT Hyderabad, TSDSI, and the Centre of Excellence in Wireless Technology (CEWiT) [citation needed]. 5Gi is designed to improve 5G coverage in rural and remote areas over varying geographical terrains. 5Gi uses Low Mobility Large Cell (LMLC) to extend 5G connectivity and the range of a base station.[52] In April 2022, 5Gi was merged with the global 5G NR standard in the 3GPP Release 17 specifications.[53] 5G TF: American carrier Verizon used a pre-standard variation of 5G known as 5G TF (Verizon 5G Technical Forum) for Fixed Wireless Access in 2018. The 5G service provided to customers in this standard is incompatible with 5G NR. Verizon has since migrated to 5G NR.[54] 5G-SIG: KT Corporation had a pre-standard variation of 5G developed called 5G-SIG. This was deployed at the Pyeongchang 2018 Winter Olympics.[55] In the Internet of things (IoT), 3GPP is going to submit the evolution of NB-IoT and eMTC (LTE-M) as 5G technologies for the LPWA (Low Power Wide Area) use case.[56] Standards are being developed by 3GPP to provide access to end devices via non-terrestrial networks (NTN), i.e. satellite or airborne telecommunication equipment to allow for better coverage outside of populated or otherwise hard to reach locations.[57][58] The enhanced communication quality relies on the unique properties of Air to Ground channel. Several manufacturers have announced and released hardware that integrates 5G with satellite networks: Samsung Electronics introduced a standardized 5G NTN modem technology in Korea in February 2023,[59] simulated on their Exynos Modem 5300, facilitating smartphone-satellite communication. MediaTek launched the world's first commercially available 5G IoT-NTN chipset, MT6825, capable of automatic satellite message receipt and extensive power efficiency.[60][61] Qualcomm, in collaboration with Skylo, announced new satellite IoT solutions on June 22, 2023, including the Qualcomm 212S and 9205S modems, supporting the Qualcomm Aware platform for real-time asset tracking and device management.[62] Motorola's Defy Satellite Link hotspot, powered by MediaTek's MT6825, became available in June 2023, providing a portable satellite messaging solution with robust battery life and built-in GPS.[63][64] Rakuten Symphony, in collaboration with Supermicro, announced high-performing Open RAN technologies and storage systems for operators of cloud-based mobile services.[65] 5G-Advanced (also known as 5.5G or 5G-A) is an evolutionary upgrade to 5G technology, defined under the 3GPP Release 18 standard. It serves as a transitional phase between 5G and future 6G networks, focusing on performance optimization, enhanced spectral efficiency, energy efficiency, and expanded functionality. This technology supports advanced applications such as extended reality (XR), massive machine-type communication (mMTC), and ultra-low latency for critical services, such as autonomous vehicles.[66][67][68] 5G-Advanced would offer a theoretical 10 Gbps downlink, 1 Gbps uplink, 100 billion device connections and lower latency.[69] Additionally, 5G-Advanced integrates artificial intelligence (AI) and machine learning (ML) to optimize network operations, enabling smarter resource allocation and predictive maintenance. It also enhances network slicing, allowing highly customized virtual networks for specific use cases such as industrial automation, smart cities, and critical communication systems. 5G-Advanced aims to minimize service interruption times during handovers to nearly zero, ensuring robust connectivity for devices in motion, such as high-speed trains and autonomous vehicles. To further support emerging IoT applications, 5G-Advanced expands the capabilities of RedCap (Reduced Capability) devices, enabling their efficient use in scenarios that require low complexity and power consumption.[70][71] Furthermore, 5G-Advanced introduces advanced time synchronization methods independent of GNSS, providing more precise timing for critical applications. For the first time in the development of mobile network standards defined by 3GPP, it offers fully independent geolocation capabilities, allowing position determination without relying on satellite systems such as GPS. The standard includes extended support for non-terrestrial networks (NTN), enabling communication via satellites and unmanned aerial vehicles, which facilitates connectivity in remote or hard-to-reach areas.[72] In December 2023, Finnish operator DNA demonstrated 10 Gbps speeds on its network using 5G-Advanced technology.[73][74] The Release 18 specifications were finalized by mid-2024.[75][76] On February 27, 2025, Elisa announced its deployment of the first 5G-Advanced network in Finland.[77] In March 2025, China Mobile started deployment of 5G-Advanced network in Hangzhou.[78] See also: List of 5G NR networks 5G 3.5 GHz cell site of Deutsche Telekom in Darmstadt, Germany 5G 3.5 GHz cell site of Vodafone in Karlsruhe, Germany Beyond mobile operator networks, 5G is also expected to be used for private networks with applications in industrial IoT, enterprise networking, and critical communications, in what being described as NR-U (5G NR in Unlicensed Spectrum)[79] and Non-Public Networks (NPNs) operating in licensed spectrum. By the mid-to-late 2020s, standalone private 5G networks are expected to become the predominant wireless communications medium to support the ongoing Industry 4.0 revolution for the digitization and automation of manufacturing and process industries.[80] 5G was expected to increase phone sales.[81] Initial 5G NR launches depended on pairing with existing LTE (4G) infrastructure in non-standalone (NSA) mode (5G NR radio with 4G core), before maturation of the standalone (SA) mode with the 5G core network.[82] As of April 2019, the Global Mobile Suppliers Association had identified 224 operators in 88 countries that have demonstrated, are testing or trialing, or have been licensed to conduct field trials of 5G technologies, are deploying 5G networks or have announced service launches.[83] The equivalent numbers in November 2018 were 192 operators in 81 countries.[84] The first country to adopt 5G on a large scale was South Korea, in April 2019. Swedish telecoms giant Ericsson predicted that 5G Internet will cover up to 65% of the world's population by the end of 2025.[85] Also, it plans to invest 1 billion reals ($238.30 million) in Brazil to add a new assembly line dedicated to fifth-generation technology (5G) for its Latin American operations.[86] When South Korea launched its 5G network, all carriers used Samsung, Ericsson, and Nokia base stations and equipment, except for LG U Plus, who also used Huawei equipment.[87][88] Samsung was the largest supplier for 5G base stations in South Korea at launch, having shipped 53,000 base stations at the time, out of 86,000 base stations installed across the country at the time.[89] The first fairly substantial deployments were in April 2019. In South Korea, SK Telecom claimed 38,000 base stations, KT Corporation 30,000 and LG U Plus 18,000; of which 85% are in six major cities.[90] They are using 3.5 GHz (sub-6) spectrum in non-standalone (NSA) mode and tested speeds were from 193 to 430 Mbit/s down.[91] 260,000 signed up in the first month and 4.7 million by the end of 2019.[92] T-Mobile US was the first company in the world to launch a commercially available 5G NR Standalone network.[93] Nine companies sell 5G radio hardware and 5G systems for carriers: Altiostar, Cisco Systems, Datang Telecom/Fiberhome, Ericsson, Huawei, Nokia, Qualcomm, Samsung, and ZTE.[94][95][96][97][98][99][100] As of 2023, Huawei is the leading 5G equipment manufacturer and has the greatest market share of 5G equipment and has built approximately 70% of worldwide 5G base stations.[101]:182 Large quantities of new radio spectrum (5G NR frequency bands) have been allocated to 5G.[102] For example, in July 2016, the U.S. Federal Communications Commission (FCC) freed up vast amounts of bandwidth in underused high-band spectrum for 5G. The Spectrum Frontiers Proposal (SFP) doubled the amount of millimeter-wave unlicensed spectrum to 14 GHz and created four times the amount of flexible, mobile-use spectrum the FCC had licensed to date.[103] In March 2018, European Union lawmakers agreed to open up the 3.6 and 26 GHz bands by 2020.[104] As of March 2019[update], there are reportedly 52 countries, territories, special administrative regions, disputed territories and dependencies that are formally considering introducing certain spectrum bands for terrestrial 5G services, are holding consultations regarding suitable spectrum allocations for 5G, have reserved spectrum for 5G, have announced plans to auction frequencies or have already allocated spectrum for 5G use.[105] 5G connectivity on a Samsung Galaxy S10 In March 2019, the Global Mobile Suppliers Association released the industry's first database tracking worldwide 5G device launches.[106] In it, the GSA identified 23 vendors who have confirmed the availability of forthcoming 5G devices with 33 different devices including regional variants. There were seven announced 5G device form factors: (telephones (×12 devices), hotspots (×4), indoor and outdoor customer-premises equipment (×8), modules (×5), Snap-on dongles and adapters (×2), and USB terminals (×1)).[107] By October 2019, the number of announced 5G devices had risen to 129, across 15 form factors, from 56 vendors.[108] In the 5G IoT chipset arena, as of April 2019 there were four commercial 5G modem chipsets (Intel, MediaTek, Qualcomm, Samsung) and one commercial processor/platform, with more launches expected in the near future.[109]An Apple iPhone showing that it is connected to a 5G Network On March 4, 2019, the first-ever all-5G smartphone Samsung Galaxy S10 5G was released. According to Business Insider, the 5G feature was showcased as more expensive in comparison with the 4G Samsung Galaxy S10e.[110] On March 19, 2020, HMD Global, the current maker of Nokia-branded phones, announced the Nokia 8.3 5G, which it claimed as having a wider range of 5G compatibility than any other phone released to that time. The mid-range model is claimed to support all 5G bands from 600 MHz to 3.8 GHz.[111] Google Pixel smartphones support 5G starting with the 4a 5G and Pixel 5,[112] while Apple smartphones support 5G starting with the iPhone 12.[113][114] See also: 5G NR frequency bands The air interface defined by 3GPP for 5G is known as 5G New Radio (5G NR), and the specification is subdivided into two frequency bands, FR1 (below 6 GHz) and FR2 (24–54 GHz). Otherwise known as sub-6, the maximum channel bandwidth defined for FR1 is 100 MHz, due to the scarcity of continuous spectrum in this crowded frequency range. The band most widely being used for 5G in this range is 3.3–4.2 GHz. The Korean carriers use the n78 band at 3.5 GHz. Some parties used the term "mid-band" frequency to refer to higher part of this frequency range that was not used in previous generations of mobile communication. The minimum channel bandwidth defined for FR2 is 50 MHz and the maximum is 400 MHz, with two-channel aggregation supported in 3GPP Release 15. Signals in this frequency range with wavelengths between 4 and 12 mm are called millimeter waves. The higher the carrier frequency, the greater the ability to support high data-transfer speeds. This is because a given channel bandwidth takes up a lower fraction of the carrier frequency, so high-bandwidth channels are easier to realize at higher carrier frequencies. 5G in the 24 GHz range or above use higher frequencies than 4G, and as a result, some 5G signals are not capable of traveling large distances (over a few hundred meters), unlike 4G or lower frequency 5G signals (sub 6 GHz). This requires placing 5G base stations every few hundred meters in order to use higher frequency bands. Also, these higher frequency 5G signals cannot penetrate solid objects easily, such as cars, trees, walls, and even humans, because of the nature of these higher frequency electromagnetic waves. 5G cells can be deliberately designed to be as inconspicuous as possible, which finds applications in places like restaurants and shopping malls.[115] Cell types Deployment environment Max. number of users Output power (W) Max. distance from base station 5G NR FR2 Femtocell Homes, businesses Home: 4–8Businesses: 16–32 indoors: 0.01–0.1outdoors: 0.2–1 tens of meters Pico cell Public areas like shopping malls,airports, train stations, skyscrapers 64 to 128 indoors: 0.1–0.25outdoors: 1–5 tens of meters Micro cell Urban areas to fill coverage gaps 128 to 256 outdoors: 5−10 few hundreds of meters Macro cell Urban areas to provide additional capacity more than 250 outdoors: 10−20 hundreds of meters Wi-Fi(for comparison) Homes, businesses fewer than 50 indoors: 0.02–0.1outdoors: 0.2–1 few tens of meters See also: Multi-user MIMO MIMO (multiple-input and multiple-output) systems use multiple antennas at the transmitter and receiver ends of a wireless communication system. Multiple antennas use the spatial dimension for multiplexing in addition to the time and frequency ones, without changing the bandwidth requirements of the system. Spatial multiplexing gains allow for an increase in the number of transmission layers, thereby boosting system capacity. Massive MIMO antennas increases sector throughput and capacity density using large numbers of antennas. This includes Single User MIMO and Multi-user MIMO (MU-MIMO). The antenna array can schedule users separately to satisfy their needs and beamform towards the intended users, minimizing interference.[116] Main article: Multi-access edge computing Edge computing is delivered by computing servers closer to the ultimate user. It reduces latency, data traffic congestion[117][118] and can improve service availability.[119] Main article: Small cell Small cells are low-powered cellular radio access nodes that operate in licensed and unlicensed spectrum that have a range of 10 meters to a few kilometers. Small cells are critical to 5G networks, as 5G's radio waves can't travel long distances, because of 5G's higher frequencies.[120][121][122][123] Main article: Beamforming There are two kinds of beamforming (BF): digital and analog. Digital beamforming involves sending the data across multiple streams (layers), while analog beamforming shaping the radio waves to point in a specific direction. The analog BF technique combines the power from elements of the antenna array in such a way that signals at particular angles experience constructive interference, while other signals pointing to other angles experience destructive interference. This improves signal quality in the specific direction, as well as data transfer speeds. 5G uses both digital and analog beamforming to improve the system capacity.[124][125] One expected benefit of the transition to 5G is the convergence of multiple networking functions to achieve cost, power, and complexity reductions. LTE has targeted convergence with Wi-Fi band/technology via various efforts, such as License Assisted Access (LAA; 5G signal in unlicensed frequency bands that are also used by Wi-Fi) and LTE-WLAN Aggregation (LWA; convergence with Wi-Fi Radio), but the differing capabilities of cellular and Wi-Fi have limited the scope of convergence. However, significant improvement in cellular performance specifications in 5G, combined with migration from Distributed Radio Access Network (D-RAN) to Cloud- or Centralized-RAN (C-RAN) and rollout of cellular small cells can potentially narrow the gap between Wi-Fi and cellular networks in dense and indoor deployments. Radio convergence could result in sharing ranging from the aggregation of cellular and Wi-Fi channels to the use of a single silicon device for multiple radio access technologies.[126] NOMA (non-orthogonal multiple access) is a proposed multiple-access technique for future cellular systems via allocation of power.[127] Main articles: Software-defined networking, SD-WAN, Network function virtualization, and 5G network slicing Initially, cellular mobile communications technologies were designed in the context of providing voice services and Internet access. Today a new era of innovative tools and technologies is inclined towards developing a new pool of applications. This pool of applications consists of different domains such as the Internet of Things (IoT), web of connected autonomous vehicles, remotely controlled robots, and heterogeneous sensors connected to serve versatile applications.[128] In this context, network slicing has emerged as a key technology to efficiently embrace this new market model.[129] The 5G Service-Based architecture replaces the referenced-based architecture of the Evolved Packet Core that is used in 4G. The SBA breaks up the core functionality of the network into interconnected network functions (NFs), which are typically implemented as Cloud-Native Network Functions. These NFs register with the Network Repository Function (NRF) which maintains their state, and communicate with each other using the Service Communication Proxy (SCP). The interfaces between the elements all utilize RESTful APIs.[130] By breaking functionality down this way, mobile operators are able to utilize different infrastructure vendors for different functions, and the flexibility to scale each function independently as needed.[130] 5G Network Functions [131] NF Name NF Acronym Analogous EPC element Authentication Server Function AUSF MME / HSS (Authentication) Access and Mobility Management Function AMF MME Unstructured Data Storage Function UDSF N/A Network Exposure Function NEF N/A Network Slice Specific Authentication and Authorization Function NSSAAF N/A Network Slice Selection Function NSSF N/A Policy Control Function PCF PCRF Session Management Function SMF MME / PGW-C Unified Data Management UDM HSS (DB Front End) Unified Data Repository UDR HSS (User Database) User Plane Function UPF SGW-U / PGW-U UE radio Capability Management Function UCMF N/A Application Function AF AF (IMS) Network Data Analytics Function NWDAF N/A CHarging Function CHF CSCF In addition, the standard describes network entities for roaming and inter-network connectivity, including the Security Edge Protection Proxy (SEPP), the Non-3GPP InterWorking Function (N3IWF), the Trusted Non-3GPP Gateway Function (TNGF), the Wireline Access Gateway Function (W-AGF), and the Trusted WLAN Interworking Function (TWIF). These can be deployed by operators as needed depending on their deployment. The channel coding techniques for 5G NR have changed from Turbo codes in 4G to polar codes for the control channels and LDPC (low-density parity check codes) for the data channels.[132][133] In December 2018, 3GPP began working on unlicensed spectrum specifications known as 5G NR-U, targeting 3GPP Release 16.[134] Qualcomm has made a similar proposal for LTE in unlicensed spectrum. 5G wireless power is a technology based on 5G standards that transfers wireless power.[135][136] It adheres to technical standards set by the 3rd Generation Partnership Project, the International Telecommunication Union, and the Institute of Electrical and Electronics Engineers. It utilizes extremely high frequency radio waves with wavelengths from one to ten millimeters, also known as mmWaves.[137][138] Up to 6μW of power has been demonstrated being captured from 5G signals at a distance of 180m by researchers at Georgia Tech.[135] Internet of things devices could benefit from 5G wireless power technology, given their low power requirements that are within the range of what has been achieved using 5G power capture.[139] See also: Concerns over Chinese involvement in 5G wireless networks and Criticism of Huawei § Espionage and security concerns A report published by the European Commission and European Agency for Cybersecurity details the security issues surrounding 5G. The report warns against using a single supplier for a carrier's 5G infrastructure, especially those based outside the European Union; Nokia and Ericsson are the only European manufacturers of 5G equipment.[140] On October 18, 2018, a team of researchers from ETH Zurich, the University of Lorraine and the University of Dundee released a paper entitled, "A Formal Analysis of 5G Authentication".[141][142] It alerted that 5G technology could open ground for a new era of security threats. The paper described the technology as "immature and insufficiently tested," and one that "enables the movement and access of vastly higher quantities of data, and thus broadens attack surfaces". Simultaneously, network security companies such as Fortinet,[143] Arbor Networks,[144] A10 Networks,[145] and Voxility[146] advised on personalized and mixed security deployments against massive DDoS attacks foreseen after 5G deployment. IoT Analytics estimated an increase in the number of IoT devices, enabled by 5G technology, from 7 billion in 2018 to 21.5 billion by 2025.[147] This can raise the attack surface for these devices to a substantial scale, and the capacity for DDoS attacks, cryptojacking, and other cyberattacks could boost proportionally.[142] In addition, the EPS solution for 5G networks has identified a design vulnerability. The vulnerability affects the operation of the device during cellular network switching.[148] Due to fears of potential espionage of users of Chinese equipment vendors, several countries (including the United States, Australia and the United Kingdom as of early 2019)[149] have taken actions to restrict or eliminate the use of Chinese equipment in their respective 5G networks. A 2012 U.S. House Permanent Select Committee on Intelligence report concluded that using equipment made by Huawei and ZTE, another Chinese telecommunications company, could "undermine core U.S. national security interests".[150] In 2018, six U.S. intelligence chiefs, including the directors of the CIA and FBI, cautioned Americans against using Huawei products, warning that the company could conduct "undetected espionage".[151] Further, a 2017 investigation by the FBI determined that Chinese-made Huawei equipment could disrupt U.S. nuclear arsenal communications.[152] Chinese vendors and the Chinese government have denied claims of espionage, but experts have pointed out that Huawei would have no choice but to hand over network data to the Chinese government if Beijing asked for it because of Chinese National Security Law.[153] In August 2020, the U.S. State Department launched "The Clean Network" as a U.S. government-led, bi-partisan effort to address what it described as "the long-term threat to data privacy, security, human rights and principled collaboration posed to the free world from authoritarian malign actors". Promoters of the initiative have stated that it has resulted in an "alliance of democracies and companies", "based on democratic values". On October 7, 2020, the UK Parliament's Defence Committee released a report claiming that there was clear evidence of collusion between Huawei and Chinese state and the Chinese Communist Party. The UK Parliament's Defence Committee said that the government should consider removal of all Huawei equipment from its 5G networks earlier than planned.[154] In December 2020, the United States announced that more than 60 nations, representing more than two thirds of the world's gross domestic product, and 200 telecom companies, had publicly committed to the principles of The Clean Network. This alliance of democracies included 27 of the 30 NATO members; 26 of the 27 EU members, 31 of the 37 OECD nations, 11 of the 12 Three Seas nations as well as Japan, Israel, Australia, Singapore, Taiwan, Canada, Vietnam, and India. Parts of this article (those related to 5G, short for the fifth generation of wireless technology, employs a range of higher-frequency radio waves than its predecessors.) need to be updated. Please help update this article to reflect recent events or newly available information. (January 2022) The spectrum used by various 5G proposals, especially the n258 band centered at 26 GHz, will be near that of passive remote sensing such as by weather and Earth observation satellites, particularly for water vapor monitoring at 23.8 GHz.[155] Interference is expected to occur due to such proximity and its effect could be significant without effective controls. An increase in interference already occurred with some other prior proximate band usages.[156][157] Interference to satellite operations impairs numerical weather prediction performance with substantially deleterious economic and public safety impacts in areas such as commercial aviation.[158][159] The concerns prompted U.S. Secretary of Commerce Wilbur Ross and NASA Administrator Jim Bridenstine in February 2019 to urge the FCC to delay some spectrum auction proposals, which was rejected.[160] The chairs of the House Appropriations Committee and House Science Committee wrote separate letters to FCC chairman Ajit Pai asking for further review and consultation with NOAA, NASA, and DoD, and warning of harmful impacts to national security.[161] Acting NOAA director Neil Jacobs testified before the House Committee in May 2019 that 5G out-of-band emissions could produce a 30% reduction in weather forecast accuracy and that the resulting degradation in ECMWF model performance would have resulted in failure to predict the track and thus the impact of Superstorm Sandy in 2012. The United States Navy in March 2019 wrote a memorandum warning of deterioration and made technical suggestions to control band bleed-over limits, for testing and fielding, and for coordination of the wireless industry and regulators with weather forecasting organizations.[162] At the 2019 quadrennial World Radiocommunication Conference (WRC), atmospheric scientists advocated for a strong buffer of −55 dBW, European regulators agreed on a recommendation of −42 dBW, and US regulators (the FCC) recommended a restriction of −20 dBW, which would permit signals 150 times stronger than the European proposal. The ITU decided on an intermediate −33 dBW until September 1, 2027, and after that a standard of −39 dBW.[163] This is closer to the European recommendation but even the delayed higher standard is much weaker than that requested by atmospheric scientists, triggering warnings from the World Meteorological Organization (WMO) that the ITU standard, at 10 times less stringent than its recommendation, brings the "potential to significantly degrade the accuracy of data collected".[164] A representative of the American Meteorological Society (AMS) also warned of interference,[165] and the European Centre for Medium-Range Weather Forecasts (ECMWF), sternly warned, saying that society risks "history repeat[ing] itself" by ignoring atmospheric scientists' warnings (referencing global warming, monitoring of which could be imperiled).[166] In December 2019, a bipartisan request was sent from the US House Science Committee to the Government Accountability Office (GAO) to investigate why there is such a discrepancy between recommendations of US civilian and military science agencies and the regulator, the FCC.[167] The United States FAA has warned that radar altimeters on aircraft, which operate between 4.2 and 4.4 GHz, might be affected by 5G operations between 3.7 and 3.98 GHz. This is particularly an issue with older altimeters using RF filters[168] which lack protection from neighboring bands.[169] This is not as much of an issue in Europe, where 5G uses lower frequencies between 3.4 and 3.8 GHz.[170] Nonetheless, the DGAC in France has also expressed similar worries and recommended 5G phones be turned off or be put in airplane mode during flights.[171] On December 31, 2021, U.S. Transportation Secretary Pete Buttigieg and Steve Dickinson, administrator of the Federal Aviation Administration asked the chief executives of AT&T and Verizon to delay 5G implementation over aviation concerns. The government officials asked for a two-week delay starting on January 5, 2022, while investigations are conducted on the effects on radar altimeters. The government transportation officials also asked the cellular providers to hold off their new 5G service near 50 priority airports, to minimize disruption to air traffic that would be caused by some planes being disallowed from landing in poor visibility.[172] After coming to an agreement with government officials the day before,[173] Verizon and AT&T activated their 5G networks on January 19, 2022, except for certain towers near 50 airports.[174] AT&T scaled back its deployment even further than its agreement with the FAA required.[175] The FAA rushed to test and certify radar altimeters for interference so that planes could be allowed to perform instrument landings (e.g. at night and in low visibility) at affected airports. By January 16, it had certified equipment on 45% of the U.S. fleet, and 78% by January 20.[176] Airlines complained about the avoidable impact on their operations, and commentators said the affair called into question the competence of the FAA.[177] Several international airlines substituted different planes so they could avoid problems landing at scheduled airports, and about 2% of flights (320) were cancelled by the evening of January 19.[178] Further information: C band (IEEE) A number of 5G networks deployed on the radio frequency band of 3.3–3.6 GHz are expected to cause interference with C-Band satellite stations, which operate by receiving satellite signals at 3.4–4.2 GHz frequency.[179] This interference can be mitigated with low-noise block downconverters and waveguide filters.[179] In regions like the US and EU, the 6 GHz band is to be opened up for unlicensed applications, which would permit the deployment of 5G-NR Unlicensed, 5G version of LTE in unlicensed spectrum, as well as Wi-Fi 6e. However, interference could occur with the co-existence of different standards in the frequency band.[180] There have been concerns surrounding the promotion of 5G, questioning whether the technology is overhyped. There are questions on whether 5G will truly change the customer experience,[181] ability for 5G's mmWave signal to provide significant coverage,[182][183] overstating what 5G can achieve or misattributing continuous technological improvement to "5G",[184] lack of new use case for carriers to profit from,[185] wrong focus on emphasizing direct benefits on individual consumers instead of for Internet of Things devices or solving the last mile problem,[186] and overshadowing the possibility that in some aspects there might be other more appropriate technologies.