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The U.S. Is Back in The 5G Game

The U.S. campaign against Huawei has opened the cellular-equipment market to a host of new players that previously didn't seem to have much of a chance

By **STU WOO**

The U.S. government has upended the \$35 billion-a-year cellular-equipment industry, ushering in a new era of competition and giving U.S. companies a shot at re-entering a sector they vacated years ago.

In the past five years, only China's Huawei Technologies Co., Sweden's Ericsson AB and Finland's Nokia Corp. captured more than a 20% share of revenue in the wireless-equipment market, according to Dell'Oro Group, a research firm. No other

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What Are They Talking About? A Guide to 5G Brand Names

Cellphone carriers have put a confusing array of labels on their services

By **DREW FITZGERALD**

Engineers developed the software and circuitry to make 5G possible. Corporate marketers are the ones explaining to the public how it all works. That's where things get complicated. As with the previous generation of wireless service, cellphone carriers have pinned a confusing array of brand

names on 5G services. Each type reveals a tradeoff: Some 5G signals can be found across broad swaths of the U.S. but have yet to deliver dramatically better internet speeds than their 4G counterparts. Other 5G connections are extremely fast but hard to find outside stadiums and business districts. For anyone confused by 5G's many flavors, here's a quick guide:

AT&T
5G
What it means: AT&T uses this label to

describe most of its next-generation cellular coverage. It applies to service in the carrier's low- and midrange frequencies. Signals carried over low-range frequencies provide the slowest connections in the 5G universe but travel the farthest. High-frequency signals transmit more data at a faster rate but don't travel very far. Midrange frequencies are a balance of speed and distance. Testing by research firm Opensignal shows that AT&T's 5G service is about twice as fast as its 4G service—far short of 5G's ultimate capability.

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Inside

Where's My 5G?
 Spectrum constraints and the lack of a killer app are among the reasons for the slow rollout of fast 5G networks in the U.S. **R2**




STORM WATCH

Engineers are testing whether changes in 5G signals can act as early warnings of severe weather **R3**

A Whole New Game

Faster networks will enhance esports both for competitors and for spectators **R9**

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Why the U.S. Rollout of 5G Is So Slow

Among the reasons: a limited availability of the needed spectrum and no killer app

By JARED COUNCIL

Fast, or some variation of the word, is often used to describe the speeds promised by 5G. The same cannot be said about the rollout of 5G networks in the U.S.

The promise of fifth-generation wireless networks has drawn headlines for at least three years, but 5G that lives up to the hype has yet to arrive for most Americans. All of the major U.S. wireless carriers say they have nationwide 5G ser-

vice, but industry analysts say that service is largely indistinguishable from 4G LTE service. Wireless services with speeds notably better than what's available today may not reach most Americans until later this year at the earliest, research firm Evercore ISI forecasts.

“Overall, you’re looking at some time in the end of ‘21 to end of ‘23 to get two-thirds of the country’s population covered with a 5G service that’s notably better than what is currently out there on 4G,” says Evercore analyst James Ratcliffe.

That time frame means the first carrier isn’t expected to reach two-thirds of the country with significantly higher-speed 5G until 30 months after the first 5G-capable phones made

their debut in mid-2019, Mr. Ratcliffe says, compared with about 18 months for 4G following the launch of the first 4G-capable phones in fall 2010.

A combination of factors play into the relatively slow rollout of 5G, analysts, academics and former industry executives say. Some of the problems involve network infrastructure: The availability of space in the portion of the airwaves that strikes a balance between fast transmission speeds and long signal ranges is limited. 5G also requires deployment of new network equipment, a sometimes cumbersome process. And much of the new equipment isn’t manufactured in the U.S., meaning purchases can take longer than buying domestic.

Verizon Communications Inc., AT&T Inc. and T-Mobile US Inc. all say their 5G networks today cover more than 200 million people, enough to qualify as nationwide service. But this coverage depends partly on low-band spectrum, limiting its speed.

The carriers are now focused on midband spectrum, doling out huge sums in a recent government auction of space in that section of the airwaves. The problem for carriers is that

high-band spectrum. High-band spectrum, also known as millimeter wave, has the highest speeds and greatest bandwidth but the shortest range. Low-band has a longer range but lacks in speed. Midband is considered the sweet spot in terms of range and speed.

