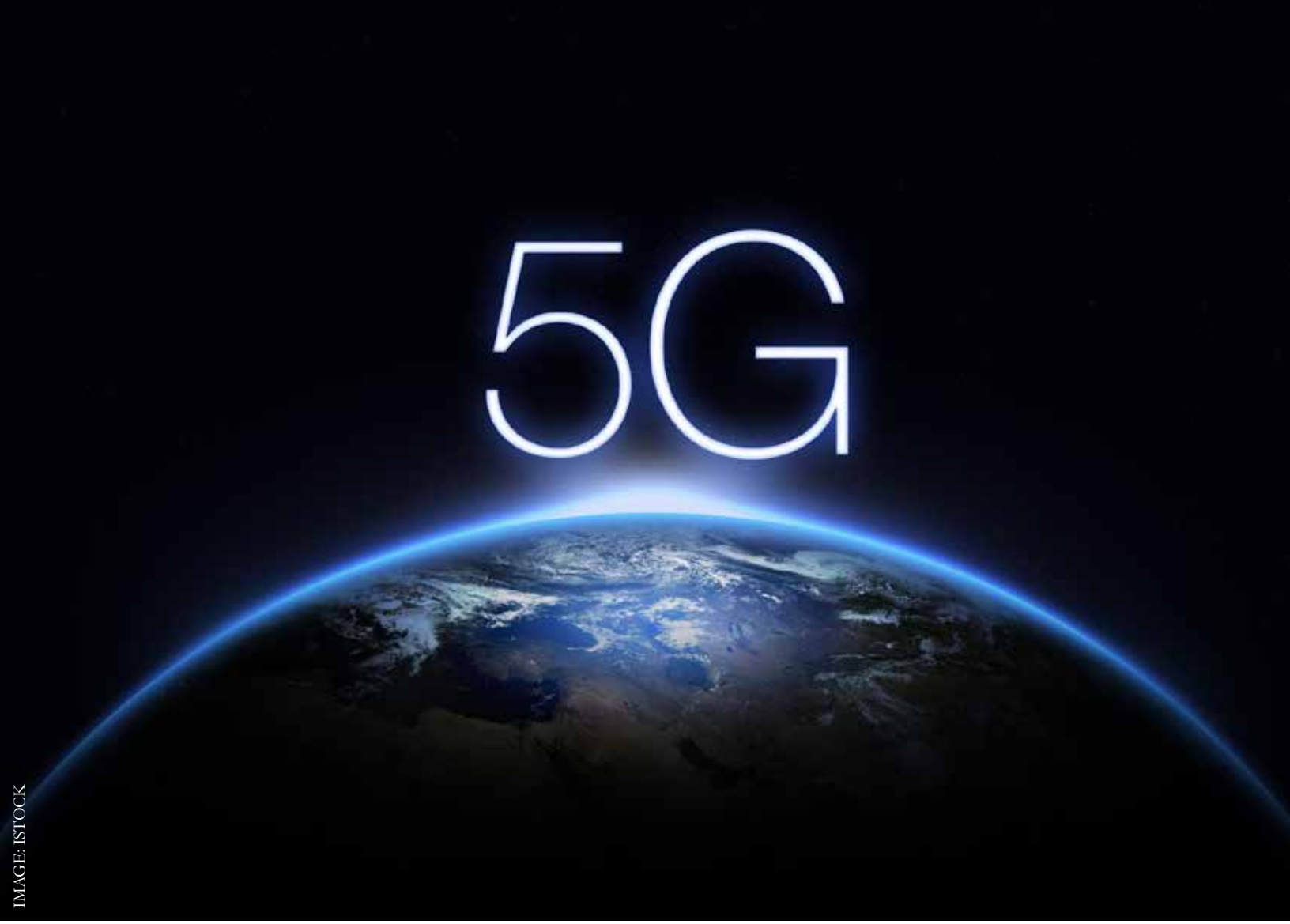

IMAGE: ISTOCK

5G MOBILE NETWORKS: A CHEAT SHEET

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TechRepublic

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5G MOBILE NETWORKS: A CHEAT SHEET

With the advent of widespread Internet of Things (IoT) adoption in enterprise applications including manufacturing, agriculture, healthcare, and more—alongside an increasing dependence on smartphones and always-connected computers—the constraints of 4G LTE technology are prompting mobile network operators to embark on an accelerated rollout of 5G communications to keep pace with the network demands of today and the very near future.