[187] Such sort of concerns have also led to consumers not trusting information provided by cellular providers on the topic.[188] Main article: 5G misinformation Further information: Wireless device radiation and health There is a long history of fear and anxiety surrounding wireless signals that predates 5G technology. The fears about 5G are similar to those that have persisted throughout the 1990s and 2000s. According to the US Centers for Disease Control and Prevention (CDC) "exposure to intense, direct amounts of non-ionizing radiation may result in damage to tissue due to heat. This is not common and mainly of concern in the workplace for those who work on large sources of non-ionizing radiation devices and instruments."[189] Some advocates of fringe health claim the regulatory standards are too low and influenced by lobbying groups.[190] An anti-5G sticker in Luxembourg There have been rumors that 5G mobile phone use can cause cancer, but this is a myth.[191] Many popular books of dubious merit have been published on the subject[additional citation(s) needed] including one by Joseph Mercola alleging that wireless technologies caused numerous conditions from ADHD to heart diseases and brain cancer. Mercola has drawn sharp criticism for his anti-vaccinationism during the COVID-19 pandemic and was warned by the Food and Drug Administration to stop selling fake COVID-19 cures through his online alternative medicine business.[190][192] According to The New York Times, one origin of the 5G health controversy was an erroneous unpublished study that physicist Bill P. Curry did for the Broward County School Board in 2000 which indicated that the absorption of external microwaves by brain tissue increased with frequency.[193] According to experts[vague] this was wrong, the millimeter waves used in 5G are safer than lower frequency microwaves because they cannot penetrate the skin and reach internal organs. Curry had confused in vitro and in vivo research. However Curry's study was widely distributed on the Internet. Writing in The New York Times in 2019, William Broad reported that RT America began airing programming linking 5G to harmful health effects which "lack scientific support", such as "brain cancer, infertility, autism, heart tumors, and Alzheimer's disease". Broad asserted that the claims had increased. RT America had run seven programs on this theme by mid-April 2019 but only one in the whole of 2018. The network's coverage had spread to hundreds of blogs and websites.[194] In April 2019, the city of Brussels in Belgium blocked a 5G trial because of radiation rules.[195] In Geneva, Switzerland, a planned upgrade to 5G was stopped for the same reason.[196] The Swiss Telecommunications Association (ASUT) has said that studies have been unable to show that 5G frequencies have any health impact.[197] According to CNET,[198] "Members of Parliament in the Netherlands are also calling on the government to take a closer look at 5G. Several leaders in the United States Congress have written to the Federal Communications Commission expressing concern about potential health risks. In Mill Valley, California, the city council blocked the deployment of new 5G wireless cells."[198][199][200][201][202] Similar concerns were raised in Vermont[203] and New Hampshire.[198] The US FDA is quoted saying that it "continues to believe that the current safety limits for cellphone radiofrequency energy exposure remain acceptable for protecting the public health".[204] After campaigning by activist groups, a series of small localities in the UK, including Totnes, Brighton and Hove, Glastonbury, and Frome, passed resolutions against the implementation of further 5G infrastructure, though these resolutions have no impact on rollout plans.[205][206][207] Low-level EMF does have some effects on other organisms.[208] Vian et al., 2006 finds an effect of microwave on gene expression in plants.[208] A meta-analysis of 95 in vitro and in vivo studies showed that an average of 80% of the in vivo research showed effects of such radiation, as did 58% of the in vitro research, but that the results were inconclusive as to whether any of these effects pose a health risk.[209] Main article: COVID-19 misinformation § 5G mobile-phone networks The World Health Organization published a mythbuster infographic to combat the conspiracy theories about COVID-19 and 5G As the introduction of 5G technology coincided with the time of the COVID-19 pandemic, several conspiracy theories circulating online posited a link between COVID-19 and 5G.[210] This has led to dozens of arson attacks being made on telecom masts in the Netherlands (Amsterdam, Rotterdam, etc.), Ireland (Cork,[211] etc.), Cyprus, the United Kingdom (Dagenham, Huddersfield, Birmingham, Belfast and Liverpool),[212][213] Belgium (Pelt), Italy (Maddaloni), Croatia (Bibinje)[214] and Sweden.[215] It led to at least 61 suspected arson attacks against telephone masts in the United Kingdom alone[216] and over twenty in The Netherlands. In the early months of the pandemic, anti-lockdown protesters at protests over responses to the COVID-19 pandemic in Australia were seen with anti-5G signs, an early sign of what became a wider campaign by conspiracy theorists to link the pandemic with 5G technology. There are two versions of the 5G-COVID-19 conspiracy theory:[190] The first version claims that radiation weakens the immune system, making the body more vulnerable to SARS-CoV-2 (the virus that causes COVID-19). The second version claims that 5G causes COVID-19. There are different variations on this. Some claim that the pandemic is coverup of illness caused by 5G radiation or that COVID-19 originated in Wuhan because that city was "the guinea-pig city for 5G". Main articles: 5G Evolution, LTE Advanced Pro, and LTE AdvancedThis section needs expansion. You can help by adding to it. (October 2023) In various parts of the world, carriers have launched numerous differently branded technologies, such as "5G Evolution", which advertise improving existing networks with the use of "5G technology".[217] However, these pre-5G networks are an improvement on specifications of existing LTE networks that are not exclusive to 5G. While the technology promises to deliver higher speeds, and is described by AT&T as a "foundation for our evolution to 5G while the 5G standards are being finalized", it cannot be considered to be true 5G. When AT&T announced 5G Evolution, 4x4 MIMO, the technology that AT&T is using to deliver the higher speeds, had already been put in place by T-Mobile without being branded with the 5G moniker. It is claimed that such branding is a marketing move that will cause confusion with consumers, as it is not made clear that such improvements are not true 5G.[218] With the rollout of 5G, 4G has become more available and affordable, with the world's most developed countries having >90% LTE coverage.[219] Because of this, 4G is still not obsolete even today.[220] 4G plans are sold alongside 5G plans on US carriers,[221] with 4G being cheaper than 5G.[222] This section needs to be updated. Please help update this article to reflect recent events or newly available information. (April 2019) Cellular network standards and generation timeline. In April 2008, NASA partnered with Geoff Brown and Machine-to-Machine Intelligence (M2Mi) Corp to develop a fifth generation communications technology approach, though largely concerned with working with nanosats.[223] That same year, the South Korean IT R&D program of "5G mobile communication systems based on beam-division multiple access and relays with group cooperation" was formed.[224] In August 2012, New York University founded NYU Wireless, a multi-disciplinary academic research centre that has conducted pioneering work in 5G wireless communications.[225] On October 8, 2012, the UK's University of Surrey secured £35M for a new 5G research centre, jointly funded by the British government's UK Research Partnership Investment Fund (UKRPIF) and a consortium of key international mobile operators and infrastructure providers, including Huawei, Samsung, Telefónica Europe, Fujitsu Laboratories Europe, Rohde & Schwarz, and Aircom International. It will offer testing facilities to mobile operators keen to develop a mobile standard that uses less energy and less radio spectrum, while delivering speeds higher than current 4G with aspirations for the new technology to be ready within a decade.[226][227][228][229] On November 1, 2012, the EU project "Mobile and wireless communications Enablers for the Twenty-twenty Information Society" (METIS) started its activity toward the definition of 5G. METIS achieved an early global consensus on these systems. In this sense, METIS played an important role in building consensus among other external major stakeholders prior to global standardization activities. This was done by initiating and addressing work in relevant global fora (e.g. ITU-R), as well as in national and regional regulatory bodies.[230] That same month, the iJOIN EU project was launched, focusing on "small cell" technology, which is of key importance for taking advantage of limited and strategic resources, such as the radio wave spectrum. According to Günther Oettinger, the European Commissioner for Digital Economy and Society (2014–2019), "an innovative utilization of spectrum" is one of the key factors at the heart of 5G success. Oettinger further described it as "the essential resource for the wireless connectivity of which 5G will be the main driver".[231] iJOIN was selected by the European Commission as one of the pioneering 5G research projects to showcase early results on this technology at the Mobile World Congress 2015 (Barcelona, Spain). In February 2013, ITU-R Working Party 5D (WP 5D) started two study items: (1) Study on IMT Vision for 2020 and beyond, and; (2) Study on future technology trends for terrestrial IMT systems. Both aiming at having a better understanding of future technical aspects of mobile communications toward the definition of the next generation mobile.[232] On May 12, 2013, Samsung Electronics stated that they had developed a "5G" system. The core technology has a maximum speed of tens of Gbit/s (gigabits per second). In testing, the transfer speeds for the "5G" network sent data at 1.056 Gbit/s to a distance of up to 2 kilometers with the use of an 8*8 MIMO.[233][234] In July 2013, India and Israel agreed to work jointly on development of fifth generation (5G) telecom technologies.[235] On October 1, 2013, NTT (Nippon Telegraph and Telephone), the same company to launch world's first 5G network in Japan, wins Minister of Internal Affairs and Communications Award at CEATEC for 5G R&D efforts.[236] On November 6, 2013, Huawei announced plans to invest a minimum of $600 million into R&D for next generation 5G networks capable of speeds 100 times higher than modern LTE networks.[237] On April 3, 2019, South Korea became the first country to adopt 5G.[238] Just hours later, Verizon launched its 5G services in the United States, and disputed South Korea's claim of becoming the world's first country with a 5G network, because allegedly, South Korea's 5G service was launched initially for just six South Korean celebrities so that South Korea could claim the title of having the world's first 5G network.[239] In fact, the three main South Korean telecommunication companies (SK Telecom, KT, and LG Uplus) added more than 40,000 users to their 5G network on the launch day.[240] In June 2019, the Philippines became the first country in Southeast Asia to roll out a 5G broadband network after Globe Telecom commercially launched its 5G data plans to customers.[241] AT&T brings 5G service to consumers and businesses in December 2019 ahead of plans to offer 5G throughout the United States in the first half of 2020.[242][243][244] In 2020, AIS and TrueMove H launched 5G services in Thailand, making it the first country in Southeast Asia to have commercial 5G.[245][246] A functional mockup of a Russian 5G base station, developed by domestic specialists as part of Rostec's digital division Rostec.digital, was presented in Nizhny Novgorod at the annual conference "Digital Industry of Industrial Russia".[247][248] 5G speeds have declined in many countries since 2022, which has driven the development of 5.5G to increase connection speeds.[249] ^ When there is only one user in the network ^ Hoffman, Chris (January 7, 2019). "What is 5G, and how fast will it be?". How-To Geek website. How-To Geek LLC. Archived from the original on January 24, 2019. Retrieved January 23, 2019. ^ "5G NR | 5g New Radio Standard | Qualcomm". www.qualcomm.com. Retrieved February 27, 2025. ^ "3GPP meets IMT-2020". www.3gpp.org. Retrieved February 26, 2025. ^ "5G explained: What it is, who has 5G, and how much faster is it really?". CNN. Archived from the original on November 27, 2021. Retrieved November 27, 2021. ^ Segan, Sascha (May 16, 2022). "What Is 5G?". PCMAG. Retrieved April 12, 2025. ^ a b Horwitz, Jeremy (December 10, 2019). "The definitive guide to 5G low, mid, and high band speeds". VentureBeat online magazine. Archived from the original on November 5, 2020. Retrieved April 23, 2020. ^ a b De Looper, Christian; Jansen, Mark (April 22, 2022). "Is 5G as fast as they're saying? We break down the speeds". Digital Trends. Archived from the original on May 27, 2023. Retrieved May 27, 2023. ^ Davies, Darrell (May 20, 2019). "Small Cells – Big in 5G". Nokia. Archived from the original on November 1, 2020. Retrieved August 29, 2020. ^ Violette, E. J.; Espeland, R. H.; DeBolt, R. O.; Schwering, F. K. (May 1988). "Millimeter-wave propagation at street level in an urban environment". IEEE Transactions on Geoscience and Remote Sensing. 26 (3). IEEE: 368–380. Bibcode:1988ITGRS..26..368V. doi:10.1109/36.3038. Archived from the original on June 23, 2021. Retrieved March 19, 2021. For non-line-of-sight (non-LOS) paths obstructed by buildings of several common materials, results that showed signal attenuations in excess of 100 dB. When the LOS followed a path directly through clear glass walls, the attenuation was small at all probe frequencies. However, when the glass wall had a metalized coating to reduce ultraviolet and infrared radiation, the attenuation increased by 25 to 50 dB for each metallized layer. In most cases no signals could be detected through steel reinforced concrete or brick buildings. ^ Ganji, Venkata Siva Santosh; Lin, Tzu-Hsiang; Espinal, Francisco A.; Kumar, P. R. (January 5, 2021). "UNBLOCK: Low Complexity Transient Blockage Recovery for Mobile mm-Wave Devices". 2021 International Conference on COMmunication Systems & NETworkS (COMSNETS). IEEE. pp. 501–508. arXiv:2104.02658. doi:10.1109/COMSNETS51098.2021.9352816. ISBN 978-1-7281-9127-0. S2CID 231976614. ^ "FCC Auction 102 – 24 GHz". fcc.gov. Federal Communications Commission. ^ "5G – Its Not Here Yet, But Closer Than You Think". October 31, 2017. Archived from the original on January 6, 2019. Retrieved January 6, 2019. ^ "Managing the Future of Cellular" (PDF). March 20, 2020. Archived (PDF) from the original on September 23, 2020. Retrieved September 24, 2020. ^ Yu, Heejung; Lee, Howon; Jeon, Hongbeom (October 2017). "What is 5G? Emerging 5G Mobile Services and Network Requirements". Sustainability. 9 (10): 1848. Bibcode:2017Sust....9.1848Y. doi:10.3390/su9101848. ^ a b "Intel Accelerates the Future with World's First Global 5G Modem". Intel Newsroom. Archived from the original on September 6, 2018. Retrieved November 21, 2019. ^ "Ford: Self-driving cars "will be fully capable of operating without C-V2X"". wirelessone.news. Archived from the original on October 27, 2020. Retrieved December 1, 2019. ^ "5GAA Tele-Operated Driving (ToD): Use Cases and Technical Requirements Technical Requirements" (PDF). 5G Automotive Association. Archived (PDF) from the original on March 3, 2021. Retrieved February 8, 2021. ^ "Smooth teleoperator: The rise of the remote controller". VentureBeat. August 17, 2020. Archived from the original on February 7, 2021. Retrieved February 8, 2021. ^ "5GAA, Audi, Ford and Qualcomm Showcase C-V2X Direct Communications Interoperability to Improve Road Safety". newswire.ca. Archived from the original on January 6, 2019. Retrieved January 14, 2019. ^ "The Promise of 5G for Public Safety". EMS World. Archived from the original on December 16, 2018. Retrieved January 14, 2019. ^ Fulton III, Scott. "What is 5G? All you need to know about the next generation of wireless technology". ZDNet. Archived from the original on April 21, 2019. Retrieved April 21, 2019. ^ "5G Fixed Wireless Access (FWA) technology | What Is It?". 5g.co.uk. Archived from the original on April 21, 2019. Retrieved April 21, 2019. ^ "Capture value with 5G Fixed Wireless Access in a world of opportunities". ^ "Sony and Verizon Demonstrate 5G transmission for covering live sports". January 11, 2020. Archived from the original on November 7, 2020. Retrieved March 22, 2020. ^ "Technology behind the project". 5g-today.de. Archived from the original on January 18, 2022. Retrieved April 8, 2022. ^ "In One Minute, What is VoNR?". academy.qualcomm.com. Retrieved April 12, 2025. ^ "What is 5G | Everything You Need to Know About 5G | 5G FAQ | Qualcomm". www.qualcomm.com. Retrieved April 12, 2025. ^ "5G explained: What it is, who has 5G, and how much faster is it really?". www.cnn.com. Retrieved April 12, 2025. ^ a b "Minimum requirements related to technical performance for IMT-2020 radio interface(s)" (PDF). Archived (PDF) from the original on January 8, 2019. Retrieved August 16, 2019. ^ "Opensignal declares T-Mo US fastest 5G carrier, again". January 30, 2023. Retrieved April 12, 2025. ^ Wyrzykowski, Robert (January 2023). "Mobile Network Experience 5G Report – USA". OpenSignal. Archived from the original on May 27, 2023. Retrieved May 27, 2023. ^ Fogg, Ian (June 22, 2022). "Benchmarking the Global 5G Experience – June 2022". OpenSignal. Archived from the original on May 27, 2023. Retrieved May 27, 2023. ^ I, Chih-Lin; Han, Shuangfeng; Bian, Sen (2020). "Energy-efficient 5G for a greener future". Nature Electronics. 3 (4): 182–184. doi:10.1038/s41928-020-0404-1. S2CID 257095960. ^ "Faroese Telecom and Ericsson claim 5G mmWave downlink speed record". www.telecoms.com. Retrieved April 12, 2025. ^ "What is the Latency of 5G?". www.verizon.com. February 2, 2020. Retrieved April 12, 2025. ^ Vanichchanunt, Pisit; Yamyuan, Ittipon; Sasithong, Pruk; Wuttisittikulkij, Lunchakorn; Paripurana, Sukritta (January 11, 2023). "Implementation of Edge Servers on an Open 5G Core Network". 2023 International Conference on Information Networking (ICOIN). IEEE. pp. 642–645. doi:10.1109/ICOIN56518.2023.10049000. ISBN 978-1-6654-6268-6. ^ Gartenberg, Chaim (December 21, 2017). "The first real 5G specification has officially been completed". The Verge. Archived

from the original on January 7, 2019. Retrieved June 25, 2018. ^ Flynn, Kevin. "Workshop on 3GPP submission towards IMT-2020". 3gpp.org. Archived from the original on January 7, 2019. Retrieved January 6, 2019. ^ Wu, Hao (March 17, 2020), "A Brief Overview of CRC Implementation for 5G NR", Moving Broadband Mobile Communications Forward - Intelligent Technologies for 5G and Beyond, IntechOpen, ISBN 978-1-83962-344-8, retrieved April 12, 2025 ^ Dave. "5G NR Only 25% to 50% Faster, Not Truly a New Generation". wirelessone.news. Archived from the original on June 20, 2018. Retrieved June 25, 2018. ^ Teral, Stephane (January 30, 2019). "5G best choice architecture" (PDF). ZTE. Archived (PDF) from the original on February 2, 2019. Retrieved February 1, 2019. ^ "Specification Numbering". 3GPP. Archived from the original on February 17, 2022. Retrieved February 17, 2022. ^ "3GPP Specification Status Report". 3GPP. Archived from the original on January 27, 2022. Retrieved February 26, 2022. ^ "ETSI TS 123 501 V16.12.0 (2022–03). 5G; System architecture for the 5G System (5GS) (3GPP TS 23.501 version 16.12.0 Release 16)" (PDF). ETSI and 3GPP. Archived (PDF) from the original on April 19, 2022. Retrieved April 6, 2022. (TS 23.501) ^ "Non-Access-Stratum (NAS) protocol for 5G System (5GS); Stage 3. (3GPP TS 24.501 version 16.10.0 Release 16) TS 24.501 release 16.10.0" (PDF). ETSI and 3GPP. Archived (PDF) from the original on February 17, 2022. Retrieved February 26, 2022. (TS 24.501) ^ "Digital cellular telecommunications system (Phase 2+) (GSM); Universal Mobile Telecommunications System (UMTS); LTE; 5G; Numbering, addressing and identification (3GPP TS 23.003 version 16.8.0 Release 16)" (PDF). ETSI and 3GPP. Archived (PDF) from the original on February 26, 2022. Retrieved February 26, 2022. (TS 23.003) ^ "DECT NR+". www.nordicsemi.com. Retrieved February 27, 2025. ^ Rowe, Martin (August 16, 2023). "The first non-cellular 5G standard: DECT NR+". 5G Technology World. Retrieved February 27, 2025. ^ Kavanagh, Sacha. "What is 5G New Radio (5G NR)". 5g.co.uk. Archived from the original on November 8, 2018. Retrieved November 8, 2018. ^ "Making 5G New Radio (NR) a Reality – The Global 5G Standard – IEEE Communications Society". comsoc.org. Archived from the original on November 8, 2018. Retrieved January 6, 2019. ^ ctrfantennas (August 24, 2021). "Status And Future Of 5G New Radio Technology - C&T RF Antennas Manufacturer". Retrieved April 12, 2025. ^ Sha, Arjun (August 3, 2022). "What is India's 5Gi Standard? Explained!". Beebom. Retrieved April 12, 2025. ^ Das, Aditi (April 29, 2022). "TSDSI 5Gi standard merged with 3GPP 5G". India's Telecom SDO. Retrieved April 12, 2025. ^ Kastrenakes, Jacob (December 7, 2018). "Is Verizon's 5G home internet real 5G?". The Verge. Archived from the original on December 7, 2018. Retrieved October 7, 2019. ^ "Mobile industry eyes 5G devices in early 2019". telecomasia.net. Archived from the original on January 6, 2019. Retrieved January 6, 2019. ^ "With LTE-M and NB-IoT You're Already on the Path to 5G". sierrawireless.com. Archived from the original on January 6, 2019. Retrieved January 6, 2019. ^ Munira Jaffar & Nicolas Chuberre (July 1, 2022). "NTN & Satellite in Rel-17 & 18". 3rd Generation Partnership Project (3GPP). ^ Xingqin Lin; Stefan Rommer; Sebastian Euler; Emre A. Yavuz; Robert S. Karlsson (2021). "5G from Space: An Overview of 3GPP Non-Terrestrial Networks". arXiv:2103.09156 [cs.NI]. ^ "Samsung Electronics Introduces Standardized 5G NTN Modem Technology To Power Smartphone-Satellite Communication". news.samsung.com. Retrieved June 30, 2023. ^ MediaTek (April 12, 2025). "MediaTek to Showcase its Groundbreaking Satellite Connectivity...". MediaTek. Retrieved April 12, 2025. ^ "5G Satellite (NTN)". MediaTek. Retrieved June 30, 2023. ^ "Qualcomm Launches New Satellite IoT Solutions to Provide Uninterrupted Remote Monitoring and Asset Tracking". www.qualcomm.com. Retrieved June 30, 2023. ^ Amadeo, Ron (June 29, 2023). "Motorola's "Satellite Link" hotspot lets you send messages via outer space". Ars Technica. Retrieved June 30, 2023. ^ "Motorola Defy Satellite Link". Motorola Rugged USA. Retrieved June 30, 2023. ^ "Supermicro and Rakuten Symphony Extend Their Collaboration and Offer Complete 5G, Telco, and Edge Solutions For Cloud Based Open RAN Mobile Networks". www.prnewswire.com. Retrieved April 12, 2025. ^ "Release 18". www.3gpp.org. Archived from the original on November 25, 2021. Retrieved November 25, 2021. ^ "The 5G Advanced, an evolution towards 6G". ericsson.com. Retrieved April 12, 2025. ^ "5G-Advanced explained". nokia.com. September 15, 2023. ^ "TDD Multi-Carrier Aggregation Builds Foundation For New 5G Advanced Experiences". www.counterpointresearch.com. Retrieved March 3, 2025. ^ "5G-Advanced's system architecture begins taking shape at 3GPP". Nokia. Archived from the original on November 25, 2021. Retrieved November 25, 2021. ^ "Four ways 5G-Advanced will transform our industry". Nokia. Archived from the original on November 26, 2021. Retrieved November 26, 2021. ^ Fattah, Hossam Abdel (February 3, 2024). "Non-Terrestrial Networks in 3GPP Release 18 for Global IoT Expansion". 5G HUB TECHNOLOGIES, INC. Retrieved April 12, 2025. ^ Mavrakis, Dimitris. "2024 Will Be the Year of 5G-Advanced". www.abiresearch.com. Retrieved April 12, 2025. ^ "体验为王！DNA现网演示吹响5G-A欧洲商用号角 - 业界资讯 — C114(通信网)" [Experience is king! DNA's live network demonstration heralds the commercial launch of 5G-A in Europe - Industry News — C114 (Communications Network)]. www.c114.com.cn. Retrieved April 12, 2025. ^ Tomás, Juan Pedro (June 30, 2023). "Huawei to launch full set of commercial 5.5G network equipment in 2024". RCR Wireless News. Retrieved September 14, 2023. ^ "5G Advanced positioning in 3GPP Release 18". ericsson.com. Retrieved April 12, 2025. ^ Turner, Annie (March 31, 2025). "Elisa launches 'world first' 5.5G network for Finnish consumers". Mobile Europe. Retrieved May 10, 2025. ^ "爱立信支持中国移动全球首发5G-A商用部署" [Ericsson supports China Mobile in the world's first commercial deployment of 5G-A.]. ericsson.com (in Chinese (China)). Retrieved April 12, 2025. ^ "NR-U Transforming 5G – Qualcomm Presentation". GSA. January 18, 2018. Archived from the original on February 9, 2022. Retrieved February 9, 2022. ^ "The Private LTE & 5G Network Ecosystem: 2023 – 2030". www.snstelecom.com. Retrieved August 14, 2023. ^ "Japan wants TSMC, Sony to build 20 nanometre chip plant -Nikkan Kogyo". Reuters. Archived from the original on June 2, 2021. Retrieved April 12, 2025. ^ "[ケータイ用語の基礎知識]第941回：NSA・SA方式とは" [[Basic Knowledge of Mobile Terminology] Episode 941: What are NSA and SA Architectures?]. ケータイ Watch. February 19, 2020. Archived from the original on February 9, 2022. Retrieved February 9, 2022. ^ "LTE and 5G Market Statistics". GSA. April 8, 2019. Archived from the original on November 18, 2020. Retrieved April 24, 2019. ^ "5G Investments: Trials, Deployments, Launches". GSA. Archived from the original on April 2, 2019. ^ Taylor, Chloe (November 25, 2019). "5G coverage will span two thirds of the global population in 6 years, Ericsson predicts". CNBC. Archived from the original on November 29, 2019. Retrieved November 29, 2019. ^ Mello, Gabriela (November 25, 2019). "Ericsson to invest over $230 million in Brazil to build new 5G assembly line". Archived from the original on October 27, 2020. Retrieved May 6, 2020. ^ "Telecom's 5G revolution triggers shakeup in base station market". Nikkei Asian Review. Archived from the original on April 21, 2019. Retrieved April 21, 2019. ^ "Samsung Electronics supplies 53,000 5G base stations for Korean carriers". RCR Wireless News. April 10, 2019. Archived from the original on April 12, 2019. Retrieved April 13, 2019. ^ " 5G 53000 ... 5 '". . April 10, 2019. Archived from the original on November 7, 2020. Retrieved April 21, 2019. ^ "Samsung dominates Korea 5G deployments". Mobile World Live. April 10, 2019. Archived from the original on April 10, 2019. Retrieved April 11, 2019. ^ "Fast but patchy: Trying South Korea's new 5G service". Nikkei Asian Review. Archived from the original on April 12, 2019. Retrieved April 11, 2019. ^ "Korea 5G Falls by Half. Miracle Over?". wirelessone.news. Archived from the original on October 27, 2020. Retrieved March 27, 2020. ^ "T-Mobile Launches World's First Nationwide Standalone 5G Network". T-Mobile Newsroom. Archived from the original on January 30, 2022. Retrieved January 30, 2022. ^ "Japan allocates 5G spectrum, excludes Chinese equipment vendors". South China Morning Post. April 11, 2019. Retrieved April 12, 2025. ^ "Huawei Launches Full Range of 5G End-to-End Product Solutions". huawei. Archived from the original on April 13, 2019. Retrieved April 13, 2019. ^ "Japan allocates 5G spectrum to carriers, blocks Huawei and ZTE gear". VentureBeat. April 10, 2019. Archived from the original on April 13, 2019. Retrieved April 13, 2019. ^ "Samsung signals big 5G equipment push, again, at factory". January 4, 2019. Archived from the original on April 13, 2019. Retrieved April 13, 2019. ^ "Nokia says it is the one-stop shop for 5G network gear | TechRadar". techradar.com. February 26, 2019. Archived from the original on April 13, 2019. Retrieved April 13, 2019. ^ "5G radio – Ericsson". Ericsson.com. February 6, 2018. Archived from the original on April 13, 2019. Retrieved April 13, 2019. ^ Riccardo Barlaam (February 21, 2019). "HHN TECH". Il Sole 24 Ore (in Italian). Archived from the original on July 25, 2019. Retrieved July 24, 2019. ^ Parzyan, Anahit (2023). "China's Digital Silk Road: Empowering Capabilities for Digital Leadership in Eurasia". China and Eurasian Powers in a Multipolar World Order 2.0: Security, Diplomacy, Economy and Cyberspace. Mher Sahakyan. New York: Routledge. ISBN 978-1-003-35258-7. OCLC 1353290533. ^ "5G Spectrum Recommendations" (PDF). Archived from the original (PDF) on December 23, 2018. Retrieved October 7, 2019. ^ "FCC Spectrum Frontier Proposal". NYU Wireless. July 15, 2016. Archived from the original on May 26, 2017. Retrieved May 18, 2017. ^ Chee, Foo Yun (March 3, 2018). "EU countries, lawmakers strike deal to open up spectrum for 5G". Reuters. Archived from the original on January 7, 2019. Retrieved March 3, 2018. ^ "Spectrum for Terrestrial 5G Networks: Licensing Developments Worldwide". GSA. March 2019. Archived from the original on April 2, 2019. ^ "GSA launches first global database of commercial 5G devices". Total Telecom. Archived from the original on April 2, 2019. ^ "5G Device Ecosystem Report". GSA. Archived from the original on April 2, 2019. ^ "5G Devices: Ecosystem Report". GSA. September 2019. Archived from the original on October 13, 2019. ^ "LTE, 5G and 3GPP IoT Chipsets: Status Update". GSA. April 2019. Archived from the original on October 30, 2020. Retrieved April 24, 2019. ^ "5G is making the smartphones we love more expensive than ever". Business Insider. March 14, 2020. Archived from the original on August 18, 2020. Retrieved March 16, 2020. ^ Collins, Katie (March 19, 2020). "The Nokia 8.3 is the 'first global 5G phone.' Here's what that means for you". CNET. Archived from the original on October 27, 2020. Retrieved March 19, 2020. ^ "Google Pixel 5". GSMArena. Archived from the original on October 17, 2022. Retrieved October 27, 2022. ^ "What consumers need to know about this week's AT&T-Verizon 5G rollout". CBS News. January 20, 2022. Archived from the original on February 26, 2022. Retrieved February 26, 2022. ^ "iPhone 12 and 5G: All the answers to your questions about the super-fast connectivity". CNET. Archived from the original on February 26, 2022. Retrieved February 26, 2022. ^ "5G speed vs 5G range-What is the value of 5G speed,5G range". rfwireless-world.com. Archived from the original on April 21, 2019. Retrieved April 21, 2019. ^ Manivasagam; Garima; Shukla, Meenu (December 19, 2023). "Massive MIMO in 5G Networks: Trends and Challenges". 