COMMUNICATIONS TECHNOLOGY

From Zero to 5G – Our Evolving Datasphere

Thanks to cutting-edge technology, we've become more and more connected, communicating with one another via text, audio, images, and video – all while on the move. What does the next generation hold?

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Our thought and emotions encompass the Earth in an almost-invisible datasphere. At this very moment, these invisible thoughts pass through your body as radio waves, and relay through cables and antennae at the speed of light. Knitted together into a complex network, the evolving datasphere is a novel and continually surprising part of our lives. How did it come to be, and what is it changing into?

As this datasphere improves over time, communication specialists have come to refer to the technical advances as new "generations". We're on the cusp of a new generation being rolled out across the world, and there's a growing realisation that these networks will be critical drivers of cultural and economic growth in the years to come. To understand the promise and enthusiasm for the upcoming Fifth Generation, or 5G, mobile telecommunications networks, we need to look back and understand the very beginnings of the datasphere.

The Zeroth Generation: Early Telecommunications

Before humanity, information travelled in ways we can only barely imagine: Whales sang songs that echoed around the oceans, and plants sent pollen drifting on the wind. Humanity's first long-distance communications were, of course, done by direct messenger, or by visual signals such as flags, smoke, or mirrors. These were limited by the ability of the courier to travel at speed, or the spans available for line of sight.

When writing developed, clay, bark, or paper letters were carried by couriers, creating a much more complex system than direct communications. As the first writers corresponded with each other, they formed an interlinked network of human minds. Three thousand years ago, Chinese authorities established a postal service – a distant ancestor of our modern communications networks.

For five thousand years, paper letters were the only method of true long-distance communication. The postal services depended on sail, horse, and foot until the adoption of powered maritime travel and railways in the 1800s. These dramatically sped up the transmission of information, but then, suddenly, postal services were outraced by new technologies operating at the speed of light.

At the Speed of Light

The first instantaneous telecommunications came as electrical impulses sparked along a wire. The first telegraph to transmit coded writing was developed in 1828 and required trained operators to decode simple pulsed signals. They also had the additional demand of requiring a strong wire to be placed between two points.

Asia's first telegraphs were colonial in nature. The first lines were built by the British in India in 1851, and within five years a network of almost 50 stations stretched over 7,000 kilometres. In the French colonies of Southeast Asia, the first wires were stretched in 1861.

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The Chinese government established telegraphy as a national project in 1881, initially expending great effort to upskill domestically instead of allowing internationally-owned networks. By the start of the 20th century, however, foreign-owned telegraph networks had arrived in China.

Japan embraced telegraphy enthusiastically in 1869. By 1891, the entire land mass of the Asian supercontinent was spanned by a telecommunications network. People on the Pacific Coast could now communicate instantaneously with the Atlantic Coast 10,000 kilometres away.

Spanning Oceans

The first efforts at undersea telegraph cables were conducted between France and England in 1850, and in 1858 a transatlantic cable between England and the USA was established. The Indian telegraph network was linked to the British network under the Arabian and Mediterranean waters in 1870, and then through Singapore towards Australia by 1872.

Telegraph wires crisscrossed the longest dimensions of land and sea over the remainder of the century. North America's coastlines were linked in 1861, South Africa was connected to England in 1879, and by 1890, South America had lines connecting directly to North America. The telegraph datasphere had evolved beyond the postal network to cover the planet.

At around this same time, development of electrical telephony meant that a network of wires could transmit the human voice. Both words and sound could be sent vast distances at unimaginable speeds. Humanity had built the first global telecommunications network, but in a few short years it would be on the road to obsolescence.

Beyond the Wires

Another technology emerged heralding vast changes – the wireless radio. In the mid-1890s, the work of Italian electrical engineer Guglielmo Marconi on wireless telegraphy revolutionised our telecommunication network. By 1901, he had demonstrated instantaneous wireless radio communication across the Atlantic Ocean, sending invisible signals along different frequencies of electromagnetic radiation. By the 1920s, radio communication was part of ocean travel, news broadcasting, and public entertainment. The radio telecommunications network depends on a series of antennae placed strategically across the landscape, often on an accessible high point.

With the launch of Sputnik, the first satellite, from the Kazakh region in 1957, the network began to include antennae orbiting the Earth. In 1959, American scientists successfully demonstrated the use of the Moon as a radio wave reflector, but this technique was soon abandoned for closer artificial satellites. Less than 70 years later, there are now more than two thousand communication satellite orbiting our planet.

In combination with the wired network, voice communications were made more and more available across the globe. But at the start of the new millennium, another great shift occurred. The most important transmissions were no longer the sound of another human's voice, but the encoded chatter of information bits between computers.

From Analog Waves to Digital Bits

The First Generation of wireless phone communications technology was based on the mathematics of analog physics. 1G transmitters modified their frequency or their strength to send a signal. Similar to how tonal language can convey information like the speaker's vocal pitch changes, a radio or mobile telephone signal can change its frequency in a way that can be interpreted by the listener. Special components known as modems allowed computers to encode information into audible noise and send it along the phone network.