This cheat sheet is an introduction to 5G mobile networks, as well as the smartphones, mobile hotspots, and IoT devices that run on them. The article will be updated periodically as new 5G technologies are standardized and as mobile network operators deploy 5G networks worldwide.

WHAT IS 5G?

5G refers to the fifth generation of mobile phone networks. Since the introduction of the first standardized mobile phone network in 1982, succeeding standards have been adopted and deployed approximately every nine years. GSM, the 2nd generation wireless network, was first deployed in 1992, while a variety of competing 3G standards began deployment in 2001. The 4G LTE wireless technology standard was deployed by service providers in 2010. Now, technology companies and mobile network operators are actively deploying 5G cellular networks around the world for new mobile devices. These 5G deployments accompany transitional LTE technologies such as LTE Advanced and LTE Advanced Pro, which are used by network operators to provide faster speeds on mobile devices.

Principally, 5G refers to "5G NR (New Radio)," which is the standard adopted by 3GPP, an international cooperative responsible for the development of the 3G UMTS and 4G LTE standards. Other 5G technologies do exist. Verizon's 5G TF network operates on 28 and 39 GHz frequencies, and is used only for fixed wireless broadband services, not in smartphones. Verizon's 5G TF deployments were halted in December 2018, and will be transitioned to 5G NR in the future. Additionally, 5G SIG was used by KT for a demonstration deployment during the 2018 Winter Olympics in Pyeongchang.

5G NR allows for networks to operate on a wide variety of frequencies, including the frequencies vacated by decommissioning previous wireless communications networks. The 2G DCS frequency bands, the 3G E-GSM and PCS frequency bands, and the digital dividend of spectrum vacated by the transition to digital TV broadcasts are some of the bands available for use in 5G NR.

5G standards divide frequencies into two groups: FR1 (450 MHz - 6 GHz) and FR2 (24 GHz - 52 GHz). Most early deployments will be in the FR1 space. Research is ongoing into using FR2 frequencies, which are also known as extremely high frequency (EHF) or millimeter wave (mmWave) frequencies. Discussions of the

suitability of millimeter wave frequencies have been published in IEEE journals as far back as 2013.

Millimeter wave frequencies allow for faster data speeds, though they do come with disadvantages. Because of the short distance of communication, millimeter wave networks have a much shorter range; for densely-populated areas, this requires deploying more base stations (conversely, this makes it well suited to densely-populated places such as arenas and stadiums). While this would be advantageous in certain use cases, it would be a poor fit for use in rural areas. Additionally, millimeter wave communication can be susceptible to atmospheric interference. Effects such as rain fade make it problematic for outdoor use, though even nearby foliage can disrupt a signal.

Tests of early 5G mmWave networks by sister site CNET surfaced a number of performance problems, with the Moto Z3, Samsung Galaxy S10 5G, and LG V50 depleting their battery faster than on 4G networks. In the case of the Moto Z3—which uses a pogo-pin connected Moto Mod add-on to deliver 5G—four hours of testing completely drained the battery in the attachment; the use of sub-6 GHz 5G networks is expected to lessen this effect. Likewise, increased efficiency in Qualcomm's upcoming Snapdragon X55 modem will alleviate some performance issues.