2023 International Conference on Power Energy, Environment & Intelligent Control (PEEIC). IEEE. pp. 1456–1460. doi:10.1109/PEEIC59336.2023.10450543. ISBN 979-8-3503-5776-9. ^ "IT Needs to Start Thinking About 5G and Edge Cloud Computing". February 7, 2018. Archived from the original on June 12, 2018. Retrieved June 8, 2018. ^ "Mobile Edge Computing – An Important Ingredient of 5G Networks". IEEE Softwarization. March 2016. Archived from the original on February 24, 2019. Retrieved February 24, 2019. ^ Brand, Aron (September 20, 2019). "3 Advantages of Edge Computing". medium.com. Archived from the original on January 22, 2023. Retrieved September 20, 2019. ^ "Scenarios and requirements for small cell enhancements for E-UTRA and E-UTRAN (3GPP TR 36.932 version 16.0.0 Release 16)" (PDF). ETSI and 3GPP. Archived (PDF) from the original on February 26, 2022. Retrieved February 26, 2022. (TR 36.932) ^ "5G small cells: everything you need to know". 5gradar.com. February 18, 2021. Archived from the original on February 26, 2022. Retrieved February 26, 2022. ^ "Small Cells – Big in 5G". Nokia. Archived from the original on November 1, 2020. Retrieved August 29, 2020. ^ "Small Cell". Ericsson. Archived from the original on February 26, 2022. Retrieved February 26, 2022. ^ Rappaport, Theodore S.; Sun, Shu; Mayzus, Rimma; Zhao, Hang; Azar, Yaniv; Wang, Kevin; Wong, George N.; Schulz, Jocelyn K.; Samimi, Mathew; Gutierrez, Felix (2013). "Millimeter Wave Mobile Communications for 5G Cellular: It Will Work!". IEEE Access. 1: 335–349. Bibcode:2013IEEEA...1..335R. doi:10.1109/ACCESS.2013.2260813. ISSN 2169-3536. ^ "What is 5G Beamforming?". Verizon Enterprise. Archived from the original on October 25, 2021. Retrieved September 6, 2022. ^ "Article – 5G | Solwise Ltd". www.solwise.co.uk. Archived from the original on May 16, 2022. Retrieved December 18, 2022. ^ Ghafoor, Umar; Ali, Mudassar; Khan, Humayun Zubair; Siddiqui, Adil Masood; Naeem, Muhammad (August 1, 2022). "NOMA and future 5G & B5G wireless networks: A paradigm". Journal of Network and Computer Applications. 204: 103413. doi:10.1016/j.jnca.2022.103413. ISSN 1084-8045. S2CID 248803932. ^ "WS-21: SDN5GSC – Software Defined Networking for 5G Architecture in Smart Communities". IEEE Global Communications Conference. May 17, 2018. Archived from the original on March 8, 2019. Retrieved March 7, 2019. ^ Ordonez-Lucena, J.; Ameigeiras, P.; Lopez, D.; Ramos-Munoz, J. J.; Lorca, J.; Folgueira, J. (2017). "Network Slicing for 5G with SDN/NFV: Concepts, Architectures, and Challenges". IEEE Communications Magazine. 55 (5): 80–87. arXiv:1703.04676. Bibcode:2017arXiv170304676O. doi:10.1109/MCOM.2017.1600935. hdl:10481/45368. ISSN 0163-6804. S2CID 206456434. ^ a b "What is a Service Based Architecture?". September 9, 2021. ^ "System architecture for the 5G System (5GS)" (PDF). ETSI. October 2020. ^ "5G Channel Coding" (PDF). Archived from the original (PDF) on December 6, 2018. Retrieved January 6, 2019. ^ Maunder, Robert (September 2016). "A Vision for 5G Channel Coding" (PDF). Archived from the original (PDF) on December 6, 2018. Retrieved January 6, 2019. ^ "5G NR 3GPP | 5G NR Qualcomm". Qualcomm. December 12, 2018. Archived from the original on April 22, 2019. Retrieved April 15, 2019. ^ a b Eid, Aline; Hester, Jimmy G. D.; Tentzeris, Manos M. (January 12, 2021). "5G as a wireless power grid". Scientific Reports. 11 (1). Nature Portfolio. 636. doi:10.1038/s41598-020-79500-x. ISSN 2045-2322. LCCN 2011250880. OCLC 732869387. PMC 7804946. PMID 33436681. ^ Linder, Courtney (April 30, 2021). "We Could Really Have a Wireless Power Grid That Runs on 5G". Popular Mechanics. Retrieved February 23, 2022. ^ Wagih, Mahmoud; Weddell, Alex S.; Beeby, Steve (October 1, 2020). Nikita, Konstantina S. (ed.). "Millimeter-Wave Power Harvesting: A Review". IEEE Open Journal of Antennas and Propagation. 1. Institute of Electrical and Electronics Engineers: 568–578. doi:10.1109/OJAP.2020.3028220. eISSN 2637-6431. ^ Khan, Talha Ahmed; Heath, Robert W. Jr. (December 21, 2018). "Wireless Power Transfer in Millimeter Wave". In Ng, Derrick Wing Kwan; Duong, Trung Q.; Zhong, Caijun; Schober, Robert (eds.). Wireless Information and Power Transfer (1 ed.). Wiley. pp. 139–156. doi:10.1002/9781119476863.ch8. ISBN 9781119476863. S2CID 116385421. Retrieved February 23, 2022. ^ Georgia Tech (March 23, 2021). Leveraging the 5G Network to Wirelessly Power IoT Devices (Videotape). Retrieved February 23, 2022. ^ Duckett, Chris (October 10, 2019). "Europe warns 5G will increase attack paths for state actors". ZDNet. Archived from the original on November 17, 2020. Retrieved January 12, 2020. ^ Basin, David; Dreier, Jannik; Hirschi, Lucca; Radomirovic, Saša; Sasse, Ralf; Stettler, Vincent (2018). "A Formal Analysis of 5G Authentication". Proceedings of the 2018 ACM SIGSAC Conference on Computer and Communications Security – CCS '18. pp. 1383–1396. arXiv:1806.10360. doi:10.1145/3243734.3243846. ISBN 9781450356930. S2CID 49480110. ^ a b "How to Prepare for the Coming 5G Security Threats". Security Intelligence. November 26, 2018. Archived from the original on July 22, 2019. Retrieved July 22, 2019. ^ Maddison, John (February 19, 2019). "Addressing New Security Challenges with 5G". CSO Online. Archived from the original on July 22, 2019. Retrieved July 22, 2019. ^ "NETSCOUT Predicts: 5G Trends for 2019". NETSCOUT. Archived from the original on July 22, 2019. Retrieved July 22, 2019. ^ "The Urgency of Network Security in the Shared LTE/5G Era". A10 Networks. June 19, 2019. Archived from the original on July 22, 2019. Retrieved July 22, 2019. ^ "Security concerns in a 5G era: are networks ready for massive DDoS attacks?". scmagazineuk.com. Archived from the original on October 28, 2020. Retrieved July 22, 2019. ^ "State of the IoT 2018: Number of IoT devices now at 7B – Market accelerating". August 8, 2018. Archived from the original on July 24, 2019. Retrieved July 22, 2019. ^ Attar, Hani; Issa, Haitham; Ababneh, Jafar; Abbasi, Mahdi; Solyman, Ahmed A. A.; Khosravi, Mohammad; Said Agieb, Ramy (October 11, 2022). "5G System Overview for Ongoing Smart Applications: Structure, Requirements, and Specifications". Computational Intelligence and Neuroscience. 2022: 1–11. doi:10.1155/2022/2476841. ISSN 1687-5273. PMC 9578857. PMID 36268153. ^ Proctor, Jason (April 29, 2019). "Why Canada's decisions on who builds 5G technology are so important". CBC News. Canadian Broadcasting Corporation. Archived from the original on July 22, 2019. Retrieved July 31, 2019. ^ "Investigative Report on the U.S. National Security Issues Posed by Chinese Telecommunications Companies Huawei and ZTE" (PDF). US House Permanent Select Committee on Intelligence. October 8, 2012. Archived (PDF) from the original on December 30, 2022. Retrieved January 6, 2023. ^ "Huawei: China's Controversial Tech Giant". Council on Foreign Relations. Archived from the original on December 30, 2022. Retrieved December 30, 2022. ^ Lillis, Katie Bo (July 23, 2022). "CNN Exclusive: FBI investigation determined Chinese-made Huawei equipment could disrupt US nuclear arsenal communications | CNN Politics". CNN. Archived from the original on December 30, 2022. Retrieved December 30, 2022. ^ Kharpal, Arjun (March 5, 2019). "Huawei says it would never hand data to China's government. Experts say it wouldn't have a choice". CNBC. Archived from the original on May 29, 2019. Retrieved December 30, 2022. ^ Corera, Gordon (October 7, 2020). "Huawei: MPs claim 'clear evidence of collusion' with Chinese Communist Party". BBC News. Archived from the original on October 14, 2020. Retrieved October 7, 2020. ^ "What's needed to keep 5G from compromising weather forecasts". GCN. September 29, 2020. Archived from the original on December 4, 2021. Retrieved December 4, 2021. ^ Misra, Sidharth (January 10, 2019). "The Wizard Behind the Curtain? – The Important, Diverse, and Often Hidden Role of Spectrum Allocation for Current and Future Environmental Satellites and Water, Weather, and Climate". 15th Annual Symposium on New Generation Operational Environmental Satellite Systems. Phoenix, AZ: American Meteorological Society. Archived from the original on May 5, 2019. Retrieved May 5, 2019. ^ Lubar, David G. (January 9, 2019). "A Myriad of Proposed Radio Spectrum Changes – Collectively Can They Impact Operational Meteorology?". 15th Annual Symposium on New Generation Operational Environmental Satellite Systems. Phoenix, AZ: American Meteorological Society. Archived from the original on May 5, 2019. Retrieved May 5, 2019. ^ Witze, Alexandra (April 26, 2019). "Global 5G wireless networks threaten weather forecasts". Nature. 569 (7754): 17–18. Bibcode:2019Natur.569...17W. doi:10.1038/d41586-019-01305-4. PMID 31040411. S2CID 140396172. ^ Brackett, Ron (May 1, 2019). "5G Wireless Networks Could Interfere with Weather Forecasts, Meteorologists Warn". The Weather Channel. Archived from the original on May 5, 2019. ^ Samenow, Jason (March 8, 2019). "Critical weather data threatened by FCC 'spectrum' proposal, Commerce Dept. and NASA say". The Washington Post. Archived from the original on March 31, 2019. Retrieved May 5, 2019. ^ Samenow, Jason (March 13, 2019). "FCC to auction off wireless spectrum that could interfere with vital weather data, rejecting requests from U.S. House and science agencies". The Washington Post. Archived from the original on May 9, 2019. Retrieved May 29, 2019. ^ Paul, Don (May 27, 2019). "Some worry 5G may pose huge problems for weather forecasting". The Buffalo Post. Archived from the original on May 30, 2019. Retrieved May 29, 2019. ^ Witze, Alexandra (November 22, 2019). "Global 5G wireless deal threatens weather forecasts". Nature. 575 (7784): 577. Bibcode:2019Natur.575..577W. doi:10.1038/d41586-019-03609-x. PMID 31772363. S2CID 208302844. ^ "WMO expresses concern about radio frequency decision" (Press release). Geneva, Switzerland: World Meteorological Organization. November 27, 2019. Retrieved November 30, 2019. ^ Freedman, Andrew (November 26, 2019). "Global 5G deal poses significant threat to weather forecast accuracy, experts warn". The Washington Post. Archived from the original on November 27, 2019. Retrieved December 1, 2019. ^ "ECMWF statement on the outcomes of the ITU WRC-2019 conference" (Press release). Reading, UK: European Centre for Medium-Range Weather Forecasts. November 25, 2019. Archived from the original on January 8, 2021. Retrieved December 1, 2019. ^ Freedman, Andrew (December 11, 2019). "'We are deeply concerned': House Science Committee seeks investigation of how 5G could hurt weather forecasting". The Washington Post. Archived from the original on December 12, 2019. Retrieved December 12, 2019. ^ "5G altimeter interference: aviation versus telecoms". 5G Technology World. December 23, 2021. Archived from the original on January 18, 2022. Retrieved January 19, 2022. ^ "U.S. FAA Issues Safety Alert on 5G Interference to Aircraft". Bloomberg News. November 2, 2021. Archived from the original on December 4, 2021. Retrieved December 4, 2021. ^ "Europe rolled out 5G without hurting aviation. Here's how". CNN. January 19, 2022. Archived from the original on January 19, 2022. Retrieved January 19, 2022. ^ "5G phones may interfere with aircraft: French regulator". France 24. February 16, 2021. Archived from the original on December 15, 2021. Retrieved December 15, 2021. ^ Shields, Todd; Levin, Allan (December 31, 2021). "Buttigieg Asks AT&T, Verizon to Delay 5G Over Aviation Concerns". Bloomberg News. Archived from the original on January 2, 2022. Retrieved January 2, 2022. ^ "Wireless carriers to limit 5G near airports after airlines warn of major disruptions". Washington Post. January 18, 2022. Archived from the original on January 19, 2022. Retrieved January 22, 2022. ^ "Verizon 5G Gets Activated Despite Warnings About Airport Problems; AT&T 5G Follows Suit". TechTimes. January 19, 2022. Archived from the original on January 22, 2022. Retrieved January 22, 2022. ^ "AT&T and Verizon are limiting C-band 5G expansion around airports even more". The Verge. January 18, 2022. Archived from the original on January 22, 2022. Retrieved January 22, 2022. ^ Federal Aviation Administration (January 21, 2022). "5G and Aviation Safety". Archived from the original on January 22, 2022. Retrieved January 22, 2022. ^ Von Drehle, David (January 18, 2022). "Opinion: The FAA's 5G freakout raises a big red flag — about its competence". Washington Post. Archived from the original on January 19, 2022. Retrieved January 22, 2022. ^ "Airlines cancel some flights after reduced 5G rollout in US". MSN. Archived from the original on January 22, 2022. Retrieved January 22, 2022. ^ a b "SatMagazine". www.satmagazine.com. Archived from the original on December 4, 2021. Retrieved December 4, 2021. ^ Naik, Gaurang; Park, Jung-Min; Ashdown, Jonathan; Lehr, William (December 15, 2020). "Next Generation Wi-Fi and 5G NR-U in the 6 GHz Bands: Opportunities and Challenges". IEEE Access. 8: 153027–56. arXiv:2006.16534. Bibcode:2020IEEEA...8o3027N. doi:10.1109/ACCESS.2020.3016036. S2CID 220265664. Archived from the original on December 15, 2021. Retrieved December 4, 2021 – via IEEE Xplore. ^ Johnson, Allison (April 29, 2021). "Dear wireless carriers: the 5G hype needs to stop". The Verge. Archived from the original on February 9, 2022. Retrieved February 9, 2022. ^ Morris, Iain (February 28, 2017). "Vodafone CTO 'Worried' About 5G mmWave Hype". Light Reading. Archived from the original on February 9, 2022. Retrieved February 9, 2022. ^ Chamberlain, Kendra (April 22, 2019). "T-Mobile says 5G mmWave deployments 'will never materially scale'". Fierce Wireless. Archived from the original on February 9, 2022. Retrieved February 9, 2022. ^ Blackman, James (December 5, 2019). "Why the 5G revolution is over-hyped nonsense – in every respect except one". Enterprise IoT Insights. Archived from the original on February 9, 2022. Retrieved February 9, 2022. ^ "Cutting through the 5G hype | McKinsey". mckinsey.com. Archived from the original on February 9, 2022. Retrieved February 9, 2022. ^ "Expert Round Up: Is 5G Worth All the Hype? – GeoLinks.com". February 21, 2019. Archived from the original on February 9, 2022. Retrieved February 9, 2022. ^ "5G isn't for everyone: How Alternate IoT Solutions come into play | Industrial Ethernet Book". iebmedia.com. Archived from the original on February 9, 2022. Retrieved February 9, 2022. ^ "Consumers Want to Cut Through the Hype About 5G". PCMAG. April 15, 2019. Archived from the original on February 9, 2022. Retrieved February 9, 2022. ^ "The Electromagnetic Spectrum: Non-Ionizing Radiation". United States Centers for Disease Control and Prevention. December 7, 2015. Archived from the original on December 31, 2015. Retrieved August 21, 2021. ^ a b c Meese, James; Frith, Jordan; Wilken, Rowan (2020). "COVID-19, 5G conspiracies and infrastructural futures". Media International Australia. 177 (1): 30–46. doi:10.1177/1329878X20952165. PMC 7506181. ^ "Do mobile phones, 4G or 5G cause cancer?". Cancer Research UK. February 8, 2022. ^ "FDA warns Mercola: Stop selling fake COVID remedies and cures". Alliance for Science. Cornell University. March 15, 2021. Archived from the original on March 16, 2021. Retrieved August 21, 2021. ^ Broad, William J. (July 16, 2019). "The 5G Health Hazard That Isn't". The New York Times. Archived from the original on October 1, 2019. Retrieved December 16, 2021. ^ Broad, William J. (May 12, 2019). "Your 5G Phone Won't Hurt You. But Russia Wants You to Think Otherwise". The New York Times. Archived from the original on May 20, 2019. Retrieved May 12, 2019. ^ "Brussels halts 5G plans over radiation rules". FierceWireless. April 8, 2019. Archived from the original on April 9, 2019. Retrieved April 11, 2019. ^ "Schweiz: Genf stoppt Aufbau von 5G-Mobilfunkantennen" (in German). April 11, 2019. Archived from the original on April 14, 2019. Retrieved April 14, 2019. ^ "5G Mobile Technology Fact Check" (PDF). asut. March 27, 2019. Archived (PDF) from the original on April 3, 2019. Retrieved April 7, 2019. ^ a b c "5G phones and your health: What you need to know". CNET. June 20, 2019. Archived from the original on June 22, 2019. Retrieved June 22, 2019. ^ "Radiation concerns halt Brussels 5G development, for now". The Brussels Times. April 1, 2019. Archived from the original on July 14, 2019. Retrieved July 19, 2019. ^ "Kamer wil eerst stralingsonderzoek, dan pas 5G-netwerk". Algemeen Dagblad. April 4, 2019. Archived from the original on December 16, 2020. Retrieved July 19, 2019. ^ "Switzerland to monitor potential health risks posed by 5G networks". Reuters. April 17, 2019. Archived from the original on July 29, 2019. Retrieved July 19, 2019. ^ "Bay Area city blocks 5G deployments over cancer concerns". TechCrunch. September 10, 2018. Archived from the original on December 30, 2020. Retrieved July 19, 2019. ^ Dillon, John (May 7, 2019). "Broadband Bill to Be Amended to Address Concerns Over 5G Technology". Vermont Public Radio (VPR). Archived from the original on May 7, 2019. Retrieved July 19, 2019. ^ "5G: What is it and how it will help us". Archived from the original on December 25, 2020. Retrieved July 29, 2019. ^ Humphries, Will (October 12, 2019). "Councils block 5G as scare stories spread". The Times. London. Archived from the original on October 14, 2019. Retrieved October 25, 2019. ^ "Brighton and Hove City Council join growing list of local authorities banning 5G masts". itpro.co.uk. October 14, 2019. Archived from the original on October 25, 2019. Retrieved October 25, 2019. ^ "5G 'no more dangerous than talcum powder and pickled vegetables', says digital minister Matt Warman". The Telegraph. London. Archived from the original on October 18, 2019. Retrieved October 25, 2019. ^ a b Levitt, Blake; Lai, Henry; Manville, Albert (2021). "Effects of non-ionizing electromagnetic fields on flora and fauna, part 1. Rising ambient EMF levels in the environment". Reviews on Environmental Health. 37 (1). Walter de Gruyter GmbH: 81–122. doi:10.1515/reveh-2021-0026. ISSN 0048-7554. PMID 34047144. S2CID 235219718. ^ Simkó; Mattsson (September 13, 2019). "5G Wireless Communication and Health Effects—A Pragmatic Review Based on Available Studies Regarding 6 to 100 GHz". International Journal of Environmental Research and Public Health. 16 (18). MDPI AG: 3406. doi:10.3390/ijerph16183406. ISSN 1660-4601. PMC 6765906. PMID 31540320. ^ Warren, Tom (April 4, 2020). "British 5G towers are being set on fire because of coronavirus conspiracy theories". The Verge. Archived from the original on December 25, 2020. Retrieved April 5, 2020. ^ Murphy, Ann (April 23, 2020). "Update: Arson attack on Cork mast linked to false 5G conspiracy theory". Echo Live. Archived from the original on October 28, 2020. Retrieved April 30, 2020. ^ Fildes, Nic; Di Stefano, Mark; Murphy, Hannah (April 16, 2020). "How a 5G coronavirus conspiracy spread across Europe". Financial Times. Archived from the original on December 13, 2020. Retrieved April 16, 2020. ^ "Mast fire probe amid 5G coronavirus claims". BBC News. April 4, 2020. Archived from the original on January 17, 2021. Retrieved April 5, 2020. ^ "Bibinje: Nepoznati glupani oštetili odašiljač za kojeg su mislili da je 5G". Seebiz (in Croatian). April 15, 2020. Archived from the original on November 7, 2020. Retrieved April 21, 2020. ^ Cerulus, Laurens (April 26, 2020). "5G arsonists turn up in continental Europe". Politico. Archived from the original on January 4, 2021. Retrieved April 30, 2020. ^ Osborne, Charlie (April 30, 2020). "5G mast arson, coronavirus conspiracy theories force social media to walk a fine censorship line". ZD Net. Archived from the original on October 18, 2020. Retrieved May 2, 2020. ^ Cheng, Roger (April 19, 2018). "AT&T brings higher speeds with pre-5G tech to 117 cities". CNET. Archived from the original on January 6, 2019. Retrieved January 6, 2019. ^ Gartenberg, Chaim (April 25, 2017). "AT&T announces it will build a fake 5G network". The Verge. Archived from the original on November 21, 2018. Retrieved January 6, 2019. ^ "Share of the population covered by at least a 4G mobile network | Access Indicators". OECD Going Digital Toolkit. Retrieved December 29, 2024. ^ Mangino, Melina (March 6, 2024). "4G vs. 5G: Which is Best for Industrial IoT Gateways?". The Safety Connection | MSA FieldServer Blog. Retrieved December 29, 2024. ^ "With the launch of 5G, will 4G continue to exist?". support.totalwireless.com. Retrieved December 29, 2024. ^ Expert, AT&T (December 30, 2023). "Does 5G Cost More? - AT&T National". get-service.us. Retrieved December 29, 2024. ^ Curie, M.; Mewhinney, M.; Cooper, S. (April 24, 2008). "NASA Ames Partners With M2MI For Small Satellite Development". NASA. Archived from the original on April 8, 2019. Retrieved April 8, 2019. ^ Sunitha, C.; Krishnan, Deepika G.; Dhanya, V. A. (January 2017). "Overview of Fifth Generation Networking" (PDF). International Journal of Computer Trends and Technology. 43 (1). Archived from the original (PDF) on February 11, 2020. Retrieved October 7, 2020. ^ "The world's first academic research center combining Wireless, Computing, and Medical Applications". NYU Wireless. June 20, 2014. Archived from the original on March 11, 2016. Retrieved January 14, 2016. ^ Kelly, Spencer (October 13, 2012). "BBC Click Programme – Kenya". BBC News Channel. Archived from the original on April 10, 2019. Retrieved October 15, 2012. Some of the world biggest telecoms firms have joined forces with the UK government to fund a new 5G research center. The facility, to be based at the University of Surrey, will offer testing facilities to operators keen to develop a mobile standard that uses less energy and less radio spectrum, while delivering faster speeds than current 4G technology that's been launched in around 100 countries, including several British cities. They say the new tech could be ready within a decade. ^ "The University Of Surrey Secures £35M For New 5G Research Centre". University of Surrey. October 8, 2012. Archived from the original on October 14, 2012. Retrieved October 15, 2012. ^ "5G research centre gets major funding grant". BBC News. BBC News Online. October 8, 2012. Archived from the original on April 21, 2019. Retrieved October 15, 2012. ^ Philipson, Alice (October 9, 2012). "Britain aims to join mobile broadband leaders with £35m '5G' research centre". The Daily Telegraph. London. Archived from the original on October 13, 2018. Retrieved January 7, 2013. ^ "METIS projet presentation" (PDF). November 2012. Archived from the original (PDF) on February 22, 2014. Retrieved February 14, 2014. ^ "Speech at Mobile World Congress: The Road to 5G". March 2015. Archived from the original on October 28, 2020. Retrieved April 20, 2015. ^ "5G Mobile Network Technology". April 2017. Archived from the original on May 18, 2017. Retrieved May 18, 2017. ^ ", 5 " [Samsung Electronics develops key technology for 5G mobile communications, a world-first.]. May 12, 2013. Archived from the original on September 19, 2018. Retrieved May 12, 2013. ^ "General METIS presentations available for public". Archived from the original on February 22, 2014. Retrieved February 14, 2014. ^ "India and Israel have agreed to work jointly on development of 5G". The Times Of India. July 25, 2013. Archived from the original on September 10, 2016. Retrieved July 25, 2013. ^ "DoCoMo Wins CEATEC Award for 5G". October 3, 2013. Archived from the original on October 13, 2018. Retrieved October 3, 2013. ^ Embley, Jochan (November 6, 2013). "Huawei plans $600m investment in 10Gbps 5G network". The Independent. London. Archived from the original on March 31, 2019. Retrieved November 11, 2013. ^ "South Korea to seize on world's first full 5G network". Nikkei Asian Review. Archived from the original on April 17, 2019. Retrieved April 17, 2019. ^ "US dismisses South Korea's launch of world-first 5G network as 'stunt' - 5G – The Guardian". amp.theguardian.com. April 4, 2019. Archived from the original on April 17, 2019. Retrieved April 17, 2019. ^ "5G 4 가...3가 가" [From the first day of 5G, 40,000 subscribers ... 3 subscription points]. Asia Business Daily. April 6, 2019. Archived from the original on April 17, 2019. Retrieved April 17, 2019. ^ "Globe 5G – The Latest Broadband Technology". globe.com.ph. Archived from the original on September 3, 2019. Retrieved June 21, 2019. ^ "AT&T Begins Extending 5G Services Across the U.S." about.att.com. Archived from the original on November 18, 2020. Retrieved November 23, 2019. ^ Blumenthal, Eli. "AT&T's next 5G network is going live in December, but don't expect big jumps in speed". CNET. Archived from the original on November 23, 2019. Retrieved November 23, 2019. ^ GUL, NAJAM (December 26, 2022). "5G! GOOD OR BAD?". deep curious. Archived from the original on January 5, 2023. Retrieved January 5, 2023. ^ Stuart Corner (March 16, 2022). "The state of 5G in Southeast Asia 2022, country-by-country guide". networkworld.com. ^ Phoonphongphiphat, Apornrath (May 20, 2020). "Thailand leads ASEAN in 5G rollout due to pandemic". Nikkei Asia. Retrieved April 18, 2023. ^ "Назаров Александр: биография заместителя генерального директора "Ростеха"" [Alexander Nazarov: Biography of the Deputy General Director of "Rostec".]. theperson.pro. Retrieved June 4, 2023. ^ "Назаров Александр Юрьевич и Игорь Анатольевич Шумаков подписали соглашение" [Alexander Yurievich Nazarov and Igor Anatolievich Shumakov signed an agreement.]. www.kremlinrus.ru. Retrieved June 4, 2023. ^ Strumpf, Dan. "5G Not Enough? Telecom Companies Look to 5.5G". The Wall Street Journal. Retrieved June 5, 2024. Karipidis, Ken; Mate, Rohan; Urban, David; Tinker, Rick; Wood, Andrew (July 2023). "5G mobile networks and health—a state-of-the-science review of the research into low-level RF fields above 6 GHz". Journal of Exposure Science & Environmental Epidemiology. 31 (4): 585–605. doi:10.1038/s41370-021-00297-6. ISSN 1559-064X. PMC 8263336. PMID 33727687. Wikimedia Commons has media related to 5G. Internet portalTelecommunication portal 5G Multi-Antenna Concepts Preceded by4th Generation (4G) Mobile telephony generations Succeeded by6th Generation (6G) Retrieved from " 4First generation of wireless cellular technology For other uses, see 1G (disambiguation). "Analog network" redirects here and is not to be confused with Analog modulation. Not to be confused with GPRS, a 2G mobile internet speed displayed as "G" on most Android and iPhone devices. Part of a series on theWireless network technologies Analog 0G1G (1.5G) Digital 2G (2.5G, 2.75G, 2.9G)3G (3.5G, 3.75G, 3.9G/3.95G)4G (4G/4.5G, 4.5G, 4.9G)5G (5.5G)6G Mobile telecommunicationsvte 1G refers to the first generation of mobile telecommunications standards, introduced in the 1980s. This generation was characterized by the use of analog audio transmissions, a major distinction from the subsequent 2G networks, which were fully digital. The term "1G" itself was not used at the time, but has since been retroactively applied to describe the early era of cellular networks. During the 1G era, various regional standards were developed and deployed in different countries, rather than a single global system. Among the most prominent were the Nordic Mobile Telephone (NMT) system and the Advanced Mobile Phone System (AMPS), which were widely adopted in their respective regions.[1] The lack of a unified global standard resulted in a fragmented landscape, with different countries and regions utilizing different technologies for mobile communication. As digital technology advanced, the inherent advantages of digital systems over analog led to the eventual replacement of 1G by 2G networks. While many 1G networks were phased out by the early 2000s, some continued to operate into the 2010s, particularly in less developed regions. The antecedent to 1G technology is the mobile radio telephone (i.e. "0G"), where portable phones would connect to a centralised operator. 1G refers to the very first generation of cellular networks.[2] Cellular technology employ a network of cells throughout a geographical area using low-power radio transmitters.[1] Cellular network standards and generation timeline. The first commercial cellular network was launched in Japan by Nippon Telegraph and Telephone (NTT) in 1979, initially in the metropolitan area of Tokyo. The first phone that used this network was called TZ-801 built by Panasonic.[3] Within five years, the NTT network had been expanded to cover the whole population of Japan and became the first nationwide 1G/cellular network. Before the network in Japan, Bell Laboratories built the first cellular network around Chicago in 1977 and trialled it in 1978.[4] As in the pre-cellular era, the Nordic countries were among the pioneers in wireless technologies. These countries together designed the NMT standard which first launched in Sweden in 1981.