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the midband range of the wireless spectrum is already widely occupied by U.S. government agencies and other entities, for uses including military communications, weather services and more. Only a relatively small portion has been made available to telecom companies so far.

Access to midband spectrum had been hampered by turf battles among government agencies. The government is now making up for lost time, selling \$81 billion of midband spectrum licenses earlier this year with another auction planned for this fall.

Stefan Pongratz, an analyst at Dell’Oro Group, says that when telecom operators first started preparing for 5G nearly a decade ago, the prevailing thought was that 5G would primarily use millimeter-wave, or high-band, spectrum, which sits in a part of the spectrum that was largely unoccupied.

But millimeter-wave 5G requires the greatest density of cell towers to be effective, he says. Adding density takes time. It wasn’t until recent years that attention in the U.S. turned to midband spectrum as

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a way to bring 5G to market faster, he says.

Where’s the profit?

The lack of killer 5G applications is another major drag on deployment, says Brian Kelley, an associate professor of electrical engineering at the University of Texas at San Antonio. “That, at the highest level, is the single largest factor guiding the pace of development,” says Dr. Kelley, a former Motorola engineer who is also the principal investigator for an experimental 5G network site at a military base in Texas for the Department of Defense.

The three main benefits of 5G are that it offers faster speeds—up to 100 times faster than 4G—that it can support a huge number of simultaneous connections and that it enables significantly faster response times between machines, says Craig Moffett of media and telecom research firm Moffett-Nathanson LLC.

“There aren’t revenue models associated with any of those three things yet,” Mr. Moffett says. “It’s not clear that consumers, for example, would be willing to pay anything extra just to be able to download videos faster.”

Mr. Moffett says businesses will likely be the biggest early adopters of 5G, which could allow them to seamlessly connect sensors and other internet-of-things devices. Their use will likely take the form of private 5G networks, which he

says “can be thought of as a next-generation Wi-Fi network, with better speeds and security, and ability to handle more connections.”

But the question, he says, is “are the carriers going to build the [private] 5G networks that enterprises use, or are enterprises going to build them themselves?” This matters, he says, because if companies opt to deploy private 5G networks without carriers, the carriers could miss out on revenue that could spur greater 5G infrastructure investments.

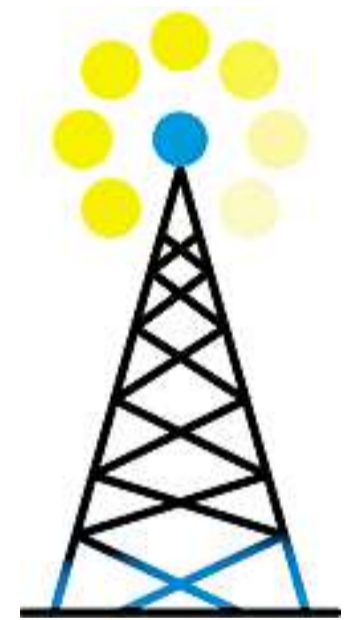
Equipment issues

5G at its best is a fundamentally different network than 4G, partly due to the implications of transmitting over higher-band spectrum. That means it requires different technology and equipment that have to be installed—not a simple process.

Installing new equipment can involve finding a site, getting proper permitting and, in some cases, digging up streets to deploy the fiber-optic cables that carry data to and from cell towers, says Mr. Ratcliffe of Evercore.

Much of the physical work needed to get cellular networks up to 5G standards isn’t expected to ramp up until 2022, according to Edward Gazzola, chief executive of Atlanta-based structural-engineering firm Bennett & Pless Inc. The coronavirus pandemic and technical hurdles added to the delay, he says, including a period when carriers were waiting for engineering standards to be better defined before buying new equipment.

Availability is also an issue in the equipment market. When 4G made its debut around 2010, there were about a dozen technology providers offering wireless network equipment, says Dell’s Mr. Roese, including Nortel in Canada and Motorola in the U.S. Today, the global provider market comprises five main players: Nokia, Ericsson, Samsung, ZTE and Huawei. “Two are in China. One is in Finland, one is in Sweden and one is in Korea,” Mr. Roese says, adding that there are



more regulatory hurdles associated with purchasing telecommunications equipment overseas.