It is vital to remember that 5G is not an incremental or backward-compatible update to existing mobile communications standards. It does not overlap with 4G standards like LTE or WiMAX, and it cannot be delivered to existing phones, tablets, or wireless modems by means of tower upgrades or software updates, despite AT&T's attempts to brand LTE Advanced as "5G E." While upgrades to existing LTE infrastructure are worthwhile and welcome advances, these are ultimately transitional 4G technologies and do not provide the full range of benefits of 5G NR.

For an overview of when 5G smartphones are being released, as well as the benefits and drawbacks of 5G smartphones, check out TechRepublic's cheat sheet about 5G smartphones.

Additional resources

- The 5G revolution: 3 things business leaders need to know (TechRepublic)
- How China, Brexit, and the US derailed global 5G wireless (ZDNet)
- 5G standards approved as tech industry signals accelerated deployment (ZDNet)
- Why 5G requires new antenna designs to deliver faster speeds (TechRepublic)
- Can this solution slash the cost of enterprise 5G network build-out? (TechRepublic)
- 5G vs. Gigabit LTE: 79% of organizations don't know the difference (TechRepublic)

WHAT CONSTITUTES 5G TECHNOLOGY?

For mobile network operators, the 3GPP has identified three aspects for which 5G should provide meaningful advantages over existing wireless mobile networks. These three heterogenous service types will coexist on the

same infrastructure using network slicing, allowing network operators to create multiple virtual networks with differing performance profiles for differing service needs.

eMBB (Enhanced Mobile Broadband)

Initial deployments of 5G NR focused on eMBB, which provides greater bandwidth, enabling improved download and upload speeds, as well as moderately lower latency compared to 4G LTE. eMBB will be instrumental in enabling rich media applications such as mobile AR and VR, 4K and 360° video streaming, and edge computing.

URLLC (Ultra Reliable Low-Latency Communications)

URLLC is targeted toward extremely latency sensitive or mission-critical use cases, such as factory automation, robot-enabled remote surgery, and driverless cars. According to a white paper (PDF link) by Mehdi Bennis, Mérouane Debbah, and H. Vincent Poor of the IEEE, URLLC should target 1ms latency and block error rate (BLER) of 10-9 to 10-5, although attaining this "represents one of the major challenges facing 5G networks," as it "introduces a plethora of challenges in terms of system design."

Technologies that enable URLLC are still being standardized; these will be published in 3GPP Release 16, scheduled for mid-2020.

mMTC (Massive Machine Type Communications)

mMTC is a narrowband access type for sensing, metering, and monitoring use cases. Some mMTC standards that leverage LTE networks were developed as part of 3GPP Release 13, including eMTC (Enhanced Machine-Type Communication) and NB-IoT (Narrowband IoT). These standards will be used in conjunction with 5G networks, and extended to support the demands of URLLC use cases on 5G networks and frequencies in the future.

The ways in which 5G technologies will be commercialized are still being debated and planned among mobile network operators and communications hardware vendors. As different groups have differing priorities, interests, and biases, including spectrum license purchases made with the intent of deploying 5G networks, the advantages of 5G will vary between different geographical markets and between consumer and enterprise market segments. While many different attributes are under discussion, 5G technology may consist of the following (the attributes are listed in no particular order).

Proactive content caching

Particularly for millimeter wave 5G networks, which require deploying more base stations compared to LTE and previous communications standards, those base stations in turn require connections to wired backhauls to transmit data across the network. By providing a cache at the base station, access delays can be minimized,

and backhaul load can be reduced. This has the added benefit of reducing end-to-end delay. As 4K video streaming services—and smartphones with 4K screens—become more widespread, this caching capability will be important to improve quality of service.

Multiple-hop networks and device-to-device communication

In LTE networks, cellular repeaters and femtocells bridge gaps in areas where signal strength from traditional base stations is inadequate to serve the needs of customers. These can be in semi-rural areas where population density complicates serving customers from one base station, as well as in urban areas where architectural design obstructs signal strength. Using multiple-hop networks in 5G extends the cooperative relay concept by leveraging device-to-device communication to increase signal strength and availability.

