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Is 6G the Last G?

Introduction

Research on the next generation of cellular technology, called *6G*, is ramping up rapidly all over the world. Now is the time to influence what should be in and what should be out under the 6G umbrella. The European Union (EU) has earmarked €900 million (~US$974 million) for research and innovation for 6G spread over seven years (2021–2028), and the EU is expecting the industry to invest the same amount of money. But is it possible to continue on the same tangent into the future for cellular networks? Cellular technology has transformed the lives of people, but have we reached the end of the transformation?

The first cellular generation was analog but was never widespread. In hindsight, this has been called 1G. The breakthrough came for cellular connectivity when it moved to digital communication in 2G. Voice calls were encrypted enabled through physical Subscriber Identity Module cards containing strong security keys, and handheld devices became smaller due to, for example, cost-efficient manufacturing of semiconductors. 2G was a success story. The mobile telephone quickly became something for everyone, not only for yuppies in the 1990s. Operators provided discounted mobile phones for the consumer market by attaching the customer to long contracts. 3G was a major hype, facilitating larger data transfers using modest data rates. Operators paid a ridiculous amount of money to lease spectrum for operating 3G networks all over the world. But the networks were silent because people used phones capable of 150 characters SMS and voice. No one used the capacity offered in 3G networks until Apple launched its first iPhone. The traditional equipment manufacturers, who had been part of the journey up until 3G providing both base stations as well as mobile phones, were laughing at the iPhone's antenna and transceiver design. But in the end, it was Apple who saved several of the manufacturers because suddenly, capacity in the costly 3G networks were used and operators earned money. Steve Jobs (former CEO of Apple) focused on user experience instead of a perfectly matched antenna for the first smartphone. This was a success, and the rest is history.

When the design of 4G took off, the telecommunications (telecom) companies did not want to use the term *4G* given all the negative publicity around 3G during its initial deployment phase. Instead, 4G was for very long, called *LTE*, even though this generation has been as disruptive as 2G. 4G adopted the Internet Protocol (IP) for addressing enabling integration with the rest of the Internet, and 4G provided a huge upgrade in terms of possible transfer rates. Video streaming and seamless access to the Internet were now on a par with using a computer.

Large-scale deployment of 5G is now taking place at the same time as 6G is being defined. Consumers can enjoy faster and more reliable networks with 5G if they are close to a base station. However, there is only a minor difference in end-user experience between 4G and 5G given that the dominating applications are watching video content in real time and interacting in social media using smartphones and tablets.

The Operators' Dilemma

The operators providing access to cellular networks for consumers are stuck in the monthly subscription business model for income. If they try to increase the monthly fee, consumers turn to Wi-Fi and change their operator. The consumer market is volatile, and it is fiercely competitive among operators. This implies that revenue streams are declining over time for operators, making them more reluctant to invest in new technology. 5G is not providing a real edge compared to 4G for end users.

There are newer telecom equipment manufacturers taking a different business model approach toward operators. Instead of operators paying upfront for network equipment, manufacturers absorb all the costs by installing the necessary hardware

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and software, and then they want to have their share once the data traffic in the network increases. This is a challenging business model for traditional equipment manufacturers who have been a part of the journey since 1G, requiring upfront payment to survive.

5G was designed to unlock new revenue streams for operators by calling on industry verticals. The three industries that caught equipment manufacturers' interest early in the definition of 5G were automotive, health care, and the Internet of Things (IoT). The narratives around how 5G would revolutionize these three industries were not emanating from the industries themselves but merely from equipment manufacturers.

The Verticals

It was drummed into operators that verticals would be the new cash cow for their 5G investments, which was a flawed prediction. In general, IoT devices generate a very small amount of data, and when in a home environment, they can be connected to Wi-Fi. Applications such as smart metering systems have used cellular connectivity since 2G, and they are now forced to move to 4G and 5G due to the sunset of 2G. 2G has been providing enough performance for many IoT applications. In short, the IoT will not provide the volume necessary for carrying investments in 5G technology.

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One of the suggested applications for the health-care domain has been remotely performing, for example, a surgery, which seems a bit farfetched if the hospital is connected to the Internet. Remote control of equipment requires short distances to avoid delays incurred by the fact that signals cannot travel faster than the speed of light. 5G is about connecting devices that cannot use wires. The base station itself will, in most cases, just put the data on a fiber link.

The last-thought revenue stream is in the automotive domain through connecting road vehicles to the public 5G network. First and foremost, vehicles require network coverage regardless of whether it is 4G or 5G. Trucks and buses have been connected to cellular networks for more than two decades. In the connected vehicle's infancy, operators took a substantial fee for every megabyte transferred to and from the vehicle, which forced automakers to develop applications using the cellular network's capacity to minimize cost. Many automakers connecting their products will continue to economize with the transferred data to and from vehicles regardless of the better capacity offered in the 5G network. Data-consuming updates of software, which can be performed when the vehicle is parked, will use, for example, Wi-Fi.

Edge computing and network slicing are two central concepts in 5G that have been geared toward the automotive domain. For autonomous vehicles, the trend is to have a central supercomputer performing advanced sensor fusion locally, and similar operations on board. Edge capability in 5G base stations will not be used to the extent anticipated by autonomous vehicles. For public road automation, automated vehicles need to be connected to the network facilitating tracking of them, but this needs network coverage rather than 5G per se.