New players are entering the market since the U.S. government effectively blocked market leader Huawei from selling its equipment in the U.S. over national-security concerns and pressured countries around the world to follow suit. For now, though, the big five dominate the equipment market.

Ericsson is emerging as a top alternative to Huawei, particularly with a new type of 5G equipment known as massive multiple-input multiple-output, or massive MIMO. But these transmitters, which make it easier to deliver 5G on existing cell towers, require computer chips, and the semiconductor industry of late has been battling supply shortages.

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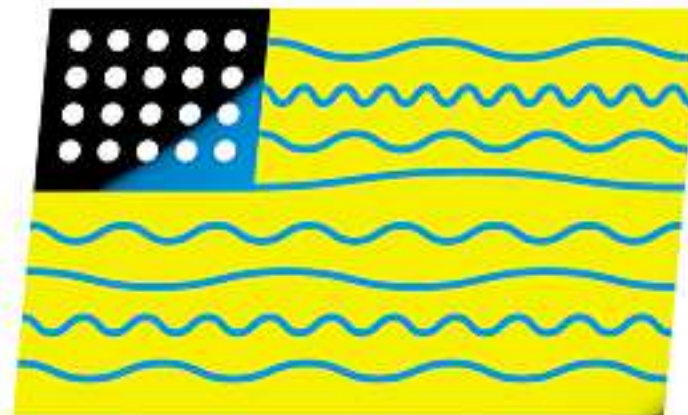
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Spectrum squeeze

5G signals are carried over three general categories of airwaves: low-band, midband and



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Severe Weather Alert!

Engineers are testing whether wireless signals can improve early warnings

By MARCO QUIROZ-GUTIERREZ

In a small office across from a dry cleaner in Wake Forest, N.C., a team of engineers is exploring the possibility of using data found in 5G wireless signals to measure a key factor in the early detection of tornadoes.

The group is part of a nonprofit test lab and engineering consulting firm called the Wireless Research Center, or WRC, which specializes in testing wireless technology and antennas. The team already has proved that humidity can be measured based on changes in signals that 4G and 5G cell towers emit. Now it wants to further test the technology to show that these same signals can help save lives by helping meteorologists forecast severe weather much sooner than current methods allow.

Meteorologists typically use weather stations or satellites to measure humidity. Both methods have their limitations. Weather stations are sparse and cover large areas, which can give less-precise readings. For a satellite, atmospheric conditions, such as clouds, and the satellite's position can hinder its ability to

measure humidity precisely.

Cellular service, by contrast, is nearly ubiquitous—and with the roll-out of 5G, even more equipment is being installed. The signals from which humidity data can be measured are known as reference signals. Cell towers emit them about every millisecond to help cellphones detect how strong or weak their connections are. These signals don't travel in straight lines. Their paths are affected by refraction, or the bending of waves, which increases when there is water vapor in the air. The change in the signals caused by refraction can be measured and used to derive humidity. The effect is particularly visible in weather fronts in which dry air mixes with a lot of humid air.

"If you measured a [cellular] signal

produce more weather data thanks to a scientist at the National Oceanic and Atmospheric Administration. In 2018, Gerard Hayes, the WRC's chief executive, was at an aviation conference in Washington, D.C., where he met Mark Weber, a research scientist at the time with the NOAA National Severe Storms Laboratory. The two got to talking and decided they would team up to tackle the idea of measuring humidity using cell-tower signals.

problems decoding the data with the software they had created.

The engineers started running low on time and money and, in the end, settled on a modified version of the experiment indoors.

In a 30-foot room, the team generated a cell signal on one side that was received by two antennas on the other. A black plastic tarp cut the room in half, keeping one side dry and one side moist with the help of a humidifier. Because the experiment was set up in a common room, Mr. Barts and his team had to work on nights and weekends so nobody would accidentally walk through their experiment and skew the results.

After weeks of testing, which finished in May 2020, the researchers concluded in a 75-page report presented to NOAA last summer that humidity could be derived from the information in 4G and 5G signals. More information and an experiment on a live tower is needed before the concept can be put into action, Mr. Barts says, but "it gave us enough proof to say this is worth pursuing."