Seamless vertical handover

Although proposals for 5G position it as the "one global standard" for mobile communications, allowing devices to seamlessly switch to a Wi-Fi connection, or fall back to LTE networks without delay, dropped calls, or other interruptions, is a priority for 5G.

Additional resources

- FCC's Ajit Pai wants to put $500M towards rural broadband access (TechRepublic)
- Trump signs executive order to boost broadband internet development in rural US (TechRepublic)
- Google's Project Loon will use balloons to bring cell service to Puerto Rico (TechRepublic)
- Terahertz wireless could help cover the planet with internet that's 10X faster than 5G (TechRepublic)
- How 'private 5G' could enable Google and Amazon to become telcos (ZDNet)
- 5G network deployments stymied by Huawei ban as other firms scramble to fill the void (TechRepublic)

WHO DOES 5G BENEFIT?

Remote workers / off-site job locations

One of the major focuses of 5G is the ability to use wireless networks to supplant traditional wireline connections by increasing data bandwidth available to devices and minimizing latency. For telecommuters, this greatly increases flexibility in work locations, allowing for cost-effective communication with your office, without being tied to a desk in a home office with a wireline connection.

For situations that involve frequently changing off-site job locations, such as location movie shoots or construction sites, lower technical requirements for 5G deployment allow for easily set up a 5G connection to which existing devices can connect to a 5G router via Wi-Fi. For scenes of live breaking news, 5G

technologies can be used to supplant the traditional satellite truck used to transmit audio and video back to the newsroom. Spectrum formerly allocated to high-speed microwave satellite links has been repurposed for 5G NR communication.

Internet of Things (IoT) devices

One priority for the design of 5G networks is to lower barriers to network connectivity for IoT devices. While some IoT devices (e.g., smartwatches) have LTE capabilities, the practical limitations of battery sizes that can be included in wearable devices and the comparatively high power requirements of LTE limit the usefulness of mobile network connectivity in these situations. Proposals for 5G networks focusing on reducing power requirements, and the use of lower-power frequencies such as 600 MHz, will make connecting IoT devices more feasible.

Smart cities, office buildings, arenas, and stadiums

The same properties that make 5G technologies a good fit for IoT devices can also be used to improve the quality of service for situations in which large numbers of connected devices make extensive use of the mobile network in densely populated areas. These benefits can be realized easily in situations with variable traffic—for instance, arenas and stadiums are generally only populated during sporting events, music concerts, and other conventions. Large office towers, such as the 54-story Mori Tower in Tokyo's Roppongi Hills district, are where thousands of employees work during the week. Additionally, densely populated city centers can benefit from the ability of 5G networks to provide service to more devices in physically smaller spaces.

Additional resources

- How will mmWave technology limit deployments of 5G to rural and suburban communities? (TechRepublic)
- 5G will impact these 10 industries the most (TechRepublic)
- Why 5G will revolutionize college campus technology (TechRepublic)
- Rise of the digital nomad: Why working remotely could draw more millennials to the tech industry (TechRepublic)
- The 6 hardest truths we've learned about 5G (CNET)

WHEN AND WHERE ARE 5G ROLLOUTS HAPPENING?

Early technical demonstrations

The first high-profile 5G rollout was at the 2018 Winter Olympic Games in Pyeongchang, South Korea. KT (a major mobile network operator) Samsung, and Intel collaborated to deliver gigabit-speed wireless broadband, and low-latency live streaming video content. During the games, 100 cameras were positioned inside the Olympic Ice Arena, which transmitted the video to edge servers, then to KT's data center to be processed into

"time-sliced views of the athletes in motion," and then transmitted back to 5G-connected tablets for viewing. This demonstration used prototype 5G SIG equipment, which is distinct from the standardized 5G NR hardware and networks being commercialized worldwide.