These First Generation technologies were directly descended from the first inventors'

TERMS TO KNOW

Bits: The smallest digital signal, either on (1) or off (0). The code used for the early telegraph transmission could be thought of as bits of information.

Bytes: A collection of 8 bits, which in combination can form 256 possible symbols. The approximately 12,000 letters in the text of this article can be encoded as about 12,000 bytes.

Mbps, Gbps: Data transmission speed measurements of bits per second. Megabits are a million bits, and gigabits, a billion bits. Multiply by 8 to get a measurement in bytes per second.

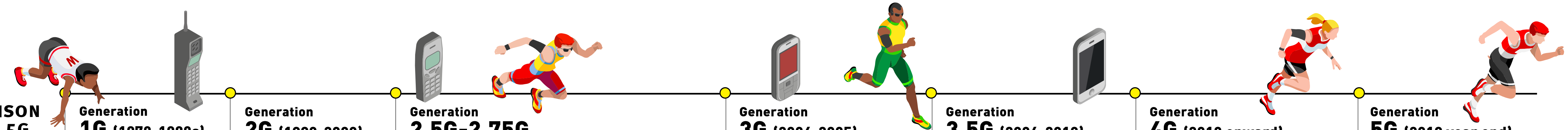
MB/s, GB/s: Data transmission speed measurements of bytes per second. Megabytes are a million bytes, and gigabytes, a billion bytes.

GSM (Global System for Mobile communication): A 2G digital network common in Asia, including text messages within the signal

DGE (Enhanced Data Rates for GSM Evolution): A speed upgrade for 2G

CDMA (Code-Division Multiple Access): 2G and 3G networks more commonly used in North America.

LTE (Long Term Evolution): High-speed 3G networks, sometimes referred to as 3.9G, are close to 4G standards



COMPARISON OF 1G TO 5G
Evolution of wireless technologies 1G to 5G in mobile communication

Generation	Speed	Technology	Key Features
1G (1970-1980s)	14.4 Kps	AMPS, NMT, TACS	Voice-only services
2G (1990-2000)	9.6/14.4 Kps	TDMA, CDMA	Voice and data sevices
2.5G-2.75G (2001-2004)	171.2 Kps 20-40 Kbps	GPRS	Voice, data, mobile Internet, low-speed streaming services and email services
3G (2004-2005)	3.1 Mbps 500-700 Kbps	CDMA2000 (1XRTT, EVDO), UMTS, EDGE	Voice, data and multimedia support for smartphone apps, faster Web browsing, video calling and TV streaming
3.5G (2006-2010)	14.4 Mbps 1-3 Mbps	HSPA	All the services from 3G networks with enhanced speed and mobility
4G (2010 onward)	100-300 Mbps 3-5 Mbps 100 Mbps (Wi-Fi)	WiMax, LTE, WiFi	High speed, high quality voice over IP, HD multimedia streaming, 3D gaming, HD video conferencing and worldwide roaming
5G (2019 year end)	1-10 Gbps	LTE advanced schemes, OMA, NOMA	Super fast mobile Internet, low-latency network for mission-critical applications, Internet of Things, security and surveillance, HD multimedia streaming, autonomous driving and smart healthcare applications

experiments with radio transmissions and phonograph recordings. The information carried by the network wasn't based on complicated encodings, but rather was based on changes in the wavelengths of electromagnetic physics. This technology is still widely used everywhere around us – broadcast radio stations still transmit a song or a news story by modifying the amplitude or the frequency of their signals. By having a correctly tuned radio set, you can hear those changes as faithfully reproduced sounds.

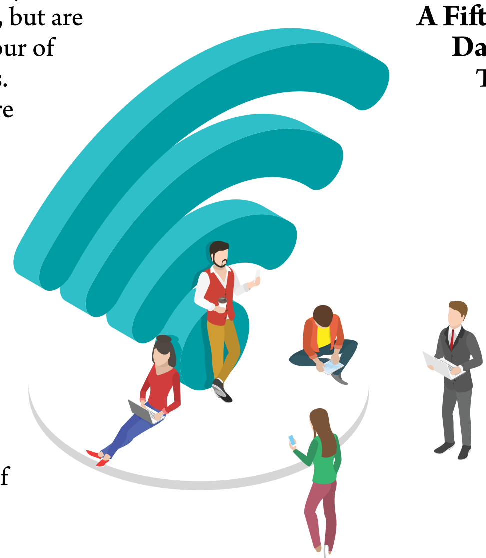
The Second Generation (2G) networks use digital encoding. Information is converted by a computer into a long sequence of bits, on-off signals that are then re-encoded into sound, text, images, or any other data. Conceptually, digital networks are similar to the pulses of telegraph lines.