To set up a more thorough experiment with signals from a cell tower, Mr. Barts says the WRC would need around \$100,000. He says the engineers are actively looking for government grants to continue the research.



Better warnings

Mr. Weber, who left NOAA last year, says that if humidity data could be collected on a large scale from 4G and 5G signals, it could help meteorologists better predict tornadoes. Detecting moisture in the air is key to predicting storms, says Mr. Weber, now a senior technical staff member at the Massachusetts Institute of Technology Lincoln Laboratory, which researches technology related to national security needs.

Meteorologists currently pick up on tornadoes by using Doppler radar, which measures the rain, hail and winds within a storm. Doppler radar generally gives people about a 15-minute warning of a possible tornado, says Mr. Weber. If meteorologists had better access to humidity data in the future through widespread adoption of the method WRC proved, Mr. Weber says, they could warn the public of a tornado much further in advance.

"Taking that out to an hour would be a huge difference in terms of the public's ability to take effective responses," he says.

The humidity levels can be gathered from existing cell signals, without accessing any private data or interfering with the operations of wireless carriers. Mr. Barts says the equipment could be set up away from cell towers and wouldn't need cooperation from wireless carriers.

"The beauty of this is if you can do this then the government doesn't have to go out and spend billions of dollars putting up signal sources to collect data from," Mr. Barts says. "AT&T and Sprint have already done that."

Mr. Quiroz-Gutierrez is a former Wall Street Journal reporter in New York. He can be reached at reports@wsj.com.



▲ Mike Barts, senior engineer, inside a chamber for antenna and wireless device testing at the Wireless Research Center in North Carolina, a nonprofit test lab and engineering consulting firm.

coming through that, the signal would hit that wet air and all of a sudden it's going to bend another way," says Mike Barts, a senior engineer at WRC.

A fateful meeting

Mr. Barts says the WRC got interested in how cellular signals could

NOAA researchers are always looking for better data to improve their weather models. The agency provided \$25,000 and the WRC set up their experiment.

At first, the team tried to use signals from an actual cell tower. They set their equipment up outside, near their office in Wake Forest, but Mr. Barts says they quickly ran into

A Guide to the Brand Names For 5G

Continued from page R1

Where it's found: AT&T says this 5G service is available to more than 240 million people in the U.S. Customers at home, at work or in motion will be seeing this label most of the time they have a 5G connection.

5G+
What it means: The plus sign signifies very high-frequency transmissions that carry lots of data at high speeds over short distances. This supercharged connection, also known as millimeter-wave for its tightly packed waveform, can download data much faster than 5G services over lower frequencies and makes 4G look like a dial-up line.

The carrier is using this technology in partnerships with businesses, governments and academic institutions seeking high-speed links on their properties.

Where it's found: AT&T says high-frequency 5G service is "best suited for high-traffic areas like stadiums, arenas, entertainment districts, airports and campuses." The company says 5G+ currently covers parts of 38 cities.

T-Mobile

5G Extended Range
What it means: T-Mobile applies this label to service over low-range frequencies. As with the other carriers, that means that while this service isn't the fastest type of 5G connection, it usually provides some improvement over 4G speeds.

Where it's found: T-Mobile says its extended-range coverage reaches 295 million people in the U.S.

5G Ultra Capacity
What it means: This name applies to T-Mobile service using mid- and high-range frequencies. That means downloads that are generally faster than those carried over the lower end of the radio spectrum used by the company's extended-range service and much



faster than 4G service.

Where it's found: The carrier says 140 million people are under the 5G Ultra Capacity umbrella, a number that it says will rise to 200 million by the end of this year.

Verizon

5G Nationwide
What it means: Verizon applies this label to all its 5G service in

the low- and midrange swaths of the radio spectrum. Like AT&T's basic 5G label, Verizon's 5G Nationwide service is about twice as fast as its 4G service, according to Opensignal, and is the one most customers will see in most places, especially while on the move.

Where it's found: Verizon, the largest U.S. carrier, says 5G Nationwide service covers 230 million people in the U.S.