Similarly, Intel and NTT Docomo have announced a partnership to demonstrate 5G technology at the 2020 Tokyo Olympic Games. The companies will use 5G networks for 360-degree, 8K-video streaming, drones with HD cameras, and smart city applications, including "pervasive facial recognition, useful for everything from stadium access to threat reduction."

Other 5G tests and rollouts have occurred worldwide. Ericsson and Intel deployed a 5G connection to connect Tallink cruise ships to the Port of Tallinn in Estonia. Huawei and Intel demonstrated 5G interoperability tests at Mobile World Congress 2018. In China, ZTE conducted tests in which the company achieved speeds in excess of 19 Gbps on a 3.5 GHz base station. Additionally, in tests of high-frequency communications, ZTE exceeded 13 Gbps using a 26 GHz base station, and a latency of 0.416 ms in a third test for uRLLC.

Where is 5G available in the US?

Verizon Wireless deployed mmWave-powered 5G, marketed as "Ultra Wideband (UWB)," in Chicago, IL and Minneapolis, MN on April 3, 2019; in Denver, CO on June 27, 2019; in Providence, RI on July 1, 2019; in St. Paul, MN on July 18, 2019; and in Atlanta, GA, Detroit, MI, Indianapolis, IN, and Washington, DC on July 31, 2019.

Future deployments of Verizon's 5G services have been announced for Boston, MA, Charlotte, NC, Cincinnati, Cleveland, and Columbus, OH, Dallas, TX, Des Moines, IA, Houston, TX, Little Rock, AR, Memphis, TN, Phoenix, AZ, Providence, RI, San Diego, CA, and Salt Lake City, UT, as well as Kansas City, by the end of 2019.

Verizon Wireless started deployments of its 5G fixed wireless internet service on October 1, 2018 in Los Angeles and Sacramento, CA, Houston, TX, and Indianapolis, IN. Verizon's initial 5G network deployments use its proprietary 5G TF hardware, though the company plans to transition these networks to 5G NR in the future. Verizon's 5G TF network is only used for home internet service, not in smartphones.

AT&T has active 5G deployments in Atlanta, GA, Austin, Dallas, Houston, San Antonio, and Waco, TX, Charlotte, NC, Indianapolis, IN, Jacksonville and Orlando, FL, Las Vegas, NV, Los Angeles, San Diego, San Francisco, and San Jose, CA, Louisville, KY, Nashville, TN, New Orleans, LA, New York City, NY, Oklahoma City, OK, and Raleigh, NC. Deployments have also been announced for Chicago, IL, Cleveland, OH, and Minneapolis, MN.

AT&T has deployed LTE Advanced nationwide; the company is marketing LTE Advanced as a "5G Evolution" network, though LTE-Advanced is not a 5G technology. AT&T has a history of mislabeling

network technologies; the company previously advertised the transitional HSDPA network as 4G, though this is commonly considered to be an "enhanced 3G" or "3.5G" standard.

Sprint started deployments of 5G on May 30, 2019 in the Dallas / Ft. Worth and Houston, TX, Kansas City / Overland Park, KS, and Atlanta, GA metro areas. Sprint's 5G networks run on 2.5 GHz, providing more widespread coverage throughout a region than is possible on line-of-sight mmWave connections, though with a modest decrease in speed compared to mmWave networks. Sprint activated 5G service in Chicago on July 11, 2019. The company has also announced plans to deploy 5G in Los Angeles, CA, New York, NY, Phoenix, AZ, and Washington, DC.

T-Mobile USA has active 5G services in Atlanta, GA and Cleveland, OH, with future plans to bring 5G services to Dallas, TX, Los Angeles, CA, Las Vegas, NV, and New York, NY. T-Mobile's deployment is powered by Ericcson AIR 3246 modems, which support both 4G LTE and 5G NR. This equipment allows for 5G and LTE networks to be operated from the same equipment.