[5] NMT was the first mobile phone network to feature international roaming. In 1983, the first 1G cellular network launched in the United States, which was Chicago-based Ameritech using the Motorola DynaTAC mobile phone. In the early to mid 1990s, 1G was superseded by newer 2G (second generation) cellular technologies such as GSM and cdmaOne. Although 1G also used digital signaling to connect the radio towers (which listen to the handsets) to the rest of the telephone system, the voice itself during a call is encoded to digital signals in 2G whereas 1G uses analog FM modulation for the voice transmission, much like a 2-way land mobile radio. Most 1G networks had been discontinued by the early 2000s. Some regions especially Eastern Europe continued running these networks for much longer. The last operating 1G network was closed down in Russia in 2017. After Japan, the earliest commercial cellular networks launched in 1981 in Sweden, Norway and Saudi Arabia, followed by Denmark, Finland and Spain in 1982, the U.S. in 1983 and Hong Kong, South Korea, Austria and Canada in 1984. By 1986 networks had also launched in Tunisia, Malaysia, Oman, Ireland, Italy, Luxembourg, Netherlands, United Kingdom, West Germany, France, South Africa, Israel, Thailand, Indonesia, Iceland, Turkey, the Virgin Islands and Australia.[6] Generally, African countries were slower to take up 1G networks, while Eastern European were among the last due to the political situation.[7] In Europe, the United Kingdom had the largest number of cellular subscribers as of 1990 numbering 1.1 million, while the second largest market was Sweden with 482 thousand.[7] Although Japan was the first country with a nationwide cellular network, the number of users was significantly lower than other developed economies with a penetration rate of only 0.15 percent in 1989.[5] As of January 1991, the highest penetration rates were in Sweden and Finland with both countries above 50 percent closely followed by Norway and Iceland. The United States had a rate of 21.2 percent. In most other European countries it was below 10 percent.[8] Analog cellular technologies that were used were:[6] Advanced Mobile Phone System (AMPS)[9] Nordic Mobile Telephone (NMT) Total Access Communication System (TACS) developed in the United Kingdom and also some other parts of the world C-450 developed in West Germany and also adopted in Portugal and South Africa Radiocom 2000 in France (France Telecom only) RTMI in Italy MCS-L1 and MCS-L2 (developed by NTT) in Japan[10] JTACS (a variant of TACS operated by Daini Denden Planning, Inc. (DDI)) in Japan[10] List of mobile phone generations 2G 3G 3.5G 4G 4.5G 5G 6G Wireless Application Protocol Wireless device radiation and health ^ a b "Chapter 3 - Technology". Wireless Communications in Developing Counties (PDF). pp. 19–32. ^ Shi 2007, p. 56. ^ "Panasonic Japan cell phone shipments hit 100 million units". 3 April 2008. ^ Shi 2007, p. 60. ^ a b Shi 2007, p. 61. ^ a b "To open or not to open a technological system: insights from the history of mobile phones and their application to 5G" (PDF). Charles River Associates. May 2021. ^ a b Shi 2007, p. 63. ^ "Mobile and PSTN Communication Services" (PDF). OECD Digital Economy Papers (13). 1995. doi:10.1787/237485605680. ^ "AMTA". amta.org.au. Archived from the original on 17 April 2008. ^ a b "Answers – The Most Trusted Place for Answering Life's Questions". Answers.com. Shi, Mingtao (2007). Technology Base of Mobile Cellular Operators in Germany and China: A Comparative Study from the Perspective of the Resource Based View. Univerlagtuberlin. ISBN 9783798320574. Glossary: 1G – First Generation wireless technology Glossary: Detailed Description on 1G Technology Preceded by0G Mobile Telephony Generations Succeeded by2G Retrieved from " 5First generation of digital cellular networks For other uses, see 2G (disambiguation). Part of a series on theWireless network technologies Analog 0G1G (1.5G) Digital 2G (2.5G, 2.75G, 2.9G)3G (3.5G, 3.75G, 3.9G/3.95G)4G (4G/4.5G, 4.5G, 4.9G)5G (5.5G)6G Mobile telecommunicationsvte 2G refers to the second-generation of cellular network technology, which were rolled out globally starting in the early 1990s. The main differentiator to previous mobile telephone systems, retrospectively dubbed 1G, is that the radio signals of 2G networks are digital rather than analog, for communication between mobile devices and base stations. In addition to voice telephony, 2G also made possible the use of data services. The most common 2G technology has been the GSM standard, which became the first globally adopted framework for mobile communications. Other 2G technologies include cdmaOne and the now-discontinued Digital AMPS (D-AMPS/TDMA),[1] as well the Personal Digital Cellular (PDC) and Personal Handy-phone System (PHS) in Japan. The transition to digital technology enabled the implementation of encryption for voice calls and data transmission, significantly improving the security of mobile communications while also increasing capacity and efficiency compared to earlier analog systems. 2G networks were primarily designed to support voice calls and Short Message Service (SMS), with later advancements such as General Packet Radio Service (GPRS) enabling always-on packet data services, including email and limited internet access. 2G was succeeded by 3G technology, which provided higher data transfer rates and expanded mobile internet capabilities. In 1990, AT&T Bell Labs engineers Jesse Russell, Farhad Barzegar and Can A. Eryaman filed a patent for a digital mobile phone that supports the transmission of digital data. Their patent was cited several years later by Nokia and Motorola when they were developing 2G digital mobile phones.[2] 2G was first commercially launched in 1991 by Radiolinja (now part of Elisa Oyj) in Finland in the form of GSM, which was defined by the European Telecommunications Standards Institute (ETSI).[3] The Telecommunications Industry Association (TIA) defined the cdmaOne (IS-95) 2G standard, with an eight to ten fold increase in voice call capacity compared to analog AMPS.[4] The first deployment of cdmaOne was in 1995.[5] In North America, Digital AMPS (IS-54 and IS-136) and cdmaOne (IS-95) were dominant, but GSM was also used. Later 2G releases in the GSM space, often referred to as 2.5G and 2.75G, include General Packet Radio Service (GPRS) and Enhanced Data Rates for GSM Evolution (EDGE). GPRS allows 2G networks to achieve a theoretical maximum transfer speed of 40 kbit/s (5 kB/s). EDGE increases this capacity, providing a theoretical maximum transfer speed of 384 kbit/s (48 kB/s). Three primary benefits of 2G networks over their 1G predecessors were: Digitally encrypted phone conversations, at least between the mobile phone and the cellular base station but not necessarily in the rest of the network. Significantly more efficient use of the radio frequency spectrum enabling more users per frequency band. Data services for mobile, starting with SMS text messages then expanding to Multimedia Messaging Service (MMS). Cellular network standards and generation timeline. (Large titles on the colored area refer to the lines to their right. Main article: GPRS 2.5G ("second-and-a-half generation") refers to 2G systems that incorporate a packet-switched domain alongside the existing circuit-switched domain, most commonly implemented through General Packet Radio Service (GPRS).[6] GPRS enables packet-based data transmission by dynamically allocating multiple timeslots to users, improving network efficiency. However, this does not inherently provide faster speeds, as similar techniques, such as timeslot bundling, are also employed in circuit-switched data services like High-Speed Circuit-Switched Data (HSCSD). Within GPRS-enabled 2G systems, the theoretical maximum transfer rate is 40 kbit/s (5 kB/s).[7] Main article: EDGE (telecommunication) 2.75G refers to the evolution of GPRS networks into EDGE (Enhanced Data Rates for GSM Evolution) networks, achieved through the introduction of 8PSK (8 Phase Shift Keying) encoding. While the symbol rate remained constant at 270.833 samples per second, the use of 8PSK allowed each symbol to carry three bits instead of one, significantly increasing data transmission efficiency. Enhanced Data Rates for GSM Evolution (EDGE), also known as Enhanced GPRS (EGPRS) or IMT Single Carrier (IMT-SC), is a backward-compatible digital mobile phone technology built as an extension to standard GSM. First deployed in 2003 by AT&T in the United States, EDGE offers a theoretical maximum transfer speed of 384 kbit/s (48 kB/s).[7] Evolved EDGE (also known as EDGE Evolution or 2.875G) is an enhancement of the EDGE mobile technology that was introduced as a late-stage upgrade to 2G networks. While EDGE was first deployed in the early 2000s as part of GSM networks, Evolved EDGE was launched much later, coinciding with the widespread adoption of 3G technologies such as HSPA and just before the emergence of 4G networks. This timing limited its practical application. Evolved EDGE increased data throughput and reduced latencies (down to 80 ms) by utilizing improved modulation techniques, dual carrier support, dual antennas, and turbo codes. It achieved peak data rates of up to 1 Mbit/s, significantly enhancing network efficiency for operators that had not yet transitioned to 3G or 4G infrastructures. However, despite its technical improvements, Evolved EDGE was never widely deployed. By the time it became available, most network operators were focused on implementing more advanced technologies like UMTS and LTE. As of 2016, no commercial networks were reported to support Evolved EDGE. See also: GSM § Discontinuation 2G, understood as GSM and CdmaOne, has been superseded by newer technologies such as 3G (UMTS / CDMA2000), 4G (LTE / WiMAX) and 5G (5G NR). However, 2G networks were still available as of 2023[update] in most parts of the world, while notably excluding the majority of carriers in North America, East Asia, and Australasia.[8][9][10] Many modern LTE-enabled devices have the ability to fall back to 2G for phone calls, necessary especially in rural areas where later generations have not yet been implemented.[11] In some places, its successor 3G is being shut down rather than 2G – Vodafone previously announced that it had switched off 3G across Europe in 2020 but still retains 2G as a fallback service.[12] In the US T-Mobile shut down their 3G services while retaining their 2G GSM network.[13][14] Various carriers have made announcements that 2G technology in the United States, Japan, Australia, and other countries are in the process of being shut down, or have already shut down 2G services so that carriers can re-use the frequencies for newer technologies (e.g. 4G, 5G).[15][16] As a legacy protocol, 2G connectivity is considered insecure.[17] Specifically, there exist well known methods to attack weaknesses in GSM since 2009[18] with practical use in crime.[19] Attack routes on 2G CdmaOne were found later and remain less publicized.[20] Android 12 and later provide a network setting to disable 2G connectivity for the device.[21] iOS 16 and later can disable 2G connectivity by enabling Lockdown Mode.[22] In some parts of the world, including the United Kingdom, 2G remains widely used for older feature phones and for internet of things (IoT) devices such as smart meters, eCall systems and vehicle trackers to avoid the high patent licensing cost of newer technologies.[23] Terminating 2G services could leave vulnerable people who rely on 2G infrastructure unable to communicate even with emergency contacts, causing harm and possibly deaths.[24] Country Status Network Shutdown date Standard Notes Åland Ålcom 2024 GSM 2G availability cannot be guaranteed after 1 Jan 2022, all stations are planned to be shut down in 2024.[25] Anguilla Digicel active GSM 900 MHz: 5 MHz GSM + 5 MHz UMTS1900 MHz: 5 MHz UMTS [26][27][28][29] FLOW 2024-04-22 GSM [30][31] Antigua and Barbuda No Service APUA 2018-04-01 GSM [32] Digicel 2024-05-31 GSM [33] FLOW 2024-07-31 GSM [34] Aruba partiallyunconfirmed Digicel 2024-06-30 GSM [35] SETAR active GSM GSM-900 & GSM-1900 Australia No Service Hutchison 3 2006-08-09 cdmaOne [36][37][38][39][40] Optus 2017-08-01 GSM 2G shut down in WA and NT on 3 Apr 2017.[41][42] Telstra 2008-04-28 cdmaOne [43][44][45][46][47] Telstra 2016-12-01 GSM [48] Vodafone 2018-06-14 GSM [49] Bahamas No Service Aliv N/A (no 2G) BTC 2024-06-30 GSM [50][51][52] Bahrain Batelco 2021-11-30 GSM [53] Barbados partiallyunconfirmed Digicel 2025-03-31 GSM 900 MHz: 6 MHz GSM /1800 MHz: 12 MHz GSM [54] FLOW 2024-04-22 GSM Belgium Orange 2030 GSM [55] Telenet 2027 GSM [56] Proximus 2027 GSM [57] Bermuda Digicel active GSM 1900 MHz: 15 MHz GSM + 15 MHz LTE [58] One active GSM 1900 MHz: 5 MHz GSM + 20 MHz LTE [58] Bonaire partiallyunconfirmed Digicel 2025-03-31 GSM FLOW 2024-04-22 GSM British Virgin Islands CCT active GSM 1900 MHz: 10 MHz GSM + 20 MHz LTE [59] Digicel active GSM 1800 MHz: 15 MHz GSM1900 MHz: 5 MHz GSM + 10 MHz UMTS [59] FLOW 2024-04-22 GSM [60] Brunei No Service UNN 2021-06-01 GSM National Wholesale Network used by DSTCom, Progresif and imagine.[61][62] Canada Bell 2019-04-30 cdmaOne Shutdown of CDMA transmitters commenced in remote areas in 2017, followed by an official announcement in June 2018 that 2G devices will lose service soon.[63][64] Rogers Wireless TBD GSM 1900 MHz shutdown in Jun 2021.850 MHz remains active.[65][66][67][68] SaskTel 2017-07-31 cdmaOne [69][70] Telus Mobility 2017-05-31 cdmaOne [71][72] Cayman Islands partiallyunconfirmed Digicel 2020-07-01 GSM [73][74] FLOW 2024-04-22 GSM China China Mobile active GSM 900 MHz: 15 MHz GSM1800 MHz: 25 MHz GSM [75] China Telecom 2025 cdmaOne Local shutdown commenced on 01 Jun 2020.CDMA2000 1xRTT, EV-DO Rev. A/B (3G) service also terminates.[75][76][77] China Unicom 2025 GSM Local shutdown commenced on 18 Apr 2018.[75][78][79][77][80] Chile Entel 2024 Q3 GSM Local shutdown commenced on 22 Jul 2024 in the Arica and Parinacota Region.[81] Colombia Claro 2023-02-23 GSM [82][83] Tigo 2022-11-01 GSM [84] Curaçao Digicel 2025-03-31 GSM FLOW 2024-02-29 GSM [85][86] Dominica partiallyunconfirmed Digicel 2027-03-31 GSM FLOW 2024-03-?? GSM [87] France Bouygues 2026-12-31 GSM [88] Orange 2026-09 GSM [55] SFR 2026 GSM [89] Germany Deutsche Telekom 2028-06-30 GSM [90] Vodafone 2030-12-31 GSM [91] Telefónica (O2) TBD GSM Grenada unconfirmed Digicel 2024-03-31 GSM FLOW 2024-04-22 GSM Guam unconfirmed GTA Teleguam ? GSM Hong Kong 3 2008-11-20 cdmaOne Shut down due to license expiry. Government originally did not allow the license to be renewed due to unpopularity, however the government later reversed the decision and held an auction for CDMA2000 service, which PCCW-HKT won the auction and provided CDMA2000 service immediately after 3's license expiry. 3 2021-09-30 GSM [92] CMHK active GSM 1800 MHz only CSL 2005 D-AMPS Service previously provided by Pacific Link, which subsequently merged into CSL. Shut down due to license expiry. Government did not allow the license to be renewed due to unpopularity. CSL 2017-10-31 cdmaOne Service previously provided by PCCW. After acquisition of CSL by HKT, its mobile business PCCW Mobile was merged into CSL. No service for local customers, only served incoming roaming tourists.CSL terminated its CDMA family business upon its licence expiry, and CDMA2000 1xRTT, EV-DO Rev. A (3G) service has also terminated along with cdmaOne.[93] CSL 2024-11-08 GSM [94] SmarTone 2022-10-14 GSM [95] Iceland Nova 2025-01-28 GSM [96] Síminn 2025 Q4 GSM [97] Vodafone Mid 2025 GSM [98][99] Israel Hot Mobile 2019-12-31 iDEN [100] 2025 GSM Per government statement.[101] Jamaica No Service Digicel 2024-08-31 GSM [102][103] FLOW 2024-04-15 GSM [104][103][105] Japan No Service au KDDI 2012-07-22 cdmaOne [106] NTT Docomo 2012-03-31 PDC [107] Softbank 2010-03-31 PDC [108] Jordan Umniah 2021-03-11 GSM [109] Luxembourg Orange 2030 GSM [55] Macau No Service CTM 2019-08-01 GSM Service for local customers terminated on 4 Jun 2015, but remained for roaming users.[110][111][112] 3 2019-08-01 GSM Service for local customers terminated on 4 Jun 2015, but remained for roaming users.[110][111] SmarTone 2019-08-01 GSM Service for local customers terminated on 4 Jun 2015, but remained for roaming users.[110][111] Mexico AT&T 2019-09-01 GSM [113]Local shutdown commenced in Q1 2019. Movistar 2021-01-01 GSM [114] Montserrat unconfirmed Digicel ? GSM FLOW 2024-04-22 GSM Netherlands KPN 2025-12-01 GSM [115] T-Mobile 2021-06-01 /2023-11-15 (IoT) GSM [116] New Caledonia OPT-NC 2025 GSM Shutdown commenced in 2022.[117] New Zealand 2degrees 2018-03-15 GSM [118] Spark 2012-07-31 cdmaOne [119][120] Norway Telenor 2027 GSM [121] Telia 2025 GSM [121] Panama Digicel 2022-06-30 GSM Complete shutdown of operations and market exit.[122][123][124][125] Peru Bitel N/A (no 2G) Poland Orange 2030 GSM [55] Romania Orange 2030 GSM [55] Saint Kitts and Nevis Digicel 2027-03-31 GSM FLOW 2024-04-22 GSM [126] Saint Lucia partiallyunconfirmed Digicel 2027-03-31 GSM FLOW 2024-04-22 GSM [127] Saint Vincent and the Grenadines Digicel 2027-03-31 GSM FLOW 2023-09-30 GSM [128][129][130][131] Singapore No Service M1 2017-04-18 GSM [132] Singtel 2017-04-18 GSM [132] StarHub 2017-04-18 GSM [132] Sint Maarten Saba Sint Eustatius No Service TelCell 2019-01-01 GSM [133] FLOW (UTS) 2017-09-26 GSM [134] Slovakia Orange 2030 GSM [55] South Africa TBD GSM Per government statement.[135][136] South Korea No Service KT 2012-03-19 cdmaOne CDMA2000 1xRTT, EV-DO Rel. 0 (3G) service has also terminated.[137] LG Uplus 2021-06-30 cdmaOne CDMA2000 1xRTT, EV-DO Rev. A/B (3G) service has also terminated.[138] SK Telecom 2020-07-27 cdmaOne CDMA2000 1xRTT, EV-DO Rel. 0 (3G) service has also terminated.[139] Spain Orange 2030 GSM [55] Sweden Net4Mobility (Telenor/Tele2) 2025-12-31 GSM 2G network will be shut down by the end of 2025.[140][141][142] Telia 2027 GSM Shutdown pushed back from 2025 to 2027.[143][144] Switzerland No Service Salt 2020-12-31 GSM Shutdown commenced on 1 Jul 2020. A few single 2G-only sites remained until Sep 2023 to preserve CSFB functionality.[145][146][147] Sunrise 2023-01-03 GSM With the introduction of S-RAN in 2018 phaseout was previously postponed to 2022.[148][149][150] Swisscom 2021-04-07 GSM Official shutdown on 31 Dec 2020 (guaranteed availability).[151][152][153] Taiwan No Service Chunghwa Telecom 2017-06-30 GSM [154] FarEasTone 2017-06-30 GSM [154] Taiwan Mobile 2017-06-30 GSM [154] Trinidad and Tobago Digicel 2024-12-31 GSM [155][156][157] bmobile (TSTT) TBD GSM 850 MHz: 2.5 MHz GSM + 5 MHz UMTS [158][159] Turks and Caicos Islands Digicel 2025-06-30 GSM 900 MHz: 9.8 MHz GSM [160] FLOW 2024-04-22 GSM [161] United Arab Emirates No Service Du 2023-12-31 GSM [162] Etisalat 2023-12-31 GSM [163] United Kingdom 2033 GSM Per government statement on confirmation by mobile providers.[164][165][166] United States Puerto Rico US Virgin Islands AT&T 2008-02-18 D-AMPS TDMA (D-AMPS) on 1900 MHz shut down on 15 July 2007.[167] 2017-01-01 GSM [168] Cellcom(US only) 2023-12-01 cdmaOne CDMA2000 1xRTT, EV-DO Rev. A (3G) service has also terminated.[169] Claro(PR only) 2028-12-31 GSM Commnet Wireless (Choice)(US only) 2022-12-31 cdmaOne CDMA2000 1xRTT, EV-DO Rev. A (3G) service has also terminated.[170] Copper Valley Wireless 2022-09-30 cdmaOne CDMA2000 1xRTT, EV-DO Rev. A (3G) service has also terminated.[171] Edge Wireless 2007-06-30 D-AMPS [172] T-Mobile 2025 GSM Shutdown commenced on 9 Feb 2025.[173][174] T-Mobile (Sprint) 2022-05-31 cdmaOne CDMA2000 1xRTT, EV-DO Rev. A (3G) service has also terminated.Shutdown commenced on 31 Mar 2022.[175][176][177][178] UScellular(US only) 2009-02 D-AMPS [179] UScellular(US only) 2024-01-14 cdmaOne CDMA2000 1xRTT, EV-DO Rev. A (3G) service has also terminated.[180][181] Verizon(US only) 2022-12-31 cdmaOne CDMA2000 1xRTT, EV-DO Rev. A (3G) service has also terminated.[182] Venezuela Digitel 2024-03-08 GSM Shutdown commenced in May 2021.[183][184] Movilnet 2025 GSM [183] Movistar 2025 GSM Shutdown commenced on 01 Jul 2022.[183] Vietnam No Service Gmobile 2024-10-16 GSM per government regulation[185] Mobifone 2024-10-16 GSM per government regulation[185] Vietnamobile N/A (no 2G) Viettel 2024-10-16 GSM per government regulation[185] Vinaphone 2024-10-16 GSM per government regulation[185] Cliff effect Dropout List of mobile phone generations Mobile radio telephone, also known as 0G 1G 3G 4G 5G 6G Wireless device radiation and health ^ "2G Sunset Brings Faster Speeds, Newer Technologies". 16 January 2017. Retrieved 27 January 2023. ^ US5257397A, Barzegar, Farhad; Eryaman, Can A. & Russell, Jesse E. et al., "Mobile data telephone", issued 1993-10-26 (filed 1990-08-13) ^ "Radiolinja's History". 20 April 2004. Archived from the original on 23 October 2006. Retrieved 23 December 2009. ^ "CDMA Network Technology: A Decade Of Advances And Challenges". www.tek.com. Retrieved 26 February 2025. ^ "4: CDMA - Cellular Technologies for Emerging Markets: 2G, 3G and Beyond [Book]". www.oreilly.com. Retrieved 26 February 2025. ^ "What is Second and a Half Generation (2.5G)". IGI Global. Archived from the original on 6 October 2019. Retrieved 6 October 2019. ^ a b "GPRS & EDGE". 3gpp.org. Archived from the original on 17 April 2020. Retrieved 17 August 2019. ^ "Germany's rural 4G users still spend one-fourth of their time on 3G and 2G networks". Opensignal. 13 June 2019. Retrieved 6 October 2019. ^ "T-Mobile Poland expects to keep 2G for five-to-six years". TeleGeography. 17 July 2019. Archived from the original on 6 October 2019. Retrieved 6 October 2019. ^ "2G phase-out – modernisation of the Swisscom mobile network". Swisscom. Archived from the original on 6 April 2020. Retrieved 6 October 2019. ^ "SUNSET ON 2G/3G MOBILE NETWORKS? NOT EXACTLY..." CSL Group. Retrieved 16 October 2023. ^ Hall, Kat. "Sod 3G, that can go, but don't rush to turn off 2G, UK still needs it – report". The Register. Archived from the original on 26 September 2020. Retrieved 16 October 2023. ^ "T-Mobile Network Evolution". T-Mobile US. Archived from the original on 21 October 2021. Retrieved 19 June 2022. ^ "T-Mobile US to shut down 3G network on 1 July 2022". TeleGeography. 17 September 2021. Archived from the original on 14 April 2022. Retrieved 18 September 2021. ^ Serr, Melanie (5 April 2017). "What You Need To Know About the 2G Network Shutdown". Geotab Blog. Archived from the original on 6 October 2019. Retrieved 6 October 2019. ^ "The status of the 2G/3G network sunset". nae_ global. 31 July 2019. Archived from the original on 11 December 2019. Retrieved 11 December 2019. ^ Cooper Quintin and Andrés Arrieta (29 June 2020). "Your Phone Is Vulnerable Because of 2G, But it Doesn't Have to Be". Electronic Frontier Foundation. Archived from the original on 16 April 2024. ^ "The GSM encryption algorithm was broken". GSMArena. Archived from the original on 5 May 2023. Retrieved 16 October 2023. ^ Russon, Mary-Ann (27 March 2014). "China Arrests 1,500 People for Sending Spam Text Messages from Fake Mobile Base Stations". International Business Times UK. Retrieved 16 October 2023. ^ Zhang, Chi; Liu, Jun-Rong; Gu, Da-Wu; Wang, Wei-Jia; Lu, Xiang-Jun; Guo, Zheng; Lu, Hai-Ning (1 September 2019). "Side-Channel Analysis for the Authentication Protocols of CDMA Cellular Networks". Journal of Computer Science and Technology. 34 (5): 1079–1095. doi:10.1007/s11390-019-1961-5. S2CID 203640029. ^ Amadeo, Ron (14 January 2022). "EFF praises Android's new 2G kill switch, wants Apple to follow suit". Ars Technica. Retrieved 14 January 2022. ^ "About Lockdown Mode". Apple. Archived from the original on 20 June 2024. Retrieved 28 June 2024. ^ "Freedom of Information: Right to know request" (PDF). Ofcom. 3 June 2020. Archived (PDF) from the original on 28 December 2023. Retrieved 28 December 2023. ^ Rockman, Simon. "Millions Will Lose Out When Government Kills 2G". Forbes. Archived from the original on 30 November 2020. Retrieved 16 October 2023. ^ "Frågor och svar (FAQ). 2G" (in Swedish). Ålcom. Archived from the original on 12 July 2023. Retrieved 12 July 2023. ^ "License and Frequency Authorisations - Digicel" (PDF). Public Utilities Commission Anguilla. 5 November 2014. Archived (PDF) from the original on 16 June 2024. Retrieved 8 September 2024. ^ "Annual Report 2016" (PDF). Public Utilities Commission Anguilla. 24 August 2017. Archived (PDF) from the original on 23 June 2024. Retrieved 8 September 2024. ^ "Annual Report 2017" (PDF). Public Utilities Commission Anguilla. 22 October 2018. Archived (PDF) from the original on 14 September 2024. Retrieved 14 September 2024. ^ "Agreement Between The Administrations Of Anguilla, France, Sint Maarten And The State Of Netherlands For Saba And St. Eustatius Concerning The Spectrum Coordination Of Land Mobile Radiocommunication Networks In The Frequency Range 698 MHz to 3800 MHz" (PDF). Agence Nationale Des Fréquences (ANFR). 1 March 2023. Archived (PDF) from the original on 15 September 2024. Retrieved 15 September 2024. ^ "License and Frequency Authorisations - Flow" (PDF). Public Utilities Commission Anguilla. 2014. Archived (PDF) from the original on 15 June 2024. Retrieved 8 September 2024. ^ "We're saying goodbye to our 2G mobile network". Flow Anguilla. 17 April 2024. Archived from the original on 10 September 2024. Retrieved 10 September 2024. ^ "APUA Seeks Portion of Premium Spectrum". Antigua Public Utilities Authority. 13 June 2019. Archived from the original on 8 September 2024. Retrieved 8 September 2024. ^ "Digicel Antigua to say good-bye to 2G this month". Loop Caribbean News by Digicel. 23 May 2024. Retrieved 8 September 2024. ^ "FLOW to retire 2G networks, shutdown in phased manner". Associates Times LLC. 7 June 2024. Retrieved 8 September 2024. ^ "Digicel Network Upgrade". Digicel Aruba. 12 December 2023. Retrieved 14 September 2024. ^ "Hutchison to upgrade Orange network". TeleGeography. 26 January 2004. Retrieved 23 December 2016. ^ "Telstra fails to prise Orange from Hutch as 3G network share talks fail". TeleGeography. 20 April 2004. Archived from the original on 23 December 2016. Retrieved 23 December 2016. ^ "Hutch to push 2G users to 3G and close Orange network". TeleGeography. 1 February 2006. Archived from the original on 23 December 2016. Retrieved 23 December 2016. ^ "Hutch to shut down CDMA network in August". TeleGeography. 10 May 2006. Archived from the original on 21 December 2016. Retrieved 26 July 2014. ^ "2G network closure increases Hutch Australia revenues and losses". TeleGeography. 23 August 2006. Archived from the original on 23 December 2016. Retrieved 23 December 2016. ^ "Optus to shutter GSM network in April 2017". TeleGeography. 5 August 2015. Archived from the original on 19 January 2021. Retrieved 23 January 2021. ^ "2G Network Closure Update". Optus. 19 October 2016. Archived from the original on 29 September 2017. Retrieved 6 July 2017. ^ "Telstra plans EV-DO upgrade". TeleGeography. 15 April 2004. Archived from the original on 23 December 2016. Retrieved 23 December 2016. ^ "'CDMA is on the way out,' says Telstra". TeleGeography. 2 May 2006. Archived from the original on 23 December 2016. Retrieved 23 December 2016. ^ "Telstra to close CDMA network by Jan 2008". TeleGeography. 6 February 2007. Archived from the original on 23 December 2016. Retrieved 23 December 2016. ^ "Telstra's CDMA shutdown: No gain without pain?". ZDNet. 24 April 2008. Archived from the original on 29 August 2024. Retrieved 23 December 2016. ^ "CDMA shut-down delayed 'til April". TeleGeography. 22 January 2008. Archived from the original on 23 December 2016. Retrieved 23 December 2016. ^ "Telstra switches off GSM network". TeleGeography. 2 December 2016. Archived from the original on 18 February 2017. Retrieved 23 January 2021. ^ "Vodafone's 2G Network shutdown starts at the end of this month – are you ready?". Ausdroid. 14 June 2018. Archived from the original on 12 September 2024. Retrieved 12 September 2024. ^ "BTC to commence mobile network optimization project". Eye Witness News. 22 May 2024. Archived from the original on 14 September 2024. Retrieved 14 September 2024. ^ "BTC readies to consolidate mobile network to 4G only". The Tribune - Ellington. 22 May 2024. Archived from the original on 14 September 2024. Retrieved 14 September 2024. ^ "BTC will be transitioning our network from 2G to 3G technology". BTC. Archived from the original on 14 September 2024. Retrieved 14 September 2024. ^ "Batelco to phase out 2G network on 30 November". TeleGeography. 28 September 2021. Retrieved 19 February 2022. ^ "spectrummonitoring.com - Barbados". spectrummonitoring.com. 1 March 2022. Retrieved 15 September 2024. ^ a b c d e f g "Orange selects 5G SA vendors; provides timetable for 2G/3G shutdowns". TeleGeography. 1 March 2022. Archived from the original on 1 March 2022. Retrieved 6 March 2022. ^ "Telenet to switch off 3G from September 2024". TeleGeography. 19 September 2022. Archived from the original on 9 October 2022. Retrieved 26 November 2022. ^ "Proximus to switch off 3G network by end-2024". TeleGeography. 30 November 2022. Archived from the original on 4 December 2022. Retrieved 18 March 2023. ^ a b "spectrummonitoring.com - Bermuda". spectrummonitoring.com. 20 May 2021. Retrieved 15 September 2024. ^ a b "spectrummonitoring.com - British Virgin Islands". spectrummonitoring.com. 6 April 2017. Retrieved 15 September 2024. ^ "Final Announcement 2G Shutdown". FLOW BVI. 17 April 2024. Archived from the original on 17 September 2024. Retrieved 18 September 2024. ^ "Cessation of 2G GSM services in Brunei Darussalam" (PDF). UNN Brunei. 16 April 2021. Archived (PDF) from the original on 8 December 2021. Retrieved 8 December 2021. ^ "FAQs - 2G Network Switch-off". Authority for Info-communications Technology Industry (AITI). Archived from the original on 8 December 2021. Retrieved 8 December 2021. ^ "CDMA Network Discontinuation". Bell Canada. Archived from the original on 23 March 2018. Retrieved 23 January 2021. ^ "Bell completing CDMA shutdown on 30 April". TeleGeography. 1 April 2019. Archived from the original on 2 March 2021. Retrieved 23 January 2021. ^ "Rogers extends availability of GSM/GPRS network to December 2020". MobileSyrup. 4 May 2018. Archived from the original on 10 October 2020. Retrieved 23 January 2021. ^ "Important Notice Regarding Upcoming 2G/3G Changes on the Rogers Network". BULWARK. 15 July 2020. Archived from the original on 21 September 2024. Retrieved 23 January 2021. ^ "1900 MHz Shutdown on our 2G and 3G Wireless Networks". Rogers Communications. 1 March 2021. Archived from the original on 13 May 2023. Retrieved 13 May 2023. ^ "2G and 3G Shutdowns Continue". blog.telegeography.com. 15 February 2023. Archived from the original on 5 May 2023. Retrieved 13 May 2023.