The company is installing new equipment capable of spreading 5G service much farther. Some of that gear could be in service as early as December.

5G Ultra Wideband

What it means: This is Verizon's name for its high-frequency, millimeter-wave 5G service, which blasts large volumes of information at high speeds.


Opensignal research shows this service makes downloads more than 20 times as fast as a typical 4G download.

The company uses these frequencies both for mobile devices and to bridge the gap between telephone poles and home routers in some areas, in place of wired connections.

Where it's found: This service is mostly available in downtown areas, stadiums and certain suburban neighborhoods.

Verizon counts parts of more than 70 cities covered by its Ultra Wideband technology.

Mr. FitzGerald is a Wall Street Journal reporter in Washington, D.C. He can be reached at andrew.fitzgerald@wsj.com.

A man and a woman are working together in a laboratory or workshop. They are focused on a small, yellow and black robot on a table. The woman is holding a thin wire, and the man is looking on. In the foreground, a tablet displays a blue circuit board graphic. The background shows shelves with various equipment and a whiteboard with a lightbulb icon.


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JOURNAL REPORT | 5G TECHNOLOGY

U.S. Is Back in The 5G Game

Continued from page R1 competitor consistently cracked even 10%.

Now that landscape is changing. Pushed by Washington's campaign to cripple Huawei over cybersecurity concerns, countries representing more than 60% of the world's cellular-equipment market are considering or have already enacted restrictions against Huawei, says Dell'Oro Group. And to take advantage of that opening, the U.S. government—as well as governments in the U.K. and European Union—are considering financial support and other measures to boost domestic cellular-equipment makers trying to crack the three incumbents' stranglehold on the market.

The result is a newly competitive market that is reminiscent of the 1990s, when bygone industry giants such as Lucent, Motorola, Nortel, Siemens and Alcatel fought for a piece of a growing telecom-equipment pie.

"It's got a Wild West feel to it," says Bill Plummer, a former Nokia and Huawei executive now working at JMA Wireless, a Syracuse, N.Y., 5G company. "We haven't seen this since probably the eve of the dot-com bust—this dynamic and thriving competitive environment in wireless."

That new environment could benefit everyone—other than, of course, Huawei, Ericsson and Nokia. It will give a host of competitors a chance to win business that only a couple of years ago seemed out of reach. And the new competitive fervor should increase innovation and lower costs for wireless carriers, which could pass on savings—and the fruits of those innovations—to customers.

American officials further say the new competitive landscape is crucial to U.S. efforts to counter China's influence in developing 5G technology, the next generation of wireless technology that will serve as the building blocks for all sorts of future technologies—whether in robot-run factories, heart-rate monitors, or any number of industries and products. The country that dominates 5G will be well-positioned to lead the technology industry in terms of profits and talent in the years ahead.

The 3G days

After a vibrant start to the 3G era in the 2000s, when manufacturers throughout North America, Europe and Asia competed, equipment manufacturers started consolidating amid pressure from Huawei and another Chinese company, ZTE Corp., which were both selling increasingly competitive hardware at lower prices. In 2016, Nokia's acquisition of Alcatel-Lucent, itself a merger of French and American companies, created today's three-giant oligopoly.

The Trump administration began loosening the trio's grip on the market in 2018 when it started urging allies to blacklist industry leader Huawei over national-security concerns. The campaign worked: Huawei lost market share outside China to both Ericsson and Nokia last year, according to Dell'Oro Group, as governments enacted or considered restrictions on Huawei's equipment.

"The big change over the past couple of years is pressure on Huawei," says James Barford, a telecom analyst for Enders Analysis. "Even in countries where there is no formal ban, you're going to be thinking twice" about using equipment from the Chinese company.

The stranglehold of the big three was further weakened by Nokia's blunder in procuring expensive chips for its 5G equipment—a mistake that resulted in its equipment costing more upfront, as well as consuming more power. That's an issue for wireless carriers, which can spend roughly 20% of operating expenses on energy. Nokia says it has since moved to cheaper, power-efficient chips, but damage was done: Some carriers looked elsewhere for supplies.

With both Huawei and Nokia under pressure, that left Ericsson as the market leader outside China. But that, in turn, made wireless carriers' executives wary. They say they want more competition to increase innovation and reduce costs.