The purchase of Sprint by T-Mobile has been approved by the Justice Department, though a multi-state lawsuit is aiming to prevent the deal from proceeding. If the merger goes forward, "only the New T-Mobile will be able to deliver… real, game-changing 5G," according to T-Mobile CEO John Legere in a June 2019 blog post. Following a merger, the New T-Mobile will have 600 MHz low-band, 2.5 GHz mid-band, and mmWave spectrum holdings, putting it at an advantage relative to AT&T and Verizon.

Additional resources

- Roughly a third of Americans think they have a 5G phone (they don't) (TechRepublic)
- Galaxy Note 10 Plus 5G won't work on AT&T and T-Mobile's fastest 5G networks (CNET)

Where is 5G available in the UK?

EE debuted 5G services in Belfast, Birmingham, Cardiff, Edinburgh, London, and Manchester on May 30, 2019. Availability of 5G by the end of 2019 is planned for Bristol, Coventry, Glasgow, Hull, Leeds, Leicester, Liverpool, Newcastle, Nottingham, and Sheffield. Availability of 5G in 2020 is planned for Aberdeen, Cambridge, Derby, Gloucester, Peterborough, Plymouth, Portsmouth, Southampton, Wolverhampton, and Worcester.

BT, which owns EE, is anticipated to deploy separate BT-branded 5G services in London, Manchester, Edinburgh, Birmingham, Cardiff, and Belfast in autumn 2019.

Vodafone provides 5G services in Birkenhead, Birmingham, Bolton, Bristol, Cardiff, Gatwick, Glasgow, Lancaster, Liverpool, London, Manchester, Newbury, Plymouth, Stoke-on-Trent, and Wolverhampton at present, with deployments planned for Blackpool, Bournemouth, Guildford, Portsmouth, Reading, Southampton, and Warrington by the end of 2019.

Three will begin rollout of 5G services in London in August 2019, with services for Birmingham, Bolton, Bradford, Brighton, Bristol, Cardiff, Coventry, Derby, Edinburgh, Glasgow, Hull, Leeds, Leicester, Liverpool, Manchester, Middlesbrough, Milton Keynes, Nottingham, Reading, Rotherham, Sheffield, Slough, Sunderland, and Wolverhampton expected before the end of the year.

Three and Vodafone do not charge a premium for 5G network services in the UK, compared to their rate plans for 4G.

O_2 announced availability of 5G services for Belfast, Cardiff, Edinburgh, London, Slough, and Leeds "from October 2019," with plans to bring expand 5G services to "parts of 20 towns and cities, before rolling out to a total of 50 by summer 2020."

Additional resources

- BT will use Ubuntu and OpenStack to power 5G transformation (ZDNet)
- The 5G fallout: Brexit triggers a global wireless fault line (ZDNet)
- Ban Huawei from core of 5G networks, government told (ZDNet)
- We ran 5G speed tests on Verizon, AT&T, EE and more: Here's what we found (CNET)

Where is 5G available in Australia?

Optus has 100 5G-capable sites in service, and has pledged to build 1,200 by March 2020.

Telstra commenced rollout of 5G networks, starting with the Gold Coast in August 2018. Telstra services select neighborhoods in Adelaide, Brisbane, Canberra, Gold Coast, Hobart, Launceston, Melbourne, Perth, Sydney, and Toowoomba.

Australia's National Broadband Network (NBN) operator has declared its intent to provide 5G fixed wireless internet access in a statement to ZDNet.

Chinese vendors Huawei and ZTE have been banned by the Australian government from providing 5G networking equipment to mobile network operators due to national security concerns.

Additional resources

- Telstra finds 5G energy levels sitting well under safety limits (ZDNet)
- Optus wants new mobile tower rules to steam roll obstinate councils and owners (ZDNet)
- Australia or Austria, the most expensive broadband plans belongs to one of them (ZDNet)
- Australia facing 'urgency' on 5G spectrum bands: AMTA (ZDNet)

Where else in the world is 5G available?