2G networks allowed for smartphones to connect in a purely digital way. This offers several advantages, since mobile devices now speak the same "language" as fixed computers: information can flow faster, can be encrypted, and uses less energy. They are still in use around the world, but are being phased out in favour of next-generation systems.

The 3G networks were under development in 1998, and they transmit information as "packets" of bits. These can be sent in any order or repeated for accuracy, and the receiving computer reorders them into a legible format. A 3G network can send about two million bits of information within a second. At this speed, a very high quality photograph would take about 20 seconds to load.

In the present day, newer networks are being built with Fourth Generation, or 4G, technologies, bringing a meteoric increase in speeds. That same image now takes only two seconds to transmit. 4G networks are often first built in the major cities and then subsequently in surrounding regions. 4G networks are best-developed in South Korea and Singapore, followed by Australia and Hungary. In recent years, the 4G networks have improved dramatically within India, Vietnam, and Indonesia.

At first, few people could imagine the uses that people would have for this speed, but then amazing new usages sprouted forth: smart homes, three-dimensional virtual reality cameras, live streaming video, autonomous vehicles and remote cloud-based computing. All of these technologies have been unlocked by faster connectivity, and who knows what the next generation will bring?



A Fifth Generation Datasphere

The most important thing to remember about 5G networks is that they don't exist yet. Even so, planning for the next phase of mobile Internet has been recognised as a critical priority by governments worldwide. While the 5G network will include much of the physical antennae and cabling of the previous networks, it will need new components to process and transmit the signals. It will also need more-advanced handsets, since most mobile phones currently can't handle 5G transmissions. Major technology companies are lining up to build these sophisticated new electronics, in a situation reminiscent of the expansion of the railway network.

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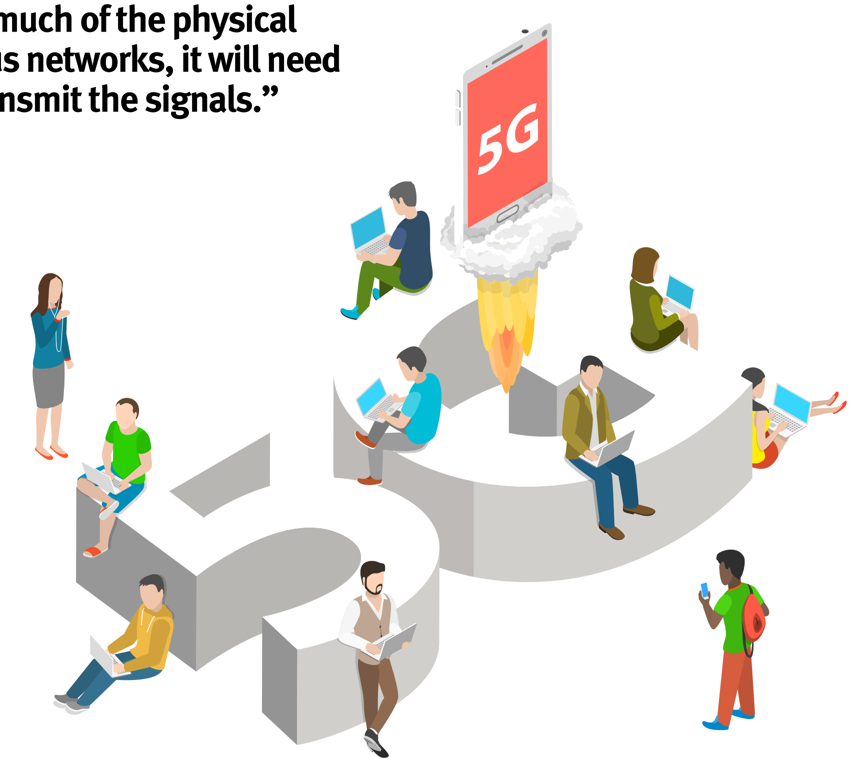
With many billions or even trillions of Internet-connected devices expected to be created in the 21st century, the new networks will play a large part in shaping the world to come.

Within Asia, as of late February 2019, 5G mobile networks are available for limited public testing or commercial uses in the cities of Hong Kong, Seoul, Jakarta, Istanbul, St. Petersburg and in Phillipines, Qatar, Kuwait and the United Arab Emirates.

5G networks are on track to be rolled out to the general public in Eastern Australasia in mid-2019, with China, Japan, South Korea, Malaysia and Australia on the forefront. Singapore, Qatar, Kuwait, and the UAE are special cases – because they cover such a small area of land, they can upgrade their entire network far faster than a large country. By the time this article is published, new 5G projects will be announced by governments and businesses around the world.

What makes it so exciting is, like the arrival of 3G or telegraphy, we can only just barely imagine what 5G networks will transform. Postal systems, telegraphs, telephones and mobile phone antennae have all quickly triggered vast societal and international changes. And once we have adjusted to these challenges and opportunities, will we be ready for 6G? ◆ AG



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