The result has been an opening for a whole new generation of competitors—



ing equipment based on these standards allow wireless carriers to mix and match the antennas with different under-antenna hardware and centralized electronics. That gives carriers more options for cost and quality.

The U.S. government is a major backer of the open-software efforts, which officials say could boost both U.S. national security and business. It potentially can help U.S. businesses by creating openings for new players, and because these new efforts rely less on hardware (where the U.S. has fallen behind) and more on software (where companies such as Microsoft Corp. and International Business Machines Corp. can potentially play a role).

"We may be able to increase security, reduce our exposure to any single foreign vendor, lower costs and push the equipment market to where the United States is uniquely

skilled—in software," Federal Communications Commission Acting Chairwoman Jessica Rosenworcel said in March.

If U.S. companies do indeed become major players in 5G equipment, then they can also play a bigger role in setting global standards for telecom equipment. That's an arena where China has made great strides. U.S. officials prefer that companies in the U.S. and allied democracies set wireless standards, which they believe would lead to greater, less hackable security.

President Biden and Japanese Prime Minister Suga Yoshihide last month agreed that the U.S. and Japan would collaborate to advance open 5G networks "by fostering innovation and by promoting trustworthy vendors and diverse markets," the White House said. Congress this year enacted a law to establish a Commerce Department fund that would award grants to support the use of such open-standards equipment in the U.S. A bipartisan group of lawmakers backing the bill requested \$750 million for the fund in fiscal year 2022.

In the U.K., a government-appointed task force to help British wireless carriers transition away from Huawei equipment recommended that new equipment makers, or those using open-standards software, represent 25% of the country's wireless infrastructure by the mid-2020s. The task force recommended government incentives for wireless carriers buying such equipment, and for suppliers to locate research facilities in the U.K. The European Union this year started examining similar options.

The focus of newcomers

Several smaller U.S. companies—such as Airspan Networks, AltioStar, Mavenir, JMA and Parallel Wireless—are focused on 5G equipment using open software. Ericsson and Nokia are also shifting to using some open-standard software.

The new challengers have signed deals with some big carriers. AT&T Inc. is testing open-standards equipment and plans to gradually introduce it, while newcomer wireless-carrier Dish Network Corp. has said its entire network would rely on such infrastructure.

Dell'Oro Group predicts that equipment using open standards, from both newcomers and incumbents transitioning into the new market, will capture 10% of the market by 2025.

"The operators say, 'We need choice, we need a strong ecosystem,'" says Thierry Maupilé, a former Motorola and Cisco Systems Inc. executive who now works at AltioStar, which provides software for open-standards 5G equipment. "You have a playing field that has been reduced to a few companies."

Still, open-standards equipment remains in its early stages, and it is too soon to know whether it will be a major player. Wireless carriers say their tests of open-standards equipment show some drawbacks. The new technology can be less energy-efficient than today's conventional systems. And while the open-standards equipment can be used in rural areas, its performance isn't yet up to snuff in densely populated urban areas.

But wireless carriers expect the open-standards equipment to be on par with Huawei, Ericsson and Nokia equipment in three or four years.

"For us, it is critical to maintain competition in our vendor system," says Michael Trabbia, chief technology officer at French carrier Orange SA. "We cannot end up with only two players."

Mr. Woo, a Wall Street Journal reporter in London, can be reached at stu.woo@wsj.com.

If U.S. companies become major players in 5G equipment, they can play a bigger role in setting global standards for telecom equipment.

and the Wild West environment.

The open gambit

Some carriers are turning to Samsung Electronics Co., the South Korean smartphone giant that is a relative newcomer to the wireless-infrastructure industry. It ranked fifth behind the three giants and China's ZTE in 2020, but won a major victory last year when Verizon Communications Inc. switched suppliers from Nokia to Samsung.

But it's the possibility of buying 5G equipment using open-standards software that has the most potential for roiling the competitive order.