South Korea was the first country to have a commercially available 5G network, with SK Telecom, KT, and LG Uplus activating 5G networks on April 3, 2019, two hours before Verizon Wireless activated 5G in the US, according to ZDNet's Cho Mu-Hyun. By April 30, 2019, 260,000 subscribers in South Korea were using 5G networks. KT, the country's second-largest mobile carrier, is working on deployments of in-building repeaters for use in crowded buildings such as airports and train stations.

5G is also seen as vital for economic development among Gulf states, with Saudi Arabia including 5G as part of the Vision 2030 economic development plan, and Qatari network operator Ooredoo claiming "the first commercially available 5G network in the world" on May 14, 2018, prior to the availability of smartphones that can use 5G.

Ookla maintains a map of 5G network services worldwide, with networks categorized into Commercial Availability, Limited Availability, and Pre-Release to demonstrate the extent of availability for each observed deployment.

Additional resources

- 5G will reach half of the world's population by 2024 (TechRepublic)
- Will India allow Huawei to sell its 5G networking equipment in the country? (ZDNet)
- Orange España uses ZTE to conduct 5G demos (ZDNet)
- Germany planning 'trustworthy' supplier requirement for all networks and 5G (ZDNet)
- As 5G mobile arrives, which countries were the real 4G winners? (ZDNet)
- It beggars belief no Five Eyes country has a major 5G vendor: Turnbull (ZDNet)
- Japanese mobile operators will spend $14.4 billion on 5G networks by 2024 (TechRepublic)

HOW DOES A 5G FUTURE AFFECT ENTERPRISES AND MOBILE USERS?

As technology advances, older devices will inevitably reach end-of-life; in the mobile space, this is an outsized concern, as wireless spectrum is a finite resource. Much in the same way that the digital switchover occurred for over-the-air TV broadcasts, older mobile networks are actively being dismantled to free spectrum for next-generation networks, including transitional LTE Advanced, LTE Advanced Pro, and "true" 5G networks.

In the US, AT&T disabled its 2G network on January 1, 2017, rendering countless feature phones—as well as the original iPhone—unusable. Verizon plans to disable its legacy 2G and 3G networks by the end of 2019, which will render most feature phones and older smartphones unusable, as well as IoT devices such as water

meters. Verizon stopped activations of 3G-only phones in July 2018. End-of-life plans for the 2G networks of Sprint and T-Mobile have not been publicly disclosed.

Additionally, as 5G is used increasingly to deliver wireless broadband, wireline broadband providers will face competition as the two services approach feature parity. With many people using smartphones both as their primary computing device and for tethering a traditional computer to the internet, the extra cost of a traditional wireline connection may become unnecessary for some people, and enable those outside the reach of traditional wireline connections to have affordable access to high-speed for the first time.

Business customers may also integrate 5G technology in proximity-targeted marketing. 5G's reliance on microcells can be used as a secondary means of verification to protect against GPS spoofing, making proximity-targeted marketing resistant to abuse.

As 5G specifications are designed around the needs of businesses, the low-power and low-latency attributes are expected to spark a revolution in IoT deployments. According to Verizon Wireless President Ronan Dunne, 5G will enable the deployment of 20 billion IoT devices by 2020, leading to the creation of the "industrial internet," affecting supply chain management, as well as agriculture and manufacturing industries. These same attributes also make 5G well suited to use cases that require continuous response and data analysis, such as autonomous vehicles, traffic control, and other edge computing use cases.

Additional resources

- Video: How 5G will enable 'wireless without limitations' by 2019 (TechRepublic)
- Fiber broadband: Is it a waste with 5G and Elon Musk's satellites on the horizon? (ZDNet)
- Intel and Ericsson 5G connected cars trial attains 1Gbps speeds (ZDNet)
- AT&T Labs' Mazin Gilbert on AI, quantum computing, data collaboration and 5G (ZDNet)
- Why wireless ISPs are still necessary in the age of 5G (TechRepublic)

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