^ "Final countdown for Saskatchewan CDMA". TeleGeography. 6 July 2016. Archived from the original on 26 February 2021. Retrieved 23 January 2021. ^ "SaskTel reminds CDMA customers of network shutdown". Sasktel. 11 January 2017. Retrieved 23 January 2021. ^ "Telus 'shutting CDMA in 2015'". TeleGeography. 21 October 2013. Retrieved 23 January 2021. ^ "CDMA network shut down - Information on the discontinuation of CDMA network support". TELUS. Archived from the original on 11 November 2020. Retrieved 23 January 2021. ^ "2G Network Shut Down". Digicel Cayman. Archived from the original on 17 September 2021. Retrieved 18 March 2022. ^ "Digicel Cayman announces network upgrade, discontinues 2G coverage". TeleGeography. 1 November 2019. Archived from the original on 19 February 2022. Retrieved 19 February 2022. ^ a b c "spectrummonitoring.com - China". spectrummonitoring.com. 21 November 2022. Retrieved 13 October 2024. ^ "China Telecom: 3G Network Will Be Shut down Gradually Starting from June". Montnets. 5 June 2020. Archived from the original on 21 September 2024. Retrieved 14 May 2022. ^ a b "Turning off 2G in China harder than it looks". Light Reading. 29 June 2022. Retrieved 4 December 2022. ^ "China Unicom to roll back 2G network". TechNode. 18 April 2018. Retrieved 13 October 2024. ^ "China Unicom to retire 2G next year". Developing Telecoms Ltd. 13 November 2020. Retrieved 23 January 2021. ^ "China Unicom given green light to refarm 900MHz band for 5G". TeleGeography. 4 November 2022. Archived from the original on 5 November 2022. Retrieved 6 November 2022. ^ "¿Cuándo se hará el recambio de la tecnología 2G en mi región? - Centro de Ayuda - Entel" [When will the 2G technology be switched to in my region?] (in Spanish). Retrieved 7 October 2024. ^ "Claro Colombia targets December 2022 2G shutdown". TeleGeography. 13 May 2022. Retrieved 14 May 2022. ^ "Claro now expects to switch off 2G network by Feb-23". TeleGeography. 20 September 2022. Archived from the original on 9 October 2022. Retrieved 6 October 2022. ^ "Tigo switches off Colombian 2G network". TeleGeography. 2 November 2022. Archived from the original on 5 November 2022. Retrieved 6 November 2022. ^ "Final Announcement 2G Shutdown". Flow Curaçao. Retrieved 15 September 2024. ^ "2G service retires February 29". Flow Curaçao. 26 February 2024. Archived from the original on 15 September 2024. Retrieved 15 September 2024. ^ "Flow repurposing its 2G network to bolster 3G & 4G". Emonews. 4 March 2024. Retrieved 13 October 2024. ^ "Bouygues Telecom to decommission 2G in 2026, 3G to follow in 2029". TeleGeography. 3 February 2023. Archived from the original on 11 February 2023. Retrieved 11 February 2023. ^ "SFR selects Nokia for 5G SA network; to decommission 2G/3G by 2028". TeleGeography. 27 January 2023. Archived from the original on 28 January 2023. Retrieved 28 January 2023. ^ "Mehr Speed auf alten Frequenzen: 2G-Abschaltung sorgt für besseres Netz" (in German). Deutsche Telekom. 22 October 2024. Retrieved 22 October 2024. ^ "GSM-Abschaltung: Vodafone will 2G-Netze bis Ende 2028 abschalten" (in German). computerbase.de. 24 October 2024. Retrieved 24 October 2024. ^ "3 Hong Kong to close 2G network at end-September". TeleGeography. 29 July 2021. Archived from the original on 29 July 2021. Retrieved 1 August 2021. ^ "不獲批頻譜改作4G LTE 香港電訊入稟司法覆核 - 香港經濟日報" (in Chinese). topick.hket.com. 22 December 2017. Retrieved 9 November 2024. ^ "HKT to terminate 2G services on 8 November 2024 reallocating spectrum resources for advanced mobile services" (PDF). HKT Limited. 2 August 2024. Retrieved 9 November 2024. ^ "SmarTone announces October shutdown for 2G network". TeleGeography. 12 August 2022. Retrieved 19 August 2022. ^ "Bless 2G!" (in Icelandic). NOVA Hlutafélag. Retrieved 28 January 2025. ^ "Lokun 2G & 3G kerfa" (in Icelandic). Síminn. Retrieved 28 January 2025. ^ "Hoppum inn í framtíðina". Vodafone Iceland. Retrieved 28 January 2025. ^ "Tímabili 2G og 3G fer senn að ljúka" (in Icelandic). Viðskiptablaðið. 9 September 2024. Retrieved 28 January 2025. ^ "מערכת אייסל 77350 נטו ועכשיו" (in Hebrew). bizzness.net. 3 September 2019. Retrieved 13 October 2024. [Dear customer, we would like to inform you that according to the directive of the Ministry of Communications, we are forced to stop using the IDEN system frequencies until December 31, 2019. And we will not be able to continue providing the network services to you.] ^ "Ministry orders shutdown of Israeli 2G, 3G networks by 2025". TeleGeography. 2 July 2021. Archived from the original on 12 August 2022. Retrieved 6 June 2022. ^ "Digicel enters final stage of 2G network shutdown | Loop Jamaica". Loop News. 3 April 2024. Retrieved 14 April 2024. ^ a b "BANGERS, BEGONE!". jamaica-gleaner. 14 April 2024. Retrieved 14 April 2024. ^ "Flow Jamaica 2G shutdown underway". TeleGeography. 5 August 2022. Archived from the original on 5 August 2022. Retrieved 5 August 2022. ^ "Flow retires 2G network". Grove Broadcasting Company Ltd. 15 April 2024. Retrieved 13 October 2024. ^ "Au's "CDMA 1X" finished service on July 2022, about 200 types of target models". gigazine.net. 18 April 2012. Retrieved 12 September 2024. ^ "DoCoMo's nine-month profits up 16%, announces 2G shutdown March 2012". TeleGeography. 30 January 2009. Archived from the original on 19 January 2021. Retrieved 23 January 2021. ^ "Discontinuation Notice of 2G Service". Softbank. 24 November 2009. Archived from the original on 30 January 2021. Retrieved 23 January 2021. ^ "Umniah switching off 2G network in Jordan". Developing Telecoms. 11 March 2021. Archived from the original on 17 January 2022. Retrieved 18 September 2024. ^ a b c "Macau mobile users reach 1.56m in 3Q13; 2G users number less than 5,000 as switch off looms". TeleGeography. 29 October 2013. Archived from the original on 30 January 2021. Retrieved 23 January 2021. ^ "Macau to shut down 2G networks for roaming users". TeleGeography. 10 April 2019. Archived from the original on 29 January 2021. Retrieved 23 January 2021. ^ "Govt to allow telecoms to end 2G service". The Macau Post Daily. 9 April 2019. Retrieved 2 July 2024. ^ "AT&T Mexico 2G switch-off imminent, report says". TeleGeography. 16 January 2019. Retrieved 14 April 2021. ^ "Movistar Mexico to switch off 2G on 1 January 2021". TeleGeography. 9 October 2020. Archived from the original on 18 January 2021. Retrieved 14 April 2021. ^ "Faster and safer - Join us on 4G and 5G". Royal KPN N.V. Retrieved 24 December 2024. ^ "T-Mobile Netherlands delays consumer 2G shutdown to Jun-21; M2M 2G continues to Jun-23". TeleGeography. 9 October 2020. Archived from the original on 27 February 2021. Retrieved 23 January 2021. ^ "OPT-NC updates on 2G sunset progress". TeleGeography. 28 July 2022. Archived from the original on 26 November 2022. Retrieved 26 November 2022. ^ "2degrees 2G shuts on 15 March". TeleGeography. 13 February 2018. Retrieved 23 January 2021. ^ "Telecom NZ to close CDMA network by mid-2012". TeleGeography. 8 July 2010. Archived from the original on 27 February 2021. Retrieved 23 January 2021. ^ "Telecom closes CDMA network". TeleGeography. 31 July 2012. Archived from the original on 20 January 2021. Retrieved 23 January 2021. ^ a b "Informasjon om slukking av 2G-nett i 2025". Nasjonal kommunikasjonsmyndighet (Nkom). 4 January 2021. Archived from the original on 15 May 2022. Retrieved 3 May 2021. ^ "Digicel ships out of Panama". GSMA Mobile World Live. 7 April 2022. Archived from the original on 18 September 2024. Retrieved 19 September 2024. ^ "Digicel ditches Panama as M&A kills competition". telecoms.com. 7 April 2022. Retrieved 19 September 2024. ^ "Digicel Leaves Panama After Government Clears C&W-Claro Merger". Nearshore Americas. 30 June 2022. Archived from the original on 18 September 2024. Retrieved 19 September 2024. ^ "Panama snags bite for Digicel's telecoms licence". Developing Telecoms. 17 March 2023. Archived from the original on 17 April 2024. Retrieved 19 September 2024. ^ "Flow to Upgrade Mobile Network 2G Network To Be Retired". SKNVibes. 4 April 2024. Archived from the original on 15 September 2024. Retrieved 15 September 2024. ^ "End of an era: The decommissioning of 2G mobile cellular networks in the caribbean". ICT Pulse & Choice TV Saint Lucia. 6 September 2024. Retrieved 13 October 2024. ^ "Flow plans 2G shutdown in Saint Vincent". Developing Telecoms. 21 August 2023. Archived from the original on 12 September 2024. Retrieved 12 September 2024. ^ "Flow to retire 2G network in Saint Vincent and the Grenadines". Data Centre Dynamics. 23 August 2023. Archived from the original on 7 October 2023. Retrieved 12 September 2024. ^ "Flow retires its 2G network to bolster 3G & 4G". Asbert News Network. 20 August 2023. Archived from the original on 12 September 2024. Retrieved 12 September 2024. ^ "FLOW SVG shutting down 2G network, upgrade to avoid interruption". St. Vincent Times. 21 August 2023. Archived from the original on 12 September 2024. Retrieved 12 September 2024. ^ a b c "IMDA: 2G shutdown will start on 1 April". TeleGeography. 28 March 2017. Archived from the original on 24 January 2021. Retrieved 23 January 2021. ^ "Out with the old on New Year's Eve: TelEm shuts 2G". TeleGeography. 20 December 2018. Archived from the original on 19 February 2022. Retrieved 19 February 2022. ^ "UTS: not turning 2G network back on post-Hurricane Irma". TeleGeography. 26 September 2017. Archived from the original on 19 February 2022. Retrieved 19 February 2022. ^ "South Africa to ban 2G devices by March 2023". TeleGeography. 16 June 2022. Archived from the original on 16 June 2022. Retrieved 19 June 2022. ^ "SA comms minister proposes 2G/3G switch-offs in 2024/2025". TeleGeography. 6 September 2022. Archived from the original on 21 September 2024. Retrieved 6 September 2022. ^ "Terminating 2G Service in Korea: Policy Issues and Suggestions". International Telecommunications Policy Review. 1 March 2014. Retrieved 23 January 2021. ^ "S. Korea to end 2G network services by June". The Korea Herald. 17 January 2021. Archived from the original on 9 July 2021. Retrieved 23 January 2021. ^ "SK Telecom shutters 2G service". TeleGeography. 28 July 2020. Archived from the original on 28 February 2021. Retrieved 23 January 2021. ^ "Nedsläckning av 2G och 3G - Tele2". www.tele2.se (in Swedish). Archived from the original on 21 September 2024. Retrieved 21 September 2024. ^ "Sverige släcker 2G och 3G – Telenor med i informationskampanjen Bytnät.nu". www.telenor.se (in Swedish). Archived from the original on 21 September 2024. Retrieved 21 September 2024. ^ "3G-nätet | Telenor". www.telenor.se (in Swedish). Archived from the original on 21 September 2024. Retrieved 21 September 2024. ^ "Telia och övriga i branschen säger adjö till 2G och 3G - byt nät nu!". Mynewsdesk (in Swedish). 30 January 2024. Retrieved 21 September 2024. ^ "Telia skjuter upp nedstängningen av 2G-nätet till 2027". Mynewsdesk (in Swedish). 30 May 2024. Archived from the original on 21 September 2024. Retrieved 21 September 2024. ^ "Salt und Swisscom beisegeln das Aus für Uralt-Handys – 2020 wird das 2G-Netz abgeschaltet" (in German). watson. 7 April 2017. Archived from the original on 29 January 2021. Retrieved 23 January 2021. ^ "Schweiz: GSM-Netz bei Salt noch nicht ganz weg" (in German). Teltarif.de. 23 June 2020. Archived from the original on 23 November 2020. Retrieved 23 January 2021. ^ "GSM-Mobilfunk: Die Schweiz schaltet ab" (in German). heise online. 29 December 2020. Archived from the original on 22 December 2023. ^ "Sun sets on 2G technology for Swiss cellco". TeleGeography. 20 June 2017. Retrieved 23 January 2021. ^ "Schweiz: Sunrise schaltet 2G vorerst doch nicht ab" (in German). Teltarif.de. 23 November 2018. Archived from the original on 13 April 2021. Retrieved 14 April 2021. ^ "Abschaltung: Die Tage von GSM sind in der Schweiz gezählt" (in German). Teltarif.de. 20 June 2020. Archived from the original on 30 January 2021. Retrieved 23 January 2021. ^ "Swisscom plots the end of 2G as it moves to launch 5G in 2020". Fierce Wireless. 9 October 2016. Retrieved 23 January 2021. ^ "Swisscom schaltet GSM-Netz komplett ab" (in German). Teltarif.de. 13 April 2021. Archived from the original on 13 April 2021. Retrieved 14 April 2021. ^ "Swisscom hat Befarming von GSM abgeschlossen" (in German). Golem.de. 13 April 2021. Archived from the original on 1 May 2021. Retrieved 14 April 2021. ^ a b c "Taiwanese cellcos shutter 2G networks". TeleGeography. 3 July 2017. Archived from the original on 28 January 2021. Retrieved 23 January 2021. ^ "Digicel to decommission 2G network". Loop News by Digicel. 10 November 2023. Retrieved 10 November 2023. ^ "Digicel to shut down Trinidadian 2G network on 31 March 2024". TeleGeography. 13 November 2023. Archived from the original on 18 November 2023. Retrieved 18 November 2023. ^ "Network - Frequently Asked Questions - Why are we decommissioning 2G Services on our Network? What are the benefits to the customers?". Digicel Trinidad and Tobago. 31 March 2024. Retrieved 9 September 2024. ^ "spectrummonitoring.com - Trinidad and Tobago". spectrummonitoring.com. 25 November 2022. Retrieved 15 September 2024. ^ "TSTT prepares for 2G sunset". TechNewsTT. 23 August 2018. Archived from the original on 8 September 2024. Retrieved 9 September 2024. ^ "spectrummonitoring.com - Turcks and Caicos Islands (GB)". spectrummonitoring.com. 10 April 2023. Archived from the original on 15 September 2024. Retrieved 15 September 2024. ^ "Flow commences Phased Shutdown of 2G Mobile Network". NewslineTCI. 26 March 2024. Archived from the original on 11 September 2024. Retrieved 11 September 2024. ^ "du - 2G Shutdown". du. Archived from the original on 15 October 2023. Retrieved 7 October 2023. ^ "Etisalat UAE: Goodbye 2G". Etisalat UAE. Archived from the original on 15 October 2023. Retrieved 7 October 2023. ^ "UK 2G and 3G networks will be switched off by 2033". Techradar. 8 December 2021. Retrieved 3 March 2022. ^ "Switching off the UK's 3G mobile networks: what you need to know". Ofcom. Archived from the original on 15 November 2022. Retrieved 3 March 2022. ^ "A joint statement on the sunsetting of 2G and 3G networks and public ambition for Open RAN rollout as part of the Telecoms Supply Chain Diversification Strategy". Gov.uk. 8 December 2021. Archived from the original on 16 November 2023. Retrieved 16 November 2023. ^ "AT&T Starts TDMA Shutdown". Phone Scoop. 19 June 2007. Retrieved 26 February 2025. ^ "AT&T confirms 2G shutdown took place on 1 January". TeleGeography. 18 January 2017. Archived from the original on 25 September 2020. Retrieved 23 January 2021. ^ "Regional US mobile operator Cellcom to switch off 2G on 1 December; 3G was deactivated in March". TeleGeography. 20 September 2023. Archived from the original on 4 October 2023. Retrieved 4 October 2023. ^ "Upgrade Your Device Today". Choice Wireless. Archived from the original on 25 January 2024. Retrieved 5 February 2024. ^ "CDMA Sunset". Copper Valley Telecom. 6 January 2023. Archived from the original on 22 February 2024. Retrieved 22 February 2024. ^ "Edge Wireless - TDMA Network Changing to GSM/GPRS FAQs". Edge Wireless, LLC. 15 March 2007. Retrieved 26 February 2025. ^ "T-Mobile to finally turn off 2G in 2024". LightReading. 15 February 2023. Archived from the original on 3 November 2023. Retrieved 3 November 2023. ^ "T-Mobile kicks off 2G shutdown in US". Data Centre Dynamics Ltd (DCD). 19 February 2025. Retrieved 19 February 2025. ^ "T-Mobile aiming to shut down legacy Sprint networks in 2022". TeleGeography. 10 November 2020. Archived from the original on 4 March 2021. Retrieved 23 January 2021. ^ "T-Mobile US to shut 3G network on 1 July 2022". TeleGeography. 17 September 2021. Archived from the original on 18 September 2021. Retrieved 18 September 2021. ^ "T-Mobile delays CDMA shutdown by three months". TeleGeography. 25 October 2021. Archived from the original on 14 April 2022. Retrieved 1 November 2021. ^ "T-Mobile US commences CDMA shutdown; expands 5G Home Internet footprint". TeleGeography. 31 March 2022. Archived from the original on 31 March 2022. Retrieved 31 March 2022. ^ "US-Cellular-2009-Annual-Report" (PDF). US-Cellular. 6 April 2010. Retrieved 5 March 2025. ^ "USCellular to Expand Cellular Service in Rural Missouri With USD 5.8 Million Grant". Telecom Talk. 6 November 2023. Archived from the original on 18 November 2023. Retrieved 18 November 2023. ^ "UScellular to switch off CDMA network on 14 January 2024". TeleGeography. 1 December 2023. Archived from the original on 2 December 2023. Retrieved 2 December 2023. ^ "Verizon to shut down 3G CDMA networks on 31 December 2022". TeleGeography. 31 March 2021. Archived from the original on 1 April 2021. Retrieved 14 April 2021. ^ "Venezuela aims to phase out 2G in 2025; targets 1.8m fibre subs by that date". TeleGeography. 27 June 2023. Archived from the original on 8 July 2023. Retrieved 8 July 2023. ^ "Información al usuario" [Information for Users] (in Spanish). Digitel. 1 February 2024. Retrieved 3 April 2025. ^ a b c d "2G network switched off by the end of October 15". VnEconomy. 17 September 2024. Retrieved 12 October 2024.