Network slicing is simply Quality of Service (QoS) in the 5G network. It is based on the traditional QoS model differentiated service (DiffServ), which is the backbone for QoS in IP on the Internet. In the end, data traffic stemming from the end user in the 5G network will end up being routed on the Internet, hence, DiffServ must be supported. Network slicing is a matter for operators to separate data traffic from specific customers to charge them appropriately.

The end-to-end delay and possible bandwidth will always be dictated by the communication channel with the lowest performance. For example, if you have an Internet subscription with fiber optics to your home capable of 1 Gb/s and you are using an Ethernet cable Category 5 in your home, you will never have a better data-transfer rate than 100 Mb/s. 5G can deliver up to 20 Gb/s between the base station and the connected device, but this depends on the distance to the base station and the number of connected devices in the same cell.

Private 5G Networks

In previous "Connected and Automated Vehicles" columns, I have written about private 5G networks, which is facilitated through a new, emerging spectrum regime for locally operating 5G technology in geographically confined areas such as a building, harbor, or quarry. This spectrum regime implies that a local frequency spectrum permit is applied for at the national spectrum agency by, e.g., the landlord for an administrative fee. 5G is designed for licensed bands and for higher output power compared to, for example, Wi-Fi using license-exempt bands. This makes 5G attractive to use for confined areas because fewer communications infrastructure (i.e., base stations) is needed for coverage and to connect devices. The private 5G network does not require an operator, but an operator can of course provide private 5G networks as a service. There are new entrants on the market who provide 5G technology for this type of application because covering a factory, quarry, or building with 5G is not big business for the established large telecom companies. Here, the volume comes from many small customers instead of one customer (e.g., operator) wanting to cover a whole country with 5G infrastructure.

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Wi-Fi and 5G

As mentioned earlier, 5G (and all previous generations of cellular technology) has been designed for licensed bands. This implies that the technology will be operated on a dedicated frequency spectrum where no other communications technologies providing similar services are present. However, sharing with other services in said band must always be considered (e.g., satellite communication). Using licensed bands with a base station as a genie in the network facilitates precise scheduling of data traffic between the base station and connected devices, allowing for advanced time-division multiple access. The licensed band also provides a huge benefit in terms of output power, providing better network coverage.

Wi-Fi, on the other hand, is designed for license-exempt bands (e.g., 2.4 GHz and 5–6 GHz) and spectrum sharing with other communication technologies. This entails lower output power and requirements on, for example, "listen before talk."

Technical comparisons between Wi-Fi and 5G will always be flawed when not considering the same output power. Wi-Fi is operated in the low-power regime 20–23 dBm/20 MHz, and 5G can be operated in the medium power range of 42 dBm/20 MHz for private 5G networks. The difference in the output power limits is due to the different spectrum regimes (licensed versus license-exempt bands), resulting in a major difference in communication range. Wi-Fi will always have more access points to cover the same geographical area compared to the number of base stations given the different output power levels.

Wi-Fi and 5G complement each other with their drawbacks and advantages, respectively. They can live side by side in full harmony. End users regard them as complementary, but industries, instead of cooperating, are fighting with each other. Wi-Fi is user friendly and easy to configure, whereas 5G is complex and difficult to grasp for someone new to the technology. Part of the complexity stems from intellectual property rights. For every new cellular generation, the complexity of scheduling and transmission of packets on the communication channel increases because the simple solutions have already been patented and the patents have expired. To be a bit harsh, the solutions not possible to patent are simply not wanted in cellular technology standards. The content is also spread over several standards documents, making it impossible to get a holistic overview, as opposed to IEEE 802.11 outlining Wi-Fi. This is one standard that contains all the information, with descriptions on how things work.

I was once accused of writing toogood and explanatory standards by a consultant, who said that he wrote as little as possible in a standard to make it barely understandable. This is because he also wanted to sell his services after the standard was published. If no one understands the content of the standard, then support is needed for interpreting it. This is clearly a barrier for small and medium-sized companies to make use of new technologies.

Wrap Up

Vertical industries will not be the new cash cow for 5G equipment manufacturers or operators. There is simply no need for such advanced wireless technology on scale among the verticals. The private 5G network regime is of great interest among verticals for local operation covering a factory, harbor, or mine, but of little or no interest among the operators or major well-established equipment manufacturers to provide this type of connectivity given the poor economy of scale.

The identification of verticals during the design of 5G was mainly due to finding new revenue streams for operators, and the narrative for why the verticals needed 5G was made up by others than the verticals themselves. The uplink is more important for bandwidth consuming applications such as remote control than the downlink. In theory, more uplink than downlink capacity can be provided, but it is not realized in 5G network equipment on the market. Applications and services using edge computing and network slicing will drive much of the cost for road vehicles connected to the public network in an industry already having very small margins on volume cars. Road vehicles connected to the public network need network coverage and support for seamless cross-border functionality, not necessarily 5G per se.

Every second generation of cellular technology has been a success: 2G and 4G. What about 6G? What possible killer app is around the corner for 6G? Will 6G be the last G given all the challenges with the 5G profitability? Cellular generations are disruptive in nature, and, for example, 4G and 5G cannot share a frequency band because they are incompatible; unlike Wi-Fi, which, despite its different generations, can live in harmony on one specific frequency band. Maybe 6G will be the first generation that can be introduced in the same band as other cellular generations. This would be a huge step in the right direction because spectrum is a scarce resource. A carrier frequency below 6 GHz is tractable to have a decent communication range, but this is a really crowded place. Hopefully, the 6G narrative will focus on being part of a sustainable wireless technology ecosystem rather than one technical solution for all manner of applications. ***VT***