To understand why, consider that the

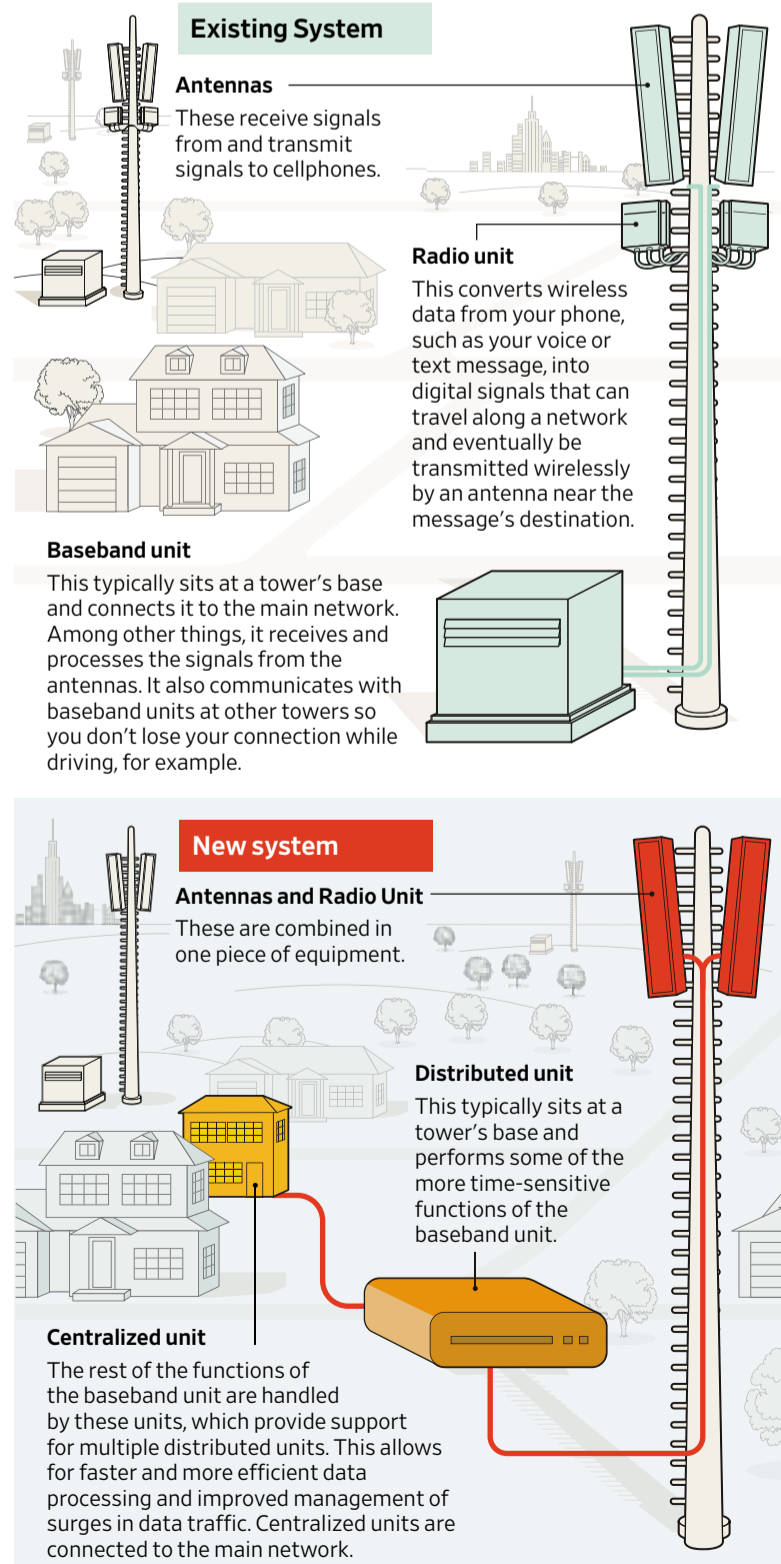
cellular equipment that transmits signals to phones consists of three parts: the antenna, hardware that sits on a pole directly under the antenna, and more hardware at the pole's base. Huawei, Ericsson and Nokia currently sell all three parts in a bundle, and they aren't interoperable. For instance, a Huawei antenna doesn't work with Ericsson electronics under the antenna.

It would be like buying a Dell laptop that works with only a Dell monitor and Dell printer. And it means customers have limited options on price, quality and features.