Preceded by1st Generation (1G) Mobile Telephony Generations Succeeded by3rd Generation (3G) Retrieved from " 6Third generation of wireless mobile telecommunications technology This article needs to be updated. Please help update this article to reflect recent events or newly available information. (April 2021) A USB modem for 3G plugged into a laptop. Part of a series on theWireless network technologies Analog 0G1G (1.5G) Digital 2G (2.5G, 2.75G, 2.9G)3G (3.5G, 3.75G, 3.9G/3.95G)4G (4G/4.5G, 4.5G, 4.9G)5G (5.5G)6G Mobile telecommunicationsv 3G refers to the third generation of cellular network technology. These networks were rolled out beginning in the early 2000s and represented a significant advancement over the second generation (2G), particularly in terms of data transfer speeds and mobile internet capabilities. The major 3G standards are UMTS (developed by 3GPP, succeeding GSM) and CDMA2000 (developed by Qualcomm, succeeding cdmaOne);[1][2] both of these are based on the IMT-2000 specifications established by the International Telecommunication Union (ITU). While 2G networks such as GPRS and EDGE supported limited data services, 3G introduced significantly higher-speed mobile internet and enhanced multimedia capabilities, in addition to improved voice quality.[3] It provided moderate internet speeds suitable for general web browsing and multimedia content including video calling and mobile TV,[3] supporting services that provide an information transfer rate of at least 144 kbit/s.[4][5] Later 3G releases, often referred to as 3.5G (HSPA) and 3.75G (HSPA+) as well as EV-DO, introduced important improvements, enabling 3G networks to offer mobile broadband access with speeds ranging from several Mbit/s up to 42 Mbit/s.[6] These updates improved the reliability and speed of internet browsing, video streaming, and online gaming, enhancing the overall user experience for smartphones and mobile modems in comparison to earlier 3G technologies. 3G was later succeeded by 4G technology, which provided even higher data transfer rates and introduced advancements in network performance. A new generation of cellular standards has emerged roughly every decade since the introduction of 1G systems in 1979. Each generation is defined by the introduction of new frequency bands, higher data rates, and transmission technologies that are not backward-compatible due to the need for significant changes in network architecture and infrastructure. Several telecommunications companies marketed wireless mobile Internet services as 3G, indicating that the advertised service was provided over a 3G wireless network. However, 3G services have largely been supplanted in marketing by 4G and 5G services in most areas of the world. Services advertised as 3G are required to meet IMT-2000 technical standards, including standards for reliability and speed (data transfer rates). To meet the IMT-2000 standards, third-generation mobile networks, or 3G, must maintain minimum consistent Internet speeds of 144 Kbps.[5] However, many services advertised as 3G provide higher speed than the minimum technical requirements for a 3G service.[7] Subsequent 3G releases, denoted 3.5G and 3.75G, provided mobile broadband access of several Mbit/s for smartphones and mobile modems in laptop computers.[8] 3G branded standards: The UMTS (Universal Mobile Telecommunications System) system, standardized by 3GPP in 2001, was used in Europe, Japan, China (with a different radio interface) and other regions predominated by GSM (Global Systems for Mobile Communications) 2G system infrastructure. The cell phones are typically UMTS and GSM hybrids. Several radio interfaces are offered, sharing the same infrastructure: The original and most widespread radio interface is called W-CDMA (Wideband Code Division Multiple Access). The TD-SCDMA radio interface was commercialized in 2009 and only offered in China. The latest UMTS release, HSPA+, can provide peak data rates up to 56 Mbit/s in the downlink in theory (28 Mbit/s in existing services) and 22 Mbit/s in the uplink. The CDMA2000 system, first offered in 2002, standardized by 3GPP2, used especially in North America and South Korea, sharing infrastructure with the IS-95 2G standard. The cell phones are typically CDMA2000 and IS-95 hybrids. The latest release EVDO Rev. B offers peak rates of 14.7 Mbit/s downstream. The 3G systems and radio interfaces are based on spread spectrum radio transmission technology. While the GSM EDGE standard ("2.9G"), DECT cordless phones and Mobile WiMAX standards formally also fulfill the IMT-2000 requirements and are approved as 3G standards by ITU, these are typically not branded as 3G and are based on completely different technologies. The common standards complying with the IMT2000/3G standard are: EDGE, a revision by the 3GPP organization to the older 2G GSM based transmission methods, which utilizes the same switching nodes, base station sites, and frequencies as GPRS, but includes a new base station and cellphone RF circuits. It is based on the three times as efficient 8PSK modulation scheme as a supplement to the original GMSK modulation scheme. EDGE is still used extensively due to its ease of upgrade from existing 2G GSM infrastructure and cell phones. EDGE combined with the GPRS 2.5G technology is called EGPRS, and allows peak data rates in the order of 200 kbit/s, just like the original UMTS WCDMA versions and thus formally fulfill the IMT2000 requirements on 3G systems. However, in practice, EDGE is seldom marketed as a 3G system, but a 2.9G system. EDGE shows slightly better system spectral efficiency than the original UMTS and CDMA2000 systems, but it is difficult to reach much higher peak data rates due to the limited GSM spectral bandwidth of 200 kHz, and it is thus a dead end. EDGE was also a mode in the IS-136 TDMA system, no longer used. Evolved EDGE, the latest revision, has peaks of 1 Mbit/s downstream and 400 kbit/s upstream but is not commonly used. The Universal Mobile Telecommunications System, created and revised by the 3GPP. The family is a full revision from GSM in terms of encoding methods and hardware, although some GSM sites can be retrofitted to broadcast in the UMTS/W-CDMA format. W-CDMA is the most common deployment, commonly operated on the 2,100 MHz band. A few others use the 850, 900, and 1,900 MHz bands. HSPA is an amalgamation of several upgrades to the original W-CDMA standard and offers speeds of 14.4 Mbit/s down and 5.76 Mbit/s up. HSPA is backward-compatible and uses the same frequencies as W-CDMA. HSPA+, a further revision and upgrade of HSPA, can provide theoretical peak data rates up to 168 Mbit/s in the downlink and 22 Mbit/s in the uplink, using a combination of air interface improvements as well as multi-carrier HSPA and MIMO. Technically though, MIMO and DC-HSPA can be used without the "+" enhancements of HSPA+. The CDMA2000 system, or IS-2000, including CDMA2000 1x and CDMA2000 High Rate Packet Data (or EVDO), standardized by 3GPP2 (differing from the 3GPP), evolving from the original IS-95 CDMA system, is used especially in North America, China, India, Pakistan, Japan, South Korea, Southeast Asia, Europe, and Africa. CDMA2000 1x Rev. E has an increased voice capacity (by three times the original amount) compared to Rev. 0 EVDO Rev. B offers downstream peak rates of 14.7 Mbit/s while Rev. C enhanced existing and new terminal user experience. While DECT cordless phones and Mobile WiMAX standards formally also fulfill the IMT-2000 requirements, they are not usually considered due to their rarity and unsuitability for usage with mobile phones.[9] The 3G (UMTS and CDMA2000) research and development projects started in 1992. In 1999, ITU approved five radio interfaces for IMT-2000 as a part of the ITU-R M.1457 Recommendation; WiMAX was added in 2007.[10] There are evolutionary standards (EDGE and CDMA) that are backward-compatible extensions to pre-existing 2G networks as well as revolutionary standards that require all-new network hardware and frequency allocations. The cell phones use UMTS in combination with 2G GSM standards and bandwidths, but do not support EDGE. The latter group is the UMTS family, which consists of standards developed for IMT-2000, as well as the independently developed standards DECT and WiMAX, which were included because they fit the IMT-2000 definition. While EDGE fulfills the 3G specifications, most GSM/UMTS phones report EDGE ("2.75G") and UMTS ("3G") functionality.[11] Cellular network standards and generation timeline. 3G technology was the result of research and development work carried out by the International Telecommunication Union (ITU) in the early 1980s. 3G specifications and standards were developed in fifteen years. The technical specifications were made available to the public under the name IMT-2000. The communication spectrum between 400 MHz to 3 GHz was allocated for 3G. Both the government and communication companies approved the 3G standard. The first pre-commercial 3G network was launched by NTT DoCoMo in Japan in 1998,[12] branded as FOMA. It was first available in May 2001 as a pre-release (test) of W-CDMA technology. The first commercial launch of 3G was also by NTT DoCoMo in Japan on 1 October 2001, although it was initially somewhat limited in scope;[13][14] broader availability of the system was delayed by apparent concerns over its reliability.[15][16][17][18][19] The first European pre-commercial network was an UMTS network on the Isle of Man by Manx Telecom, the operator then owned by British Telecom, and the first commercial network (also UMTS based W-CDMA) in Europe was opened for business by Telenor in December 2001 with no commercial handsets and thus no paying customers. The first network to go commercially live was by SK Telecom in South Korea on the CDMA-based 1xEV-DO technology in January 2002. By May 2002, the second South Korean 3G network was by KT on EV-DO and thus the South Koreans were the first to see competition among 3G operators. The first commercial United States 3G network was by Monet Mobile Networks, on CDMA2000 1x EV-DO technology, but the network provider later shut down operations. The second 3G network operator in the US was Verizon Wireless in July 2002, also on CDMA2000 1x EV-DO. AT&T Mobility was also a true 3G UMTS network, having completed its upgrade of the 3G network to HSUPA. The first commercial United Kingdom 3G network was started by Hutchison Telecom which was originally behind Orange S.A.[20] In 2003, it announced first commercial third generation or 3G mobile phone network in the UK. The first pre-commercial demonstration network in the southern hemisphere was built in Adelaide, South Australia, by m.Net Corporation in February 2002 using UMTS on 2100 MHz. This was a demonstration network for the 2002 IT World Congress. The first commercial 3G network was launched by Hutchison Telecommunications branded as Three or "3" in June 2003.[21] In India, on 11 December 2008, the first 3G mobile and internet services were launched by a state-owned company, Mahanagar Telecom Nigam Limited (MTNL), within the metropolitan cities of Delhi and Mumbai. After MTNL, another state-owned company, Bharat Sanchar Nigam Limited (BSNL), began deploying the 3G networks country-wide. Emtel launched the first 3G network in Africa.[22] Videotelephony through cellular networks were possible using 3G technologies Japan was one of the first countries to adopt 3G, the reason being the process of 3G spectrum allocation, which in Japan was awarded without much upfront cost. The frequency spectrum was allocated in the US and Europe based on auctioning, thereby requiring a huge initial investment for any company wishing to provide 3G services. European companies collectively paid over 100 billion dollars in their spectrum auctions.[23] Nepal Telecom adopted 3G Service for the first time in southern Asia. However, its 3G was relatively slow to be adopted in Nepal. In some instances, 3G networks do not use the same radio frequencies as 2G, so mobile operators must build entirely new networks and license entirely new frequencies, especially to achieve high data transmission rates. Other countries' delays were due to the expenses of upgrading transmission hardware, especially for UMTS, whose deployment required the replacement of most broadcast towers. Due to these issues and difficulties with deployment, many carriers could not or delayed the acquisition of these updated capabilities. In December 2007, 190 3G networks were operating in 40 countries and 154 HSDPA networks were operating in 71 countries, according to the Global Mobile Suppliers Association (GSA). In Asia, Europe, Canada, and the US, telecommunication companies use W-CDMA technology with the support of around 100 terminal designs to operate 3G mobile networks. The roll-out of 3G networks was delayed by the enormous costs of additional spectrum licensing fees in some countries. The license fees in some European countries were particularly high, bolstered by government auctions of a limited number of licenses and sealed bid auctions, and initial excitement over 3G's potential. This led to a telecoms crash that ran concurrently with similar crashes in the fibre-optic and dot.com fields. The 3G standard is perhaps well known because of a massive expansion of the mobile communications market post-2G and advances of the consumer mobile phone. An especially notable development during this time is the smartphone (for example, the iPhone, and the Android family), combining the abilities of a PDA with a mobile phone, leading to widespread demand for mobile internet connectivity. 3G has also introduced the term "mobile broadband" because its speed and capability made it a viable alternative for internet browsing, and USB Modems connecting to 3G networks, and now 4G became increasingly common. By June 2007, the 200 millionth 3G subscriber had been connected of which 10 million were in Nepal and 8.2 million in India. This 200 millionth is only 6.7% of the 3 billion mobile phone subscriptions worldwide. (When counting CDMA2000 1x RTT customers—max bitrate 72% of the 200 kbit/s which defines 3G—the total size of the nearly-3G subscriber base was 475 million as of June 2007, which was 15.8% of all subscribers worldwide.) In the countries where 3G was launched first – Japan and South Korea – 3G penetration is over 70%.[24] In Europe the leading country[when?] for 3G penetration is Italy with a third of its subscribers migrated to 3G. Other leading countries[when?] for 3G use include Nepal, UK, Austria, Australia and Singapore at the 32% migration level. According to ITU estimates,[25] as of Q4 2012 there were 2096 million active mobile-broadband[vague] subscribers worldwide out of a total of 6835 million subscribers—this is just over 30%. About half the mobile-broadband subscriptions are for subscribers in developed nations, 934 million out of 1600 million total, well over 50%. Note however that there is a distinction between a phone with mobile-broadband connectivity and a smart phone with a large display and so on—although according[26] to the ITU and informatandm.com the US has 321 million mobile subscriptions, including 256 million that are 3G or 4G, which is both 80% of the subscriber base and 80% of the US population, according[25] to ComScore just a year earlier in Q4 2011 only about 42% of people surveyed in the US reported they owned a smart phone. In Japan, 3G penetration was similar at about 81%, but smart phone ownership was lower at about 17%.[25] In China, there were 486.5 million 3G subscribers in June 2014,[27] in a population of 1,385,566,537 (2013 UN estimate). Since the increasing adoption of 4G networks across the globe, 3G use has been in decline. Several operators around the world have already or are in the process of shutting down their 3G networks (see table below). In several places, 3G is being shut down while its older predecessor 2G is being kept in operation; Vodafone UK is doing this, citing 2G's usefulness as a low-power fallback.[28] EE in the UK, plans to switch off their 3G networks in early 2024.[29] In the US, Verizon shutdown their 3G services on 31 December 2022,[30] T-Mobile shut down Sprint's networks on 31 March 2022 and shutdown their main networks on 1 July 2022,[31] and AT&T has done so on 22 February 2022.[32] Currently 3G around the world is declining in availability and support. Technology that depends on 3G for usage are becoming inoperable in many places. For example, the European Union plans to ensure that member countries maintain 2G networks as a fallback[citation needed], so 3G devices that are backwards compatible with 2G frequencies can continue to be used. However, in countries that plan to decommission 2G networks or have already done so as well, such as the United States and Singapore, devices supporting only 3G and backwards compatible with 2G are becoming inoperable.[33] As of February 2022, less than 1% of cell phone customers in the United States used 3G; AT&T offered free replacement devices to some customers in the run-up to its shutdown.[34] It has been estimated that there are almost 8,000 patents declared essential (FRAND) related to the 483 technical specifications which form the 3GPP and 3GPP2 standards.[35][36] Twelve companies accounted in 2004 for 90% of the patents (Qualcomm, Ericsson, Nokia, Motorola, Philips, NTT DoCoMo, Siemens, Mitsubishi, Fujitsu, Hitachi, InterDigital, and Matsushita). Even then, some patents essential to 3G might not have been declared by their patent holders. It is believed that Nortel and Lucent have undisclosed patents essential to these standards.[36] Furthermore, the existing 3G Patent Platform Partnership Patent pool has little impact on FRAND protection because it excludes the four largest patent owners for 3G.[37][38] ITU has not provided a clear[39][vague] definition of the data rate that users can expect from 3G equipment or providers. Thus users sold 3G service may not be able to point to a standard and say that the rates it specifies are not being met. While stating in commentary that "it is expected that IMT-2000 will provide higher transmission rates: a minimum data rate of 2 Mbit/s for stationary or walking users, and 348 kbit/s in a moving vehicle,"[40] the ITU does not actually clearly specify minimum required rates, nor required average rates, nor what modes[clarification needed] of the interfaces qualify as 3G, so various[vague] data rates are sold as '3G' in the market. In a market implementation, 3G downlink data speeds defined by telecom service providers vary depending on the underlying technology deployed; up to 384 kbit/s for UMTS (WCDMA), up to 7.2 Mbit/sec for HSPA, and a theoretical maximum of 21.1 Mbit/s for HSPA+ and 42.2 Mbit/s for DC-HSPA+ (technically 3.5G, but usually clubbed under the tradename of 3G).[citation needed] See also: Mobile security § Attacks based on the GSM networks 3G networks offer greater security than their 2G predecessors. By allowing the UE (User Equipment) to authenticate the network it is attaching to, the user can be sure the network is the intended one and not an impersonator.[41] 3G networks use the KASUMI block cipher instead of the older A5/1 stream cipher. However, a number of serious weaknesses in the KASUMI cipher have been identified. In addition to the 3G network infrastructure security, end-to-end security is offered when application frameworks such as IMS are accessed, although this is not strictly a 3G property. The bandwidth and location information available to 3G devices gives rise to applications not previously available to mobile phone users. Some of the applications are: Mobile TV, video on demand, video conferencing, telemedicine, location-based services, and global positioning system (GPS), although many were previously impractical or unavailable on 2G networks. Among the most significant advancements was the ability to perform data-intensive tasks, such as browsing the internet seamlessly while on the move, as well as engaging in other activities that benefited from faster data speeds and enhanced reliability. Beyond personal communication, 3G networks supported applications in various fields, including medical devices, fire alarms, and ankle monitors. This versatility marked a significant milestone in cellular communications, as 3G became the first network to enable such a broad range of use cases.[42] By expanding its functionality beyond traditional mobile phone usage, 3G set the stage for the integration of cellular networks into a wide array of technologies, paving the way for further advancements with subsequent generations of mobile networks. Both 3GPP and 3GPP2 are working on the extensions to 3G standards that are based on an all-IP network infrastructure and using advanced wireless technologies such as MIMO. These specifications already display features characteristic for IMT-Advanced (4G), the successor of 3G. However, falling short of the bandwidth requirements for 4G (which is 1 Gbit/s for stationary and 100 Mbit/s for mobile operation), these standards are classified as 3.9G or Pre-4G. 3GPP plans to meet the 4G goals with LTE Advanced, whereas Qualcomm has halted UMB development in favour of the LTE family.[43] On 14 December 2009, TeliaSonera announced in an official press release that "We are very proud to be the first operator in the world to offer our customers 4G services."[44] With the launch of their LTE network, initially they are offering pre-4G (or beyond 3G) services in Stockholm, Sweden and Oslo, Norway. Country Status Network Shutdown date Standard References Notes Argentina Personal TBD UMTS [45] Local shutdowns commenced in Q1 2023. Australia No Service Optus 2024-10-28 UMTS [46][47] Telstra 2024-10-28 UMTS [48][49] 2100 MHz band shutdown on 25 Mar 2019. TPG / Vodafone 2023-12-15 UMTS [50][51] Austria Magenta Telekom 2024 (est.) UMTS [52] Belgium Orange 2025-12-31 (est.) UMTS [53][54] Local shutdowns commenced in Jan 2024. Telenet 2024-09-30 (est.) UMTS [55] Local shutdowns commenced in Sep 2024. Proximus 2024-12-31 (est.) UMTS [56] Canada Bell 2025-12-31 (est.) UMTS [57] Rogers 2025-07-31 UMTS [57][58][59][60][61][62] 1900 MHz shutdown in Jun 2021.850 MHz remains active until 31 July 2025. Telus 2025-12-31 (est.) UMTS [57] Videotron 2025-07-31 UMTS [63] China Mobile 2020 TD-SCDMA [64][65][66][67] Local shutdowns commenced on 16 Mar 2016. China Telecom TBD CDMA2000 [68][69][70] CDMA2000 1X, 1xEV-DO Rev. ALocal shutdowns commenced on 16 Jun 2020. China Unicom TBD UMTS [71] Local shutdowns commenced in Q4 2022. Croatia HT 2025 (est.) UMTS [72] Local shutdowns commenced in Dec 2023. Czech Republic No Service O2 2021-11-30 UMTS [73] T-Mobile 2021-11-30 UMTS [73] Vodafone 2021-03-31 UMTS [74] Denmark 3 2025-12-01 (est.) UMTS [75] Local shutdowns commenced in 2022. TT-Netværket(Telenor, Telia) 2023-03-20 UMTS [77][78] The service on the 2100 MHz band ended in 2021.Shutdown on the 900 MHz band commenced in summer 2022. Estonia Elisa 2024-11-26 UMTS [79] Tele2 2025-12-31 (est.) UMTS [80] Telia Eesti 2023-12-13 UMTS [81][82][83][84] Finland No Service DNA 2024-01-25 UMTS [85][86][87][88] Local shutdowns commenced in May 2023. Elisa 2023-11-30 UMTS [89] Local shutdowns commenced in Apr 2023. Finnish Shared Network [fi] 2024-12 UMTS [90] Joint company by Telia and DNA to manage networks in Northern and Eastern Finland. Telia 2024-10-28 UMTS [91][92][93] Local shutdowns commenced on 9 Sep 2023. France Bouygues 2029 (est.) UMTS [94] Orange 2028-12-31 (est.) UMTS [53] SFR 2028 (est.) UMTS [95] Germany No Service Deutsche Telekom 2021-07-01 UMTS [96] O2 2021-12-31 UMTS [97][98][99] Vodafone 2021-06-30 UMTS [100] Greece No Service Cosmote 2021-12-31 UMTS [101] Nova 2023-03-27 UMTS [102][103][104][105] Vodafone 2023-05-31 UMTS [106] Greenland Tusass TBD UMTS [107] Hong Kong 3 active UMTS CMHK 2025-06-30 (est.) UMTS [108] CSL 2017-10-31 CDMA2000 [109] CDMA2000 1X, 1xEV-DO Rev. A.Service previously provided by PCCW. After acquisition of CSL by HKT,its mobile business PCCW Mobile was merged into CSL.No services for local customers, only serving incoming roaming tourists.CSL terminated its CDMA family business upon its licence expire,and cdmaOne service has also terminated along with CDMA2000. CSL active UMTS Smartone active UMTS Hungary No Service Magyar Telekom 2022-06-30 UMTS [110][111] Yettel Hungary 2023-11-13 UMTS [110][112] Vodafone Hungary 2023-03-31 UMTS [114][112] Iceland Nova 2025-12-31 (est.) UMTS [115][116] Síminn 2025-12-31 (est.) UMTS [116] India Airtel 2020-03-31 UMTS [117][118] Vodafone Idea 2022-10-06 UMTS [119] Complete network reforming to 4G/LTE. Indonesia Smartfren 2017-11-13 CDMA2000 [120] CDMA2000 1X, 1xEV-DO Rev. A, EV-DO Rev. B Telkomsel 2023-06-23 UMTS [121][122] Indosat 2022-12-31 UMTS [123][124] Local shutdown commenced in 2021. Ireland Vodafone TBD UMTS [125] Local shutdowns commenced in Sep 2023. Israel 2025-12-31 (est.) [126] Per government statement. Italy Iliad 2025 (est.) UMTS [127] TIM 2022-10-21 UMTS [128][129][130][131] Vodafone 2021-02-28 UMTS [132] Wind Tre 2025 (est.) UMTS [127] Japan KDDI 2022-03-31 CDMA2000 [133][134][135] CDMA2000 1X, 1xEV-DO Rel. 0, 1xEV-DO Rev. A NTT docomo 2026-03-31 (est.) UMTS [136] Softbank 2024-04-15 UMTS [137][138][139] Kazakhstan Tele2 TBD UMTS [140][141] Local shutdowns commenced on 28 Mar 2024. Lithuania Telia 2022-12-15 UMTS [142][143][144] Tele2 2025-12 (est.) UMTS [145] Luxembourg Orange 2025-12-31 (est.) UMTS [53] Tango / Telindus 2024-01-31 UMTS [146] Macau China Telecom 2025-06-04 (est.) CDMA2000 [147][148][149] CDMA2000 1X, 1xEV-DO Rev. A CTM 2025-06-04 (est.) UMTS [149] 3 2025-06-04 (est.) UMTS [149] Smartone 2024-11-11 UMTS [150] Smartone ceased operations in Macau and returned its license. Malaysia No Service Celcom 2021-12-31 UMTS [151][152] Maxis 2021-12-31 UMTS [153] U Mobile 2021-12-31 UMTS [153] Digi 2021-12-31 UMTS [153] Moldova Interdnestrcom 2023-08-01 CDMA2000 [154] Montenegro Crnogorski Telekom 2024-01-22 UMTS [155][156] Netherlands KPN 2022-05-10 UMTS [157][158][159] Local shutdown commenced on 31 Mar 2022. Odido 2024-06-30 UMTS [160] Vodafone 2020-02-04 UMTS [161] New Zealand 2degrees 2025-03-31 (est.) UMTS [162][163][164] Local shutdown will commence by 31 Mar 2025. Spark 2025-12-31 (est.) UMTS [165][166] Local shutdown will commence "towards the end of 2025". Vodafone 2025-08-31 (est.) UMTS [167] Norway No Service Telia 2021-11-11 UMTS [167] Telenor 2021-01-13 UMTS [168] Oman Ooredoo 2024 Q3 (est.) UMTS [169][170] Pakistan No Service Jazz 2024-11-18 UMTS [171][172] Philippines Smart (PLDT) TBD UMTS [173][174] Globe TBD UMTS [173][174] Globe TBD UMTS [174] Shutdown commenced in 2024. Poland T-Mobile 2023-04 (est.) UMTS [175][176][177] Shutdown commenced in Apr 2023. Orange 2025-12-31 (est.) UMTS [53][178][179] Local shutdown commenced on 26 Sep 2023. Portugal MEO 2024-01-31 UMTS [180] Local shutdown commenced on 4 Sep 2023. Vodafone 2024-07 (est.) UMTS [181] NOS 2024-05 (est.) UMTS [182] Shutdown commenced in 2024. Romania Digi 2023-08-29 UMTS [183] Orange 2025-12-31 (est.) UMTS [53] Telekom 2023-03-31 UMTS [184] Vodafone 2025-07-01 (est.) UMTS [185] Russia Beeline 2025 (est.) UMTS [186] Shutdown commenced in Moscow in Feb 2023. MTS 2025 (est.) UMTS [187] Shutdowns commenced in Saint-Petersburg in Oct 2024. Saudi Arabia stc 2022-12-31 UMTS [188] Singapore No Service M1 2024-08-01 UMTS [189][190] StarHub 2024-11-01 UMTS [189][190] Slovakia O2 TBD UMTS [191][192] Local shutdowns commenced in Jan 2024. Orange 2024-02-22 UMTS [53][193][194][195] Local shutdown commenced on 3 Oct 2023. Slovak Telekom 2024-01-31 UMTS [196] Slovenia Telekom Slovenije 2022-09-30 UMTS [197] South Africa Vodacom TBD UMTS [198] Per government statement. South Korea KT 2012-03-19 CDMA2000 [199][200][201] CDMA2000 was also referred to as "2G" in South Korea, besides cdmaOne (IS-95).[203]CDMA2000 1X, 1xEV-DO Rel. 0KT also operates an UMTS "3G" network. LG U+ 2021-06-30 CDMA2000 [204][205][206] CDMA2000 1X, 1xEV-DO Rev. A, EV-DO Rev. B SK Telecom 2020-07-27 CDMA2000 [207][202][208] CDMA2000 was also referred to as "2G" in South Korea, besides cdmaOne (IS-95).[203]CDMA2000 1X, 1xEV-DO Rel. 0SKT also operates an UMTS "3G" network. Spain Movistar 2025 (est.) UMTS Orange 2025-12-31 (est.) UMTS [53] Vodafone España 2024-10-29 (est.) UMTS [209][210] Sri Lanka Airtel 2022-06-12 UMTS [211] Dialog Axiata TBD UMTS [212] Sweden Telenor 2025-12-31 (est.) UMTS [213] Telia 2025 (est.) UMTS [214] Three 2025-12-01 (est.) UMTS [215][216] Local shutdown of 2100 MHz band commenced in Jul 2021. Switzerland Sunrise 2025-06 (est.) UMTS [217][218] Swisscom 2025-12-01 (est.) UMTS [219][220] Taiwan No Service Asia Pacific Telecom 2017-12-31 CDMA2000 [219][220] CDMA2000 1X, 1xEV-DO Rev. A Chunghwa Telecom 2018-12-31 (Voice) 2024-06-30 (Data) UMTS [221][222][223] Far EasTone 2018-12-31 (Voice) 2024-06-30 (Data) UMTS [221][222][223] Taiwan Star 2018-12-31 (Data)2024-06-30 (Voice) UMTS [221][222][223] Taiwan Mobile 2018-12-31 (Data)2024-06-30 (Voice) UMTS [221][222][223] United Kingdom EE 2024-02-25 UMTS [224][225][226][227] Three 2024-12-31 UMTS [228] Virgin Media O2 2025-12-31 (est.) UMTS [229][230] Local shutdowns commenced in Feb 2025. Vodafone 2024-02-28 UMTS [231][232][233][234] Local shutdown commenced in Jun 2023. United States Puerto Rico US Virgin Islands No Service Appalachian Wireless 2023-01-03 CDMA2000 [235][236][237] CDMA2000 1X, 1xEV-DO Rev. A AT&T 2022-02-22 UMTS [238][239] Cellcom 2023-03-31 UMTS [240] Cellular One of North East Arizona 2023-05-04 UMTS [241] Commnet Wireless (Choice) 2022-12-31 CDMA2000 [242] Liberty 2022-02-22 UMTS [243] Silver Star 2022-12-30 CDMA2000 [244][245] CDMA2000 1X & 1xEV-DO Rev. A Strata Networks 2022-12-31 CDMA2000 [246] T-Mobile 2022-07-01 UMTS [247][248][249][250] T-Mobile (Sprint) 2022-05-31 CDMA2000 [251][247][248][249][252][253] CDMA2000 1X, 1xEV-DO Rev. A T-Mobile 2022-03-31 CDMA2000 [254][255][256] CDMA2000 1X1xEV-DO Rev. A UScellular 2024-01-14 CDMA2000 [257][258][259] CDMA2000 1X, 1xEV-DO Rel. 0, 1xEV-DO Rev. AVerizon 2022-12-31 CDMA2000 [260][261][262] CDMA2000 1X, 1xEV-DO Rel. 0, 1xEV-DO Rev. A Vietnam 2028-09 (est.) [263] Per government statement List of mobile phone generations Mobile radio telephone (also known as "0G") Mobile broadband Mobile radiation and health IC 2G 4G 5G GTE [verification needed] ^ "Mobility and Session Management: UMTS vs. cdma2000" (PDF). IEEE Wireless Communications. August 2004.

^ Nunno, Richard (September 2003). "Migration to 3G Technology: A Comparison of Selected Countries" (PDF). FCC. ^ a b "All about the Technology=2011-04-04". itu.int. Retrieved 17 August 2019. ^ "3G CELLULAR STANDARDS WITH PATENTS". projectsatbangalore.com. 24 June 2014. Retrieved 17 August 2019. ^ a b "3G vs. 4G: What's the Difference?". PC Magazine. 10 February 2015. Retrieved 17 August 2019. ^ "HSPA - About Us". GSMA. 9 July 2017. Archived from the original on 9 July 2017. Retrieved 29 November 2022. ^ "Download Speeds: Comparing 2G, 3G, 4G & 5G Mobile Networks". Ken's Tech Tips. 23 November 2019. Retrieved 17 August 2019. ^ "HSPA". 3gpp.org. Retrieved 17 August 2019. ^ "HTC - Touch Phone, PDA Phone, Smartphone, Mobile Computer". Archived from the original on 22 November 2008. Retrieved 17 August 2019. ^ "ITU Radiocommunication Assembly approves new developments for its 3G standards" (Press release). ITU. Archived from the original on 19 May 2009. Retrieved 1 June 2009. ^ "EDGE, 3G, H+, Etc: What Are All These Networks On My Phone?". MakeUseOf. 15 February 2019. Retrieved 17 August 2019. ^ A Brand New Mobile Millennium Ericsson/CATT/DoCoMo jointly demonstrate pioneering W-CDMA technology at PT/Wireless" (Press release). NTT DOCOMO Global. 9 November 1999. Archived from the original on 6 February 2012. Retrieved 30 October 2012. ^ "Economists' Pick". HKTDC Research. Archived from the original on 22 April 2020. Retrieved 12 January 2020. ^ "3G grinds to a start". broadbandmag.co.uk. Archived from the original on 23 April 2009. Retrieved 7 April 2009. ^ "DoCoMo Delays 3G Launch". Wired. 24 April 2001. ^ Charny, Ben (1 October 2001). "World's first 3G phone network goes live". ZDNet. Retrieved 16 August 2019. ^ McCarthy, Kieren (1 October 2001). "World's first 3G phone network live today". theregister.co.uk. Retrieved 16 August 2019. ^ "THE EVOLUTION TO 3G MOBILE – STATUS REPORT". itu.int. 29 July 2003. Retrieved 16 August 2019. ^ "First 3G mobiles launched in Japan". 1 October 2001. Retrieved 16 August 2019. ^ "3G in UK". 3G.co.uk. Retrieved 16 August 2019. ^ "About Hutchison". Hutchison Telecommunications (Australia) Limited. 11 June 2008. Retrieved 7 April 2012. ^ "Emtel | Africa Outlook Magazine". Africa Outlook Magazine. Archived from the original on 3 February 2018. Retrieved 3 February 2018. ^ "Radiocommunications Agency : The Auction of Radio Spectrum for the Third Generation of Mobile Telephones – National Audit Office (NAO) Report". National Audit Office. 19 October 2001. Retrieved 17 August 2019. ^ "Plus 8 Star presentation, The 3G is a Dog or a Demon - Hints from 7 years of 3G Hype in Asia". PlusStar.com. 11 June 2008. Archived from the original on 18 February 2012. Retrieved 16 September 2010. ^ a b c "Global mobile statistics 2013 Part A: Mobile subscribers; handset market share; mobile operators". mobiThinking. May 2013. Archived from the original on 6 September 2014. Retrieved 15 October 2013. ^ "The 100 million club: the top 10 mobile markets by number of mobile subscriptions". mobiThinking. Archived from the original on 26 September 2013. Retrieved 15 October 2013. ^ Steven Millward (29 July 2014). "China now has 486.5 million 3G subscribers, but only 14 million on new 4G network". Tech in Asia. Retrieved 4 August 2014. ^ Hall, Kat. "Sod 3G, that can go, but don't rush to turn off 2G, UK still needs it – report". www.theregister.com. Retrieved 3 October 2021. ^ "We're Switching Off Our 3G Network". EE. Retrieved 2 January 2024. ^ "3G CDMA Network Shut off date set for December 31, 2022", www.verizon.com. 30 March 2021. Retrieved 2 January 2024. ^ "T-Mobile Network Evolution". T-Mobile Support. Retrieved 2 January 2024. ^ Kelly, Samantha Murphy (22 February 2022). "AT&T is shutting down its 3G network. Here's how it could impact you | CNN Business". CNN. Retrieved 2 January 2024. ^ arsyline.rz. "2G and 3G networks are shutting down globally?". SECTRON s.r.o. Retrieved 26 February 2022. ^ Kelly, Samantha Murphy (22 February 2022). "AT&T is shutting down its 3G network. Here's how it could impact you". CNN. ^ "3G CELLULAR STANDARDS AND PATENTS". engpaper.com. 13 June 2005. Retrieved 24 June 2012. ^ a b David J. Goodman (13 June 2005). "3G CELLULAR STANDARDS AND PATENTS" (PDF). IEEE Wireless Communications. Polytechnic Institute of New York University. Archived from the original (PDF) on 20 June 2015. Retrieved 24 June 2012. ^ "Study on the Interplay between Standards and Intellectual Property Rights (IPRs)" (PDF). European Commission. 18 July 2009. Archived from the original (PDF) on 24 December 2012. Retrieved 24 June 2012. Pools that cover only a fraction of the actual IPR for a standard are not very useful. It is essential that the large licensees sign up. Examples of pools that have little impact are the 3G Licensing pool (which excludes the four largest IPR owners for 3G) and the 802.11 pool by ViaLicensing. ^ "Possible 'showstoppers' shadow 3G patent pool". eetimes.com. 21 May 1999. Retrieved 24 June 2012. Even so, Qualcomm (San Diego) is still a wild card in the patent-pooling effort. Qualcomm was a member of the UMTS group when it was formed in February 1998, but deactivated its membership last September. ^ "3G Licensing Workshop 19-21 September 2001". Retrieved 17 June 2021. ^ "Cellular Standards for the Third Generation". ITU. 1 December 2005. Archived from the original on 24 May 2008. ^ "Security for the Third Generation (3G) Mobile System" (PDF). Network Systems & Security Technologies. Archived from the original (PDF) on 13 October 2007. ^ Ashworth, Boone. "3G Service Is Going Away Next Year. Here's What That Means". WIRED. Retrieved 26 February 2022. ^ Qualcomm halts UMB project, Reuters, 13 November 2008 ^ "first in the world with 4G services". TeliaSonera. 14 December 2009. Retrieved 6 September 2010. ^ "Personal to commence 3G shutdown in 1Q23". TeleGeography. 2 November 2022. Retrieved 13 November 2022. ^ "We're upgrading our network with changes to 3G". Optus. Retrieved 16 February 2023. ^ a b "Australian 3G Network Shutdown: Everything you need to know". whistleOut. 6 May 2024. Retrieved 14 June 2024. ^ "3G Service Closure". Telstra. Archived from the original on 21 November 2019. Retrieved 21 November 2019. ^ "How Telstra, Optus and Vodafone Will Deal With The 3G Shutdown". Gizmodo Australia. 13 December 2021. Retrieved 12 April 2022. ^ "TPG Telecom confirms it will switch off 3G network in December 2023". TeleGeography. 27 September 2022. Retrieved 6 October 2022. ^ "Vodafone Australia poised to switch off its 3G network tomorrow". TeleGeography. 14 December 2023. Retrieved 14 December 2023. ^ "Magenta will start 3G shutdown in 2024". TeleGeography. 8 April 2022. Retrieved 18 April 2022. ^ a b c d e f g "Orange selects 5G SA vendors; provides timetable for 2G/3G shutdowns". TeleGeography. 1 March 2022. Retrieved 3 March 2022. ^ "Telenet to switch off 3G from September 2024". TeleGeography. 16 September 2022. Retrieved 17 September 2022. ^ "Proximus to switch off 3G network by end-2024". TeleGeography. 30 November 2022. Retrieved 6 December 2022. ^ a b "Orange Belgium to kick off 3G shutdown in January 2024". TeleGeography. 3 October 2023. Retrieved 8 October 2023. ^ "What's the 3G Sunset and How Will It Affect Existing IoT Deployments?". hologram.io. Retrieved 24 October 2020. ^ "Important Notice Regarding Upcoming 2G/3G Changes on the Rogers Network". Bulwark. 15 July 2020. Retrieved 24 October 2020. ^ "1900 MHz Shutdown on our 2G and 3G Wireless Networks". Rogers Communications. 1 March 2021. Retrieved 13 May 2023. ^ "2G and 3G Shutdowns Continue". blog.telegeography.com. 15 February 2023. Retrieved 13 May 2023. ^ "3G Alarm Systems Need To Be Upgraded". alarmtech.ca. Retrieved 15 February 2023. ^ "3G phase-out in Canada". Videotron. Retrieved 3 February 2025. ^ "China's 3G failure". Fierce Network. 30 May 2008. Retrieved 29 August 2024. ^ "China Mobile Not Serious About TD-SCDMA, Betting Big on TD-LTE". TechNode. 9 May 2011. Retrieved 29 August 2024. ^ "China Mobile starts to turn off 3G base stations". GSM Association (GSMA). 16 March 2016. Retrieved 21 September 2024. ^ "China Daily. 13 March 2019. Retrieved 29 August 2024. ^ "CDMA2000 Operators - China Telecom". CDG. Retrieved 7 October 2023. ^ "China Telecom: 3G Network Will Be Shut down Gradually Starting from June". Montnets. 5 June 2020. Retrieved 14 May 2022. ^ "Turning off 2G in China harder than it looks". Light Reading. 29 June 2022. Retrieved 4 December 2022. ^ "China Unicom given green light to refarm 900MHz band for 5G". TeleGeography. 4 November 2022. Retrieved 6 November 2022. ^ "HT to begin 3G shutdown soon". TeleGeography. 7 December 2023. Retrieved 14 December 2023. ^ a b "T-Mobile, O2 switch off Czech 3G networks". TeleGeography. 1 December 2021. Retrieved 6 December 2021. ^ "Začala bombastický s vrtulníkem, skončí v tichosti za dva týdny. 3G síť Vodafonu" [It started bombastically with a helicopter, ending in silence in two weeks. Vodafone's 3G network] (in Czech). mobilmania.zive.cz. 17 March 2021. Retrieved 3 March 2022. ^ "3 Denmark trials 3G switch-off at Roskilde Festival". Telecompaper. 4 July 2019. Retrieved 7 September 2024. ^ "Udfasningen af 3G-nettet - Danmarks bedste mobilnetværk fremtidssikres - farvel til 3G for at sikre hurtigere 4G og 5G forbindelser i fremtiden" (in Danish). TDC. 22 February 2022. Retrieved 7 September 2024. ^ "Telenor Denmark launching 5G SA in 2022, shutting 3G in late summer". TeleGeography. 9 February 2022. Retrieved 11 April 2022. ^ "Telia, Telenor decommission their 3G networks in Denmark". TeleGeography. 20 April 2023. Retrieved 23 April 2023. ^ "Elisa Estonia completes 3G shutdown". Data Centre Dynamics Ltd. 26 November 2024. Retrieved 24 December 2024. ^ "Tele2 Estonia to close 3G network by end-2025". TeleGeography. 24 August 2022. Retrieved 27 August 2022. ^ "Telia Eesti plans 3G shutdown by end-2023". TeleGeography. 28 May 2021. Retrieved 11 April 2022. ^ "Telia Estonia to initiate 3G shutdown at end-February". TeleGeography. 17 January 2023. Retrieved 17 January 2023. ^ "Telia switches off 3G in capital Tallinn". TeleGeography. 22 September 2023. Retrieved 2 October 2023. ^ "Telia completes 3G shutdown in Estonia". TeleGeography. 14 December 2023. Retrieved 14 December 2023. ^ "Schedule published. This is how DNA's 3G network will be shut down in 2023". DNA Oyj. 16 November 2023. Retrieved 3 March 2024. ^ "DNA will densify 4G with 3G spectrum after shutdowns". mobileurope.co.uk. 31 January 2023. Retrieved 3 March 2024. ^ "DNA to Permanently Shut Down its 3G Networks Next Week – Common Devices Will Need to Transition to 2G Network". Alma Media Oyj 2024. 5 January 2024. Retrieved 3 March 2024. ^ "3G network became history - we are investing in faster connections". Elisa Oyj. 30 November 2023. Retrieved 3 March 2024. ^ "Suomen Yhteisverkon 5G-urakka valmistui, uusi 3G-tajuudet otettu 4G:n käyttöön" (in Finnish). STT Info. 24 March 2025. Retrieved 17 May 2025. ^ "Telia Finland to commence 3G shutdown on 11 September". TeleGeography. 8 September 2023. Retrieved 3 March 2024. ^ "3G-verkko on siirtymässä historiaan" (in Finnish). Telia. 3 March 2024. ^ "Telian 3G-verkon viimeiset tukiasemat sammuvat lokakuun lopussa Helsingissä" (in Finnish). Telia. 9 October 2024. Retrieved 17 May 2025. ^ "Bouygues Telecom to decommission 2G in 2026, 3G to follow in 2029". TeleGeography. 3 February 2023. Retrieved 11 February 2023. ^ "SFR selects Nokia for 5G SA network; to decommission 2G/3G by 2028". TeleGeography. 27 January 2023. Retrieved 28 January 2023. ^ "Telekom shuts off its 3G network". TeleGeography. 1 July 2021. Retrieved 14 April 2021. ^ "Telefónica Deutschland accelerates 3G shutdown". TeleGeography. 19 November 2019. Retrieved 14 April 2021. ^ "Telefonica Deutschland to begin 3G switch-off on 1 July". TeleGeography. 8 June 2021. Retrieved 8 June 2021. ^ "Telefonica accelerates 3G switch-off in Germany". TeleGeography. 27 August 2021. Retrieved 27 August 2021. ^ "Vodafone Germany to switch off 3G on 30 June 2021". TeleGeography. 11 May 2020. Retrieved 14 April 2021. ^ "Cosmote to switch off 3G by end of year". TeleGeography. 15 April 2021. Retrieved 5 February 2022. ^ "Wind Hellas to shut down 3G by end-2022". TeleGeography. 6 July 2021. Retrieved 14 April 2021. ^ "Wind Hellas to begin 3G shutdown". TeleGeography. 4 July 2022. Retrieved 9 July 2022. ^ "NOVA to finalise 3G shutdown in March". TeleGeography. 13 January 2023. Retrieved 13 January 2023. ^ "NOVA hangs up on 3G". TeleGeography. 27 March 2023. Retrieved 27 March 2023. ^ "Vodafone Greece to switch off 3G by mid-2023". TeleGeography. 26 January 2023. Retrieved 26 January 2023. ^ "Communications Authority Grants Consent to CMHK to Cease its 3G Services". Office of the Communications Authority, Government of Hong Kong. 28 April 2024. Retrieved 31 March 2023. ^ "不獲批頻譜改作4G LTE 香港電訊入稟司法覆核 - 香港經濟日報" (in Chinese). topick.hket.com. 22 December 2017. Retrieved 18 November 2024. ^ a b "Subsidies offered to customers exchanging 3G phones from Feb-22". CommsUpdate. 13 October 2021. Retrieved 19 June 2022. ^ a b "National 2G/3G handset replacement scheme ends; 120,000 devices subsidised". TeleGeography. 20 April 2023. Retrieved 23 April 2023. ^ "Yettel switching off Hungary's last 3G network on 13 November". TeleGeography. 13 October 2023. Retrieved 15 October 2023. ^ "Hírek/Cikkek - Vodafon 3G-hálózat lekapcsolása" (in Hungarian). T.E.L.L. Software Hungaria Kft. 4 October 2022. Retrieved 23 April 2023. ^ "ECOI postpones 2G shutdown to 2025". TeleGeography. 24 November 2022. Retrieved 4 December 2022. ^ a b "Lokun 2G og 3G farsímaþjónustu" (in Icelandic). Fjarskiptastofa. 6 September 2024. Retrieved 28 January 2025. ^ "Airtel begins phasing out 3G services across 11 circles". livemint.com. 5 February 2020. Retrieved 14 April 2021. ^ "Vi Enhances 4G Network in Maharashtra & Goa to Enable Seamless Conversations and Internets Experience" (PDF). Vodafone Idea Limited. 6 October 2022. Retrieved 28 January 2023. ^ "13 November, Smartfren Tutup Sepenuhnya Jaringan CDMA" (in Indonesian). kumparanTECH. 8 November 2017. Retrieved 2 July 2024. ^ "Telkomsel switches off 3G network Nationwide" (in Indonesian). Inilah. 23 June 2023. Retrieved 14 January 2024. ^ "Siap-Siap Indosat Matikan Sinyal 3G di Akhir 2022". detikcom. 31 May 2022. Retrieved 16 July 2022. ^ "Penataan Ulang Teknologi 3G ke 4G" [Reconfiguring 3G to 4G Technology] (in Indonesian). XL Axiata. Retrieved 25 January 2024. ^ "XL Axiata to expand 4G network across Indonesia with its IDR 8 trillion Capex". Indonesia Business Post. 21 February 2023. Retrieved 25 January 2024. ^ "Vodafone Ireland unveils plans to phase out 3G". TeleGeography. 30 June 2022. Retrieved 30 June 2022. ^ "Ministry orders shutdown of Israeli 2G, 3G networks by 2025". TeleGeography. 2 July 2021. Retrieved 6 June 2022. ^ "WindTre e Iliad verso il cambiamento definitivo [] Il 2025 dice addio alla rete storica" (in Italian). Player.it - Dadafree Srl. 4 September 2023. Retrieved 4 February 2024. ^ "TIM to begin 3G shutdown in April". TeleGeography. 5 February 2021. Retrieved 5 February 2022. ^ "TIM to delay 3G shutdown until July". TeleGeography. 26 March 2021. Retrieved 5 February 2022. ^ "TIM reportedly set to finish 3G switch-off in August". TeleGeography. 13 January 2022. Retrieved 5 February 2022. ^ "TIM completes 3G shutdown". TeleGeography. 21 October 2022. Retrieved 22 October 2022. ^ "Vodafone begins 3G switch-off in Italy". TeleGeography. 25 January 2021. Retrieved 14 April 2021. ^ "CDMA2000 Operators - KDDI". CDG. Retrieved 7 July 2023. ^ "KDDI to Discontinue 3G Services in March 2022". nippon.com. 16 November 2018. Retrieved 14 April 2021. ^ "KDDI (au) shutting 3G network today; advises users to upgrade if they wish to keep its services". TeleGeography. 31 March 2022. Retrieved 31 March 2022. ^ "「FOMA」および「iモード」のサービス終了について" [End of service for "FOMA" and "i-mode"] (in Japanese). NTT DOCOMO Inc. 29 October 2019. Retrieved 14 April 2021. ^ "SoftBank confirms date for 3G switch-off". TeleGeography. 21 November 2022. Retrieved 4 December 2022. ^ "SoftBank delays 3G closure due to earthquake". Mobile World Live. 17 January 2024. Retrieved 3 March 2024. ^ "The End of an Era: SoftBank Corp. Closes Curtain on its 3G Services". SoftBank. 15 April 2024. Retrieved 18 May 2024. ^ "Tele2 to shut 3G in Almaty and partially Almaty Oblast". Tele2 Kazakhstan. 26 February 2024. Retrieved 6 March 2024. ^ "Tele2/Altel отключает 3G в части городов Казахстана" [Tele2/Altel to Disable 3G in Six Cities of Kazakhstan] (in Russian). Digital Business KZ. 17 July 2024. Retrieved 17 July 2024. ^ "Telia to commence Lithuanian 3G shutdown in March". TeleGeography. 17 February 2022. Retrieved 19 February 2022. ^ "Telia shuts down a third of 3G base stations". TeleGeography. 6 June 2022. Retrieved 6 June 2022. ^ "Telia switches off 3G network". TeleGeography. 15 December 2022. Retrieved 18 December 2022. ^ "Tele2 is bidding farewell to the old 3G network by the end of 2025". Tele2 LT. 4 April 2024. Retrieved 19 October 2024. ^ "Tango and Telindus to shut down 3G network in January 2024". TeleGeography. 2 March 2023. Retrieved 5 March 2023. ^ "CDMA2000 Operators - China Telecom". CDG. Retrieved on 13 December 2021. Retrieved 27 August 2024. ^ "China Unicom switches off CDMA arm to China Telecom". ChinaDaily. 29 July 2008. Retrieved 27 August 2024. ^ a b "Macau will switch off 3G in 2025". Data Centre Dynamics. 9 December 2024. Retrieved 29 April 2025. ^ "Important Customer Notice". Smartone. Retrieved 29 April 2025. ^ "Celcom to shutter 3G network in stages; ready for 5G launch by end-2021". TeleGeography. 8 September 2021. Retrieved 12 September 2021. ^ a b "Digi confirms 3G shutdown timeline". TeleGeography. 26 November 2021. Retrieved 26 November 2021. ^ "3G network to be terminated on Dec 31, users advised to switch to 4G". New Straits Times. 25 November 2021. Retrieved 16 February 2022. ^ "Перспективы развития сети LTE и завершение оказания услуг сотовой связи в стандарте CDMA" [Prospects for the development of the LTE network and the termination of the provision of cellular services in the CDMA standard] (in Russian). Interdnestrcom. 4 August 2023. Retrieved 22 September 2023. ^ "Crnogorski Telekom to shut down 3G network by year-end". TeleGeography. 2 October 2023. ^ "Crnogorski Telekom to shutter 3G network on 22 January". TeleGeography. 10 January 2024. Retrieved 12 January 2024. ^ "KPN shutting 3G by January 2022". TeleGeography. 27 July 2018. Retrieved 14 April 2021. ^ "More capacity on KPN's mobile network with 3G-frequencies". KPN. 30 March 2022. Retrieved 31 March 2022. ^ "KPN's 3G network has been phased out". Thingsdata. 11 May 2023. Retrieved 11 May 2023. ^ "VodafoneZiggo closing 3G network on 4 February 2020". TeleGeography. 10 November 2019. Retrieved 14 April 2021. ^ "2degrees to shut down 3G services in 2025". TeleGeography. 10 July 2023. Retrieved 9 August 2023. ^ "Vodafone announces 4G or 5G to fully replace 3G in late 2024". TeleGeography. 21 August 2022. Retrieved 27 August 2022. ^ "One NZ reschedules 3G shutdown, plots 2G termination". GSMA Mobile World Live. 4 April 2024. Retrieved 4 April 2024. ^ "The 3G farewell is coming". One NZ. Retrieved 5 March 2025. ^ "Spark to shutter 3G network in late 2025 to clear space for rural 5G". TeleGeography. 29 March 2023. Retrieved 3 March 2024. ^ "3G network closure | Spark NZ". Spark NZ. Retrieved 3 March 2024. ^ "Telia completes 3G shutdown". TeleGeography. 11 November 2021. Retrieved 11 November 2021. ^ "Vi forbereder nettverket for fremtiden" [We are preparing the network for the future] (in Norwegian). Telenor. 31 January 2021. Retrieved 3 March 2024. ^ "Oman plans 3G shutdown from Q3 2024". TeleGeography. 27 February 2023. Retrieved 7 March 2023. ^ "TRA prepares for 3G shutdown starting Q3 2024". TeleGeography. 17 August 2023. Retrieved 1 September 2023. ^ "Jazz to completely phase out 3G services by Nov". Business Recorder. 9 October 2024. Retrieved 13 October 2024. ^ "Jazz Sunsets 3G in Support of Its '4G for All' Vision, Marking 50 Million 4G Subscribers and Driving Digital Transformation". ProPakistani. 18 November 2024. Retrieved 30 December 2024. ^ "Globe Removes Consumer 3G SIMs Across Distribution Channels". Globe Telecom. 19 October 2020. Retrieved 20 October 2020. ^ "PLDT-Smart to sunset 3G in 2023". TeleGeography. 10 August 2022. Retrieved 19 August 2022. ^ "T-Mobile Poland to close 3G network in April; no plans for tower sale or fixed access rollout". TeleGeography. 9 January 2023. Retrieved 14 January 2023. ^ "T-Mobile Poland to begin 3G switch-off in April". TeleGeography. 2 February 2023. Retrieved 5 February 2023. ^ "T-Mobile PL completes 900MHz 3G migration in Poland". TeleGeography. 14 September 2023. Retrieved 14 September 2023. ^ "Orange to begin 3G switch-off in Poland in September". TeleGeography. 29 August 2023. Retrieved 31 March 2023. ^ "3G shutdown process to get underway this month at Orange Poland". TeleGeography. 11 September 2023. Retrieved 14 September 2023. ^ "Ajuda e Suporte - Em que data deixará de ter acesso à rede 3G" [In what date will you no longer have access to the 3G network] (in European Portuguese). MEO. Retrieved 21 October 2023. ^ "Descontinuação 3G" (in European Portuguese). Vodafone Portugal. 10 October 2023. Retrieved 10 October 2023. ^ "Desligamento da rede 3G em Portugal | Forum NOS". forum.nos.pt (in Portuguese). 4 January 2024. Retrieved 14 February 2024. ^ "DIGI shuts 3G network, refarms 2100MHz spectrum for 4G and 5G". TeleGeography. 29 August 2023. Retrieved 1 September 2023. ^ "Retragere tehnologie 3G" [Withdrawal of 3G technology] (in Romanian). Telekom. Retrieved 27 February 2023. ^ "Modernizare rețea mobilă Vodafone" [Modernization of Vodafone mobile network] (in Romanian). Vodafone. Retrieved 17 April 2025. ^ "Beeline starts replacing 3G UMTS-900 with LTE in Moscow". TeleGeography. 15 February 2023. Retrieved 18 March 2023. ^ "MTS switching off 3G this year in Moscow city, large parts of Moscow region". TeleGeography. 2 February 2024. Retrieved 2 November 2024. ^ "3G network - How much time do I have to switch to a 4G device?". Saudi Telecom Company. 29 November 2022. Retrieved 29 November 2022. ^ a b "Singapore MNOs fully retire 3G services by end-2024". TeleGeography. 27 July 2023. Retrieved 9 August 2023. ^ a b "Farewell 3G: M1 to retire services from August; StarHub, Singtel from November". The Business Times. 24 July 2024. Retrieved 9 November 2024. ^ "O2 Slovakia to start 3G shutdown next month; e& purchase gains local approval". TeleGeography. 5 December 2023. Retrieved 14 December 2023. ^ "4ka warning users of 3G switch-off". TeleGeography. 16 November 2023. Retrieved 19 November 2023. ^ "Orange Slovakia to complete 3G shutdown on 22 February". TeleGeography. 4 January 2024. Retrieved 5 January 2024. ^ "Slovak Telekom to begin 3G shutdown on 3 October". TeleGeography. 27 September 2023. Retrieved 2 October 2023. ^ "Slovak Telekom waves goodbye to 3G". TeleGeography. 23 November

2023. Retrieved 26 November 2023. ^ "Telekom Slovenije 3G shutdown by end-September". TeleGeography. 5 April 2022. Retrieved 18 April 2022. ^ "A1 Slovenia to say goodbye to 3G in June". TeleGeography. 26 April 2023. Retrieved 27 April 2023. ^ "South Africa to ban 2G devices by March 2023". TeleGeography. 16 June 2022. Retrieved 19 June 2022. ^ "SA comms minister proposes 2G/3G switch-offs in 2024/2025". TeleGeography. 6 September 2022. Retrieved 6 September 2022. ^ a b c "cdma users top 30 million". TeleGeography. 19 July 2004. Retrieved 23 January 2021. ^ "Terminating 2G Service in Korea: Policy Issues and Suggestions". International Telecommunications Policy Review. 1 March 2014. Retrieved 23 January 2021. ^ a b "2G Phone Users Create Dilemma for Telecom Carriers ahead of Beginning of 5G Era". BusinessKorea. 27 March 2018. Retrieved 24 April 2022. ^ a b "2G Bows Out, 5G Grows in South Korea - Older Technologies in Decline". TeleGeography Blog. 5 November 2020. Retrieved 15 February 2021. ^ "CDMA2000 Operators - LG U+". CDG. Retrieved 7 July 2023. ^ "LGT plans EV-DO Rev. A tests ahead of commercial launch in 1H07". TeleGeography. 11 October 2006. Retrieved 31 December 2016. ^ "S. Korea to end 2G network services by June". The Korea Herald. 17 January 2021. Retrieved 23 January 2021. ^ "CDMA2000 Operators - SK Telecom". CDG. Retrieved 7 July 2023. ^ "SK Telecoms shutters 2G service". TeleGeography. 28 July 2020. Retrieved 28 July 2020. ^ "Vodafone activa la fase final del apagado del 3G" (in Spanish). BandaAncha. 12 September 2024. Retrieved 10 October 2024. ^ "Vodafone Spain to complete 3G shutdown next month". Data Centre Dynamics Ltd. 16 September 2024. Retrieved 10 October 2024. ^ "Airtel Lanka given go-ahead to shut down 3G network from June". TeleGeography. 29 April 2022. Retrieved 7 May 2022. ^ "Dialog trials 5G mmWave; announces 3G shutdown plan". TeleGeography. 3 January 2023. Retrieved 6 January 2023. ^ "3G-nätet | Telenor" (in Swedish). Telenor. Retrieved 26 November 2023. ^ "Nu släcker vi 3G- och 2G-näten - så påverkas du" (in Swedish). Telia. Retrieved 26 November 2023. ^ "Vi förnyar mobilnätet – vi fasar ut 3G" (in Swedish). Tre. Retrieved 26 November 2023. ^ "Så bör du tänka när 2G och 3G-nätet avvecklas" (in Swedish). Tre. Retrieved 26 November 2023. ^ "Sunrise confirms mid-2025 date for 3G shutdown". TeleGeography. 29 November 2023. Retrieved 4 December 2023. ^ "So long, 3G". Swisscom. ^ "CDMA2000 Operators - Asia Pacific Telecom". CDG. Retrieved 7 July 2023. ^ "FET to decommission 5,000 APT towers post-merger". TeleGeography. 28 March 2023. Retrieved 1 April 2023. ^ a b c d "Taiwan to switch off 3G networks at year end". Telecom Asia. 10 January 2018. Retrieved 14 April 2021. ^ a b c d "Taiwan to shut down 3G networks by year end". ZDNet. 18 December 2018. Retrieved 14 April 2021. ^ a b c d "NCC urges updating old phones ahead of 3G shutdown". The Taipei Times. 28 May 2024. Retrieved 24 August 2024. ^ "EE details plans for upcoming 3G shutdown pilot in Warrington". TeleGeography. 30 May 2023. Retrieved 30 May 2023. ^ "EE's 3G network shutdown to be completed by March 2024". TeleGeography. 19 September 2023. Retrieved 2 October 2023. ^ "EE to commence 3G shutdown in January". TeleGeography. 13 December 2023. Retrieved 14 December 2023. ^ Mark Jackson (26 February 2024). "EE Switches Off Final 3G Mobile Network Site in the UK". ISPreview. Retrieved 26 February 2024. ^ "Three UK confirms it will switch off 3G at the end of 2024". TeleGeography. 12 May 2022. Retrieved 14 May 2022. ^ "VMO2 confirms it will complete 3G switch off by end-2025". TeleGeography. 11 September 2023. Retrieved 11 September 2023. ^ "VM O2 to start 3G switch-off in April". TelcoTitans. 13 January 2025. Retrieved 18 April 2025. Virgin Media O2 (VM O2) has confirmed plans to switch off 3G services from April this year, beginning in the city of Durham. ^ "Vodafone UK to begin retiring its 3G network in 2023". TeleGeography. 26 January 2022. Retrieved 18 April 2022. ^ "Vodafone UK confirms its first 3G network switch-off in two locations". TeleGeography. 13 March 2023. Retrieved 1 April 2023. ^ "Vodafone UK to begin 3G switch-off in June 2023". TeleGeography. 10 May 2023. Retrieved 13 May 2023. ^ "Vodafone UK completes 3G shutdown to enhance 4G/5G services". Telecoms Tech News. 28 February 2024. Retrieved 3 March 2024. ^ "CDMA2000 Operators - Appalachian Wireless". CDG. Retrieved 7 July 2023. ^ "3G Shutdown Information". Appalachian Wireless. 1 December 2022. Retrieved 1 April 2023. ^ "Appalachian Wireless to shut down 3G/CDMA service this month". Mountain Top Media. 4 January 2023. Retrieved 18 March 2023. ^ "AT&T reconfiguring 3G spectrum ahead of February 2022 shutdown". TeleGeography. 21 March 2019. Retrieved 14 April 2021. ^ "AT&T switches off 3G network". TeleGeography. 23 February 2022. Retrieved 23 February 2022. ^ "Regional US mobile operator Cellcom to switch off 2G on 1 December; 3G was deactivated in March". TeleGeography. 20 September 2023. Retrieved 2 October 2023. ^ "Cellular One phases out 3G; transitions to VoLTE". TeleGeography. 4 May 2023. Retrieved 4 May 2023. ^ "Upgrade Your Device Today". Choice Wireless. Retrieved 5 February 2024. ^ "Liberty to switch off Puerto Rican 3G network on 22 February". TeleGeography. 31 January 2022. Retrieved 31 January 2022. ^ "CDMA2000 Operators - Silver Star Communications". CDG. Retrieved 7 July 2023. ^ "Wireless Exit FAQs". Silver Star. 20 April 2022. Retrieved 25 January 2023. ^ "STRATA Announces Plans to Retire 3G Network". 5 August 2021. Retrieved 2 November 2023. ^ a b "T-Mobile's 2G, 3G shutdown dates leaked". TeleGeography. 8 February 2021. Retrieved 14 April 2021. ^ a b "T-Mobile US eyes October 2021 W-CDMA shutdown". TeleGeography. 10 August 2021. Retrieved 11 August 2021. ^ a b "T-Mobile US to shut down 3G network on 1 July 2022". TeleGeography. 17 September 2021. Retrieved 18 September 2021. ^ "Sprint reaches the finishing line: legacy LTE networks switched off by T-Mobile". TeleGeography. 4 July 2022. Retrieved 5 July 2022. ^ "CDMA2000 Operators - Sprint". CDG. Retrieved 7 July 2023. ^ "T-Mobile delays CDMA shutdown by three months". TeleGeography. 25 October 2021. Retrieved 1 November 2021. ^ "T-Mobile US commences CDMA shutdown; expands 5G Home Internet footprint". TeleGeography. 31 March 2022. Retrieved 18 April 2022. ^ "CDMA2000 Operators - U.S. Cellular". CDG. Retrieved 7 July 2023. ^ "UScellular shuts off some 3G services as it upgrades LTE". Fierce Wireless. 4 October 2021. Retrieved 18 March 2023. ^ "UScellular to switch off CDMA network on 14 January 2024". TeleGeography. 1 December 2023. Retrieved 1 December 2023. ^ "CDMA2000 Operators - Verizon Wireless". CDG. Retrieved 7 July 2023. ^ "Verizon to shut down 3G CDMA networks on 31 December 2022". TeleGeography. 31 March 2021. Retrieved 14 April 2021. ^ "Verizon ramps up 5G coverage as 3G shutdown looms". TeleGeography. 6 December 2022. Retrieved 11 December 2022. ^ "Báo VietnamNet" (in Vietnamese). VietNamNet News. 18 July 2024. Retrieved 4 March 2025. Media related to 3G at Wikimedia Commons Preceded by2nd Generation (2G) Mobile Telephony Generations Succeeded by4th Generation (4G) Retrieved from " 7Mobile phone specification system project 3rd Generation Partnership Project 2Abbreviation3GPP2TypeStandards organization The 3rd Generation Partnership Project 2 (3GPP2) was a collaboration between telecommunications associations to make a globally applicable third generation (3G) mobile phone system specification within the scope of the ITU's IMT-2000 project. In practice, 3GPP2 was the standardization group for CDMA2000, the set of 3G standards based on the earlier cdmaOne 2G CDMA technology. The participating associations were ARIB/TTC (Japan), China Communications Standards Association, Telecommunications Industry Association (North America) and Telecommunications Technology Association (South Korea). The agreement was established in December 1998. Ultra Mobile Broadband (UMB) was a 3GPP2 project to develop a fourth-generation successor to CDMA2000. In November 2008, Qualcomm, UMB's lead sponsor, announced it was ending development of the technology, favoring LTE instead.[1] 3GPP2 should not be confused with 3GPP; 3GPP is the standard body behind the Universal Mobile Telecommunications System (UMTS) that is the 3G upgrade to GSM networks, while 3GPP2 was the standard body behind the competing 3G standard CDMA2000 that is the 3G upgrade to cdmaOne networks that was used mostly in the United States (and to some extent also in Japan, China, Canada, South Korea and India). GSM/UMTS were the most widespread 2G/3G wireless standards worldwide. Most countries used only the GSM family. A few countries, including China, the United States, Canada, Ukraine, Trinidad and Tobago, India, South Korea and Japan, used both standards. 3GPP2 had its last activity in 2013,[2] and the group has been dormant ever since. The 3GPP2 website was taken offline in 2023, primarily due to CDMA carriers deploying 3GPP's LTE instead of UMB the decade prior and later shutting down CDMA networks making the 3GPP2 redundant and unneeded. However, as of 2024 the 3GPP2 website has since come back online. ^ Qualcomm halts UMB project, Reuters, 13 November 2008 ^ "3GPP2 Technology Webinar". 3GPP2. 3GPP2 Official Web site About 3GPP2 TIA – U.S. 3GPP2 Standards Developer This article about wireless technology is a stub. You can help Wikipedia by expanding it.vte Retrieved from " 8Mobile telecommunications standards body 3rd Generation Partnership ProjectAbbreviation3GPPFormation1998; 27 years ago (1998)TypeStandards organizationRegion served WorldwideWebsitewww.3gpp.org The 3rd Generation Partnership Project (3GPP) is an umbrella term for a number of standards organizations which develop protocols for mobile telecommunications. Its best known work is the development and maintenance of:[1] GSM and related 2G and 2.5G standards, including GPRS and EDGE UMTS and related 3G standards, including HSPA and HSPA+ LTE and related 4G standards, including LTE Advanced and LTE Advanced Pro 5G NR and related 5G standards, including 5G-Advanced An evolved IP Multimedia Subsystem (IMS) developed in an access independent manner 3GPP is a consortium with seven national or regional telecommunication standards organizations as primary members ("organizational partners") and a variety of other organizations as associate members ("market representation partners"). The 3GPP organizes its work into three different streams: Radio Access Networks, Services and Systems Aspects, and Core Network and Terminals.[2] The project was established in December 1998 with the goal of developing a specification for a 3G mobile phone system based on the 2G GSM system, within the scope of the International Telecommunication Union's International Mobile Telecommunications-2000, hence the name 3GPP.[3] It should not be confused with 3rd Generation Partnership Project 2 (3GPP2), which developed a competing 3G system, CDMA2000.[4] The 3GPP administrative support team (known as the "Mobile Competence Centre") is located at the European Telecommunications Standards Institute headquarters in the Sophia Antipolis technology park in France.[5] The seven 3GPP Organizational Partners are from Asia, Europe and North America. Their aim is to determine the general policy and strategy of 3GPP and perform the following tasks: The approval and maintenance of the 3GPP scope; The maintenance of the Partnership Project Description; Take the decision to create or cease a Technical Specification Groups, and approve their scope and terms of reference; The approval of Organizational Partner funding requirements; The allocation of human and financial resources provided by the Organizational Partners to the Project Co-ordination Group; Act as a body of appeal on procedural matters referred to them. Together with the Market Representation Partners (MRPs) perform the following tasks: The maintenance of the Partnership Project Agreement; The approval of applications for 3GPP partnership; Take the decision against a possible dissolution of 3GPP. The Organizational Partners are:[6] Organizational Partners Organization Country/region Website Association of Radio Industries and Businesses (ARIB) Japan ARIB Alliance for Telecommunications Industry Solutions (ATIS) USA ATIS China Communications Standards Association (CCSA) China CCSA European Telecommunications Standards Institute (ETSI) Europe ETSI Telecommunications Standards Development Society (TSDSI) India TSDSI Telecommunications Technology Association (TTA) South Korea TTA Telecommunication Technology Committee (TTC) Japan TTC The 3GPP Organizational Partners can invite a Market Representation Partner to take part in 3GPP, which: Has the ability to offer market advice to 3GPP and to bring into 3GPP a consensus view of market requirements (e.g., services, features and functionality) falling within the 3GPP scope; Does not have the capability and authority to define, publish and set standards within the 3GPP scope, nationally or regionally; Has committed itself to all or part of the 3GPP scope; Has signed the Partnership Project Agreement. As of January 2025[update], the Market Representation Partners are:[6] Market Representation Partners Organization Website 5G-ACIA 5G Automotive Association 5G Americas Deterministic Networking Alliance (5GDNA) 6G Smart Network and Services Industry Association (6G-IA) 5G Slicing Association (5GSA) 5G Media Action Group (5G-MAG) Automotive Edge Computing Consortium (AECC) Broadband India Forum Cellular Operators Association of India (COAI) China Society of Automotive Engineers (CSAE) CTIA Global Satellite Operators Association (GSOA) Global Certification Forum (GCF) Global mobile Suppliers Association (GSA) GSMA IPV6 Forum Next Generation Mobile Networks (NGMN) Public Safety Communication Europe (PSCE) Forum Small Cell Forum TCCA TD Industry Alliance Wireless Broadband Alliance 3GPP standards are structured as Releases. Discussion of 3GPP thus frequently refers to the functionality in one release or another. Version[7] Released[8] Info Phase 1 1992 GSM Features Phase 2 1995 GSM Features, EFR Codec, Release 96 1997 Q1 GSM Features, 14.4 kbit/s User Data Rate, Release 97 1998 Q1 GSM Features, GPRS Release 98 1999 Q1 GSM Features, AMR codec, EDGE, GPRS for PCS1900 Release 99 2000 Q1 Specified the first UMTS 3G networks, incorporating a CDMA air interface[9] Release 4 2001 Q2 Originally called the Release 2000 – added features including an all-IP Core Network[10] Release 5 2002 Q1 Introduced IMS and HSDPA[11] Release 6 2004 Q4 Integrated operation with Wireless LAN networks and adds HSUPA, MBMS, enhancements to IMS such as Push to Talk over Cellular (PoC), GAN[12] Release 7 2007 Q4 Focuses on decreasing latency, improvements to QoS and real-time applications such as VoIP.[13] This specification also focus on HSPA+ (High Speed Packet Access Evolution), SIM high-speed protocol and contactless front-end interface (Near Field Communication enabling operators to deliver contactless services like Mobile Payments), EDGE Evolution. Release 8 2008 Q4 First LTE release. All-IP Network (SAE). New OFDMA, FDE and MIMO based radio interface, not backwards compatible with previous CDMA interfaces. Dual-Cell HSDPA. UMTS HNB. Release 9 2009 Q4 SAES Enhancements, WiMAX and LTE/UMTS Interoperability. Dual-Cell HSDPA with MIMO, Dual-Cell HSUPA. LTE HeNB. Evolved multimedia broadcast and multicast service (eMBMS). Release 10 2011 Q1 LTE Advanced fulfilling IMT Advanced 4G requirements. Backwards compatible with release 8 (LTE). Multi-Cell HSDPA (4 carriers). Release 11 2012 Q3 Advanced IP Interconnection of Services. Service layer interconnection between national operators/carriers as well as third-party application providers. Heterogeneous networks (HetNet) improvements, Coordinated Multi-Point operation (CoMP). In-device Co-existence (IDC). Release 12 2015 Q1 Enhanced Small Cells (higher order modulation, dual connectivity, cell discovery, self configuration), Carrier aggregation (2 uplink carriers, 3 downlink carriers, FDD/TDD carrier aggregation), MIMO (3D channel modeling, elevation beamforming, massive MIMO), New and Enhanced Services (cost and range of MTC, D2D communication, eMBMS enhancements)[14] Release 13 2016 Q1 LTE-Advanced Pro. LTE in unlicensed, LTE enhancements for Machine-Type Communication. Elevation Beamforming / Full-Dimension MIMO, Indoor positioning.[15] Release 14 2017 Q2 Energy Efficiency, Location Services (LCS), Mission Critical Data over LTE, Mission Critical Video over LTE, Flexible Mobile Service Steering (FMSS), Multimedia Broadcast Supplement for Public Warning System (MBSP), enhancement for TV services over eMBMS, massive Internet of Things, Cell Broadcast Service (CBS)[16] Release 15 2018 Q2 First 5G NR ("New Radio") release. Support for 5G Vehicle-to-x service, IP Multimedia Core Network Subsystem (IMS), Future Railway Mobile Communication System[17] Release 16 2020 Q3 The 5G System – Phase 2: 5G enhancements, NR-based access to unlicensed spectrum (NR-U), Satellite access[18] Release 17 2022 Q1 TSG RAN: Several features that continue to be important for overall efficiency and performance of 5G NR: MIMO, Spectrum Sharing enhancements, UE Power Saving and Coverage Enhancements. RAN1 will also undertake the necessary study and specification work to enhance the physical layer to support frequency bands up to 71 GHz. TSG SA groups focused on further enhancements to the 5G system and enablers for new features and services: Enhanced support of: non-public networks, industrial Internet of Things, low complexity NR devices, edge computing in 5GC, access traffic steering, switch and splitting support, network automation for 5G, network slicing, advanced V2X service, multiple USIM support, proximity-based services in 5GS, 5G multicast broadcast services, Unmanned Aerial Systems (UAS), satellite access in 5G, 5GC location services, Multimedia Priority Service...[19] Release 18 2023 Q4 5G-Advanced. Introducing further machine-learning based techniques at different levels of the wireless network. Edge computing, Evolution of IMS Multimedia Telephony Service, Smart Energy and Infrastructure, Vehicle-Mounted Relays, Low Power High Accuracy Positioning for industrial IoT scenarios, Enhanced Access to and Support of Network slicing, Satellite backhaul in 5G...[20][21][19] Release 19 [22] 2025 Q4 5G-Advanced. Each release incorporates hundreds of individual Technical Specification and Technical Report documents, each of which may have been through many revisions. Current 3GPP standards incorporate the latest revision of the GSM standards. The documents are made available without charge on 3GPP's web site. The Technical Specifications cover not only the radio part ("Air Interface") and Core Network, but also billing information and speech coding down to source code level. Cryptographic aspects (such as authentication, confidentiality) are also specified. The 3GPP specification work is done in Technical Specification Groups (TSGs) and Working Groups (WGs).[23] There are three Technical Specifications Groups, each of which consists of multiple WGs: RAN (Radio Access Network): RAN specifies the UTRAN and the E-UTRAN. It is composed of six working groups. WG Shorthand Scope Specifications RAN WG1 RAN1 Radio Layer 1 (Physical layer) List of specs RAN WG2 RAN2 Radio Layer 2 and Radio Layer 3 Radio Resource Control List of specs RAN WG3 RAN3 UTRAN, E-UTRAN, NG-RAN architecture and related network interfaces List of specs RAN WG4 RAN4 Radio performance and protocol aspects List of specs RAN WG5 RAN5 Mobile terminal conformance testing List of specs SA (Service and System Aspects): SA specifies the service requirements and the overall architecture of the 3GPP system. It is also responsible for the coordination of the project. SA is composed of six working groups. WG Shorthand Scope Specifications SA WG1 SA1 Services List of specs SA WG2 SA2 Architecture List of specs SA WG3 SA3 Security List of specs SA WG4 SA4 Codec List of specs SA WG5 SA5 Management, Orchestration and Charging List of specs SA WG6 SA6 Application Enablement and Critical Communication Applications List of specs CT (Core Network and Terminals): CT specifies the core network and terminal parts of 3GPP. It includes the core network – terminal layer 3 protocols. It is composed of five working groups. WG Shorthand Scope Specifications CT WG1 CT1 User Equipment – Core Network protocols List of specs CT WG2 CT2 closed CT WG3 CT3 Interworking with external networks List of specs CT WG4 CT4 Core Network Protocols List of specs CT WG5 CT5 closed CT WG6 CT6 Smart Card Application Aspects List of specs GERAN (GSM/EDGE Radio Access Network): The closure of GERAN was announced in January 2016.[24] The specification work on legacy GSM/EDGE system was transferred to RAN WG, RAN6. RAN6 was closed in July 2020 (. The 3GPP structure also includes a Project Coordination Group, which is the highest decision-making body. Its missions include the management of overall timeframe and work progress. 3GPP standardization work is contribution-driven. Companies ("individual members") participate through their membership to a 3GPP Organizational Partner. As of December 2020, 3GPP is composed of 719 individual members.[25] Specification work is done at WG and at TSG level:[26] the 3GPP WGs hold several meetings a year. They prepare and discuss change requests against 3GPP specifications. A change request accepted at WG level is called "agreed". the 3GPP TSGs hold plenary meetings quarterly. The TSGs can "approve" the change requests that were agreed at WG level. Some specifications are under the direct responsibility of TSGs and therefore, change requests can also be handled at TSG level. The approved change requests are subsequently incorporated in 3GPP specifications. 3GPP follows a three-stage methodology as defined in ITU-T Recommendation I.130:[27] stage 1 specifications define the service requirements from the user point of view. stage 2 specifications define an architecture to support the service requirements. stage 3 specifications define an implementation of the architecture by specifying protocols in details. Test specifications are sometimes defined as stage 4, as they follow stage 3. Specifications are grouped into releases. A release consists of a set of internally consistent set of features and specifications. Timeframes are defined for each release by specifying freezing dates. Once a release is frozen, only essential corrections are allowed (i.e. addition and modifications of functions are forbidden). Freezing dates are defined for each stage. The 3GPP specifications are transposed into deliverables by the Organizational Partners. List of mobile phone generations Universal Mobile Telecommunications System (UMTS) 3GPP Long Term Evolution Evolution to 3G IP Multimedia Subsystem 3GP 3GPP2 – The 3GPP's counterpart in the CDMA2000 sphere. GSM services LoRaWAN Telecoms & Internet converged Services & Protocols for Advanced Networks (TISPAN) Open Mobile Alliance Service data adaptation protocol Service layer European Telecommunications Standards Institute ^ 3GPP Scope and Objectives, 31 August 2007 ^ "About 3GPP". 3GPP. Retrieved 10 March 2019. ^ "3GPP Background". 7 June 2000. Archived from the original on 6 July 2000. ^ "3rd Generation Partnership Project 2". Archived from the original on 23 January 2004. Retrieved 25 November 2012. ^ "Mobile Competence Centre". 3GPP. Retrieved 10 March 2019. ^ a b "Partners". 3GPP. Retrieved 1 January 2025. ^ Releases ^ "3GPP Specifications – Releases (and phases and stages)". Retrieved 16 September 2010. ^ Overview of 3GPP Release 99, Summary of all Release 99 Features. ETSI Mobile Competence Centre, Version xx/07/04 ^ Overview of 3GPP Release 4, Summary of all Release 4 Features, v.1.1.0 (draft) ETSI Mobile Competence Centre 2004 ^ Summary of all Release 5 Features, ETSI Mobile Competence Centre, Version 9 September 2003 ^ Overview of 3GPP Release 6, Summary of all Release 6 Features, Version TSG #33, ETSI Mobile Competence Centre 2006 ^ Review of the Work Plan at Plenaries #31, 3GPP, SP-060232 3GPP TSG SA#31 Sanya, 13–16 March 2006 ^ "Highlights of 3GPP Release 12". Retrieved 20 November 2014. ^ "Release 13 priorities". Retrieved 20 November 2014. ^ "3GPP Portal > Specifications". portal.3gpp.org. Retrieved 27 October 2016. ^ "3GPP Portal > Specifications". portal.3gpp.org. Retrieved 27 October 2016. ^ "3GPP Portal > Specifications". portal.3gpp.org. Retrieved 14 July 2020. ^ a b "5G evolution toward 5G advanced: An overview of 3GPP releases 17 and 18". Ericsson. Retrieved 25 August 2022. ^ "Release 18". 3gpp.org. Retrieved 25 November 2021. ^ "5G-Advanced's system architecture begins taking shape at 3GPP". Nokia. Retrieved 25 November 2021. ^ "Release 19". 3GPP. Retrieved 8 September 2024. ^ "Specification Groups". Archived from the original on 9 May 2011. Retrieved 11 April 2011. ^ closure of GERAN ^ 3GPP membership ^ 3GPP TR 21.900 Technical Specification Group working methods ^ ITU-T Recommendation I.130 3GPP website 3GPP Standards List of Acronyms & Terminology 3GPP freely published, detailed technical specifications 3GPP releases descriptions ETSI GSM UMTS 3GPP Numbering Cross Reference TS/TR specification numbering Tool for visualizing multiple inter-related 3gpp standards Tool for visualizing, decoding, encoding network protocol messages defined by 3gpp LTE-3GPP.info: online 3GPP messages decoder fully supporting Rel.15 Retrieved from " 9Multimedia file format families 3GPFilename extension .3gp, .3gppInternet media type video/3gpp, audio/3gppUniform Type Identifier (UTI)public.3gppDeveloped by3GPPInitial release4 April 2003; 22 years ago (2003-04-04)[1]Latest release17.0.0[1]7 April 2022; 3 years ago (2022-04-07) Type of formatContainer formatContainer foraudio, video, textExtended fromMPEG-4 Part 12Open format?YesFree format?No 3G2Filename extension .3g2, .3gp2, .3gpp2Internet media type video/3gpp2, audio/3gpp2Uniform Type Identifier (UTI)public.3gpp2Developed by3GPP2Initial releaseJanuary 2004; 21 years ago (2004-01)[2]Latest releaseC.S0050-B v1.0[2]September 2024; 8 months ago (2024-09) Type of formatContainer formatContainer foraudio, video, textExtended fromMPEG-4 Part 12Open format?YesFree format?yes 3GP (3GPP file format) is a digital multimedia container format defined by the Third Generation Partnership Project (3GPP) for 3G UMTS multimedia services, largely based on MPEG-4 Part 12. A 3GP container may consist of H.263 or H.264 video codecs or AMR or AAC-LC audio codecs. 3G2 (3GPP2 file format) is a multimedia container format defined by the 3GPP2 for 3G CDMA2000 multimedia services. It is very similar to the 3GP file format but consumes less space and bandwidth, and has some extensions and limitations in comparison to 3GP. 3GP is defined in the ETSI 3GPP technical specification.[1] 3GP is a required file format for video and associated speech/audio media types and timed text in ETSI 3GPP technical specifications for IP Multimedia Subsystem (IMS), Multimedia Messaging Service (MMS), Multimedia Broadcast/Multicast Service (MBMS) and Transparent end-to-end Packet-switched Streaming Service (PSS).[3][4][5][6] 3G2 is defined in the 3GPP2 technical specification.[2] The factual accuracy of parts of this article (those related to 3GP codec list (see release 12 of 2016 p.65)) may be compromised due to out-of-date information. The reason given is: 3GP has expanded codec lists while 3G2 has stagnated. Please help update this article to reflect recent events or newly available information. (February 2021) Relations between ISO Base Media File Format, MP4 File Format, 3GPP file format and 3GPP2 file format. Based on the 3GPP2 technical specification published on 18 May 2007.[7] The 3GP and 3G2 file formats are both structurally based on the ISO base media file format defined in ISO/IEC 14496-12 – MPEG-4 Part 12,[8][9][10] but older versions of the 3GP file format did not use some of its features.[7] 3GP and 3G2 are container formats similar to MPEG-4 Part 14 (MP4), which is also based on MPEG-4 Part 12. The 3GP and 3G2 file format were designed to decrease storage and bandwidth requirements to accommodate mobile phones. They are good for lower end smartphones for faster streaming & download. 3GP and 3G2 are similar standards, but with some differences: 3GPP file format was designed for GSM-based phones and may have the filename extension .3gp 3GPP2 file format was designed for CDMA-based phones and may have the filename extension .3g2 Some cell phones use the .mp4 extension for 3GP video. The 3GP file format stores video streams as MPEG-4 Part 2, H.263, or MPEG-4 Part 10 (AVC/H.264), and audio streams as AMR-NB, AMR-WB, AMR-WB+, AAC-LC, HE-AAC v1 or Enhanced aacPlus (HE-AAC v2). 3GPP allowed use of AMR and H.263 codecs in the ISO base media file format (MPEG-4 Part 12), because 3GPP specified the usage of the Sample Entry and template fields in the ISO base media file format as well as defining new boxes to which codecs refer. These extensions were registered by the registration authority for code-points in ISO base media file format ("MP4 Family" files).[11][12] For the storage of MPEG-4 media specific information in 3GP files, the 3GP specification refers to MP4 and the AVC file format, which are also based on the ISO base media file format. The MP4 and the AVC file format specifications described usage of MPEG-4 content in the ISO base media file format.[8] A 3GP file is always big-endian, storing and transferring the most significant bytes first. [citation needed] The 3G2 file format can store the same video streams and most of the audio streams used in the 2007 3GP file format. In addition, 3G2 stores audio streams as EVRC, EVRC-B, EVRC-WB, 13K (QCELP), SMV or VMR-WB, which was specified by 3GPP2 for use in ISO base media file format.[12] The 3G2 specification also defined some enhancements to 3GPP Timed Text. 3G2 file format does not store Enhanced aacPlus (HE-AAC v2) and AMR-WB+ audio streams.[7] For the storage of MPEG-4 media (AAC audio, MPEG-4 Part 2 video, MPEG-4 Part 10 – H.264/AVC) in 3G2 files, the 3G2 specification refers to the MP4 file format and the AVC file format specification, which described usage of this content in the ISO base media file format. For the storage of H.263 and AMR content 3G2 specification refers to the 3GP file format specification.[7] Most 3G capable mobile phones support the playback and recording of video in 3GP format (memory, maximum filesize for playback and recording, and resolution limits exist and vary).[citation needed] Some newer/higher-end phones without 3G capabilities may also playback and record in this format (again, with said limitations).[citation needed] Audio imported from CD onto a PlayStation 3 when it is set to encode to the MPEG-4 AAC format copies onto USB devices in the 3GP format. [citation needed] The Nintendo 3DS used 3GP technology to play YouTube videos. Apple iDevices used to support files for playback only as passthrough files, hence no editing ability, but since iOS 9 this has been deprecated meaning files of this format have to be manually converted to H.264.[citation needed] When transferred to a computer, 3GP movies can be viewed on Microsoft Windows, Apple macOS, and the various Linux-based operating systems; on the former two with Windows Media Player[13] and Apple QuickTime[14] respectively (their built-in media players), and on all three with VLC media player.[15] Programs such as Media Player Classic, K-Multimedia Player, Totem, RealPlayer, MPlayer, and GOM Player can also be used. 3GP and 3G2 files can be encoded and decoded with open source software FFmpeg.[16] Media tags can be read and written on Linux, macOS and Windows using the open source AtomicParsley command-line utility.[17] computer programming portal Comparison of (audio/video) container formats SIF (Source Input Format) CIF (Common Intermediate Format) ^ a b c ETSI 3GPP 3GPP TS 26.244; Transparent end-to-end packet switched streaming service (PSS); 3GPP file format (3GP) Retrieved on 2009-06-02. ^ a b c "3GPP2 C.S0050, 3GPP2 File Formats for Multimedia Services, File Format for Multimedia Services for cdma2000". 3GPP2. 2003. Retrieved 2009-06-12. ^ ETSI (2009-04) ETSI TS 126 234 V8.2.0 (2009-04); 3GPP TS 26.234; Transparent end-to-end Packet-switched Streaming Service (PSS); Protocols and codecs Page 58. Retrieved on 2009-06-02. ^ ETSI (2009-01) ETSI TS 126 140 V8.0.0 (2009-01); 3GPP TS 26.140; Multimedia Messaging Service (MMS); Media formats and codes Page 11. Retrieved on 2009-06-02. ^ "ETSI TS 126 346 V8.3.0 (2009-06); 3GPP TS 26.346; Multimedia Broadcast/Multicast Service (MBMS); Protocols and codecs". ETSI. June 2009. p. 85. Retrieved 2009-10-13. ^ ETSI (2009-01) ETSI TS 126 141 V8.0.0 (2009-01); 3GPP TS 26.141; IP Multimedia System (IMS) Messaging and Presence; Media formats and codecs Page 10. Retrieved on 2009-06-02. ^ a b c d "3GPP2 C.S0050-B Version 1.0, 3GPP2 File Formats for Multimedia Services" (PDF). 3GPP2. 18 May 2007. pp. 67, 68. Archived from the original (PDF) on 7 October 2009. Retrieved 2009-06-12. ^ a b "3GPP TS 26.244; Transparent end-to-end packet switched streaming service (PSS); 3GPP file format (3GP)" (PDF). ETSI 3GPP. 2008-12-11. p. 9. Retrieved 2009-05-30. ^ "ISO Base Media File Format white paper – Proposal". April 2006. Archived from the original on 2008-07-14. Retrieved 2009-12-26. ^ "ISO Base Media File Format white paper – Proposal". Chiariglione. October 2009. Retrieved 2009-12-26. ^ "ISO/IEC 14496-12:2008, Information technology -- Coding of audio-visual objects -- Part 12: ISO base media file format" (PDF). International Organization for Standardization. 2008. p. 95. Retrieved 2009-05-30. ^ a b "Registered types – Codecs". Registration authority for code-points in "MP4 Family" files – mp4ra.org. 2008. Archived from the original on 2009-04-19. Retrieved 2009-05-31. ^ "File types supported by Windows Media Player". Microsoft. Retrieved 2020-07-25. ^ "What's New in QuickTime 6.3 + 3GPP". Apple, Inc. Retrieved 2020-07-25. ^ "VLC Media Player features". VLC. Retrieved 2020-07-25. ^ "FFmpeg, General Documentation, Supported File Formats and Codecs". FFmpeg. Retrieved 2009-06-11. ^ "AtomicParseley". Wez Furlong. Retrieved 2024-06-24. 3GPP codecs specifications; 3G and beyond / GSM, 26 series 3GPP file format (3GP); 3GPP TS 26.244; Transparent end-to-end packet switched streaming service (PSS) - specification 3GPP2 specifications 3GPP2 File Formats for Multimedia Services; 3GPP2 C.S0050-B Version 1.0 - specification RFC 3839, MIME Type Registrations for 3rd Generation Partnership Project (3GPP) Multimedia files RFC 4393, MIME Type Registrations for 3GPP2 Multimedia Files RFC 4281, The Codecs Parameter for "Bucket" Media Types 3GP & 3G2 File Formats Retrieved from " 11 The following pages link to 3GP and 3G2 External tools (link count transclusion count sorted list) · See help page for transcluding these entries Showing 50 items. View (previous 50 | next 50) (20 | 50 | 100 | 250 | 500)Au file format (links | edit) Data compression (links | edit) GIF (links | edit) H.263 (links | edit) ITU-T (links | edit) JPEG (links | edit) JPEG Network Graphics (links | edit) MP3 (links | edit) Moving Picture Experts Group (links | edit) MPEG-1 (links | edit) MPEG-2 (links | edit) MPEG-4 (links | edit) Multiple-image Network Graphics (links | edit) Ogg (links | edit) PNG (links | edit) QuickTime (links | edit) Run-length encoding (links | edit) Vorbis (links | edit) WAV (links | edit) Windows Media Audio (links | edit) Audio Video Interleave (links | edit) M-law algorithm (links | edit) ATRAC (links | edit) Image compression (links | edit) RealMedia (links | edit) Video codec (links | edit) RealAudio (links | edit) Discrete cosine transform (links | edit) JPEG 2000 (links | edit) Shorten (codec) (links | edit) Interchange File Format (links | edit) Audio Interchange File Format (links | edit) DivX (links | edit) FLAC (links | edit) Dolby Digital (links | edit) G.723.1 (links | edit) G.711 (links | edit) Resource Interchange File Format (links | edit) TIFF (links | edit) Material Exchange Format (links | edit) MPEG-1 Audio Layer II (links | edit) Theora (links | edit) Dirac (video compression format) (links | edit) Monkey's Audio (links | edit) Motion JPEG (links | edit) MPEG-7 (links | edit) MPEG-21 (links | edit) Xvid (links | edit) FFmpeg (links | edit) Advanced Audio Coding (links | edit) View (previous 50 | next 50) (20 | 50 | 100 | 250 | 500) Retrieved from " WhatLinksHere/3GP_and_3G2"