Enter a new technology based on open standards, dubbed Open RAN, or radio access network. Companies mak-

Network News

Changes are coming to the infrastructure of cellular networks. A new technology called Open RAN allows equipment from different makers to work together, which will offer wireless carriers more options as they build their 5G networks, and encourage innovation and price competition. At the same time, the equipment itself is changing. Here's a look at the current equipment on cellular towers and how the new setup differs.



Source: Open RAN Policy Coalition; AT&T; Kevin Hand/THE WALL STREET JOURNAL

JOURNAL REPORT | 5G TECHNOLOGY



U.S. vs. China: The Coming Battle Over Cars

Chinese firms have a head start using a 5G cellular standard.

By CHIEKO TSUNEOKA

It has been more than two years since people started being able to talk to each other over 5G networks. Now cars can use 5G technology to talk to each other, too.

But the business could develop into another source of U.S.-China competition. Chinese companies have been working longer on such vehicle communications based on advanced cellular technology, using a standard the U.S. embraced only last year, and they hope to take the lead in global markets. The U.S. and its allies, meanwhile, are cautious about using Chinese communications equipment.

The use of 5G in car-to-car communication is still in its infancy. But it has the potential to make driving safer, more convenient and eventually autonomous. Planners describe a world where smartcars tell one another where they are and where they are headed, preventing accidents. Pedestrians could be protected as well by signals through their phones. And traffic lights and road signs could relay real-time information to prevent congestion.

In a few Chinese cities, “customers are already using the technology to receive red-light warnings and other notifications,” says Ford Motor Co. spokesman Wesley Sherwood. “We believe there is great potential for the technology globally.”

It is likely to take a while for in-

dustry players and local governments to build out systems supporting car-to-car 5G communication and address security issues such as the risk of hackers disrupting car communications. The ultimate application—a purely autonomous network of cars coordinating among themselves—remains a distant vision.

The idea of cars communicating is nothing new. More than two decades ago, the Federal Communications Commission allocated spectrum for a particular type of short-range communication between vehicles.

Speaking last November, the FCC’s chairman, Ajit Pai, said the slow rollout of services on that spectrum reminded him of a 1970 song by the group Chairmen of the Board, “Give Me Just a Little More Time.”

At the urging of Mr. Pai, who stepped down from his post this year, the FCC voted in November to give part of the spectrum to a different standard called “cellular vehicle-to-everything” or C-V2X that is backed by Qualcomm Inc. By piggybacking on existing networks for regular smartphones, C-V2X can take advantage of high data speeds and work with a variety of devices.

China has already been working on C-V2X services for years. Initially those were designed for fourth-generation networks, including a city-level network in eastern Jiangsu province installed by Huawei Technologies Co. in 2018. Now the transition to 5G is under way.

“China is at the forefront of C-V2X development and has strongly consolidated it in its industrial transport policy over the past few years,” Johannes

Springer, director general of the Munich-based trade group 5GAA, said in a February news release.

According to Mr. Springer’s group, China is the only country where vehicles are commercially available that can use 5G with C-V2X. Last year, several leading Chinese auto makers including state-controlled FAW Group Corp. and Warren Buffett-backed

deploying C-V2X models in 2022.

In Europe, major car makers such as Volkswagen AG’s Audi, BMW AG and Daimler AG are working on equipping cars with the new technology. One project backed by European car makers and Huawei has been testing remote-controlled driving, in which an operator at a central location could take over a car using 5G if

The head start enjoyed by some Chinese suppliers in developing the backbone of the technology could cause some friction, as it has with 5G itself.

The U.S. and its allies have limited the use of Chinese equipment in their 5G networks, sometimes prompting threats of retaliation by Beijing. A spokesman for SoftBank says its test of vehicle merging didn’t rely on Chinese equipment, relying instead on European suppliers as with the rest of its 5G network.

State Department spokesman Ned Price said on May 11 that allowing major Chinese telecommunications suppliers “to participate in or to have any control over any part of a 5G network creates, we think, unacceptable risk to national security.”

Regarding 5G, a Chinese government spokesman said “setting up barriers or abusing the national security concept to suppress specific countries runs counter to the basic law of scientific progress and the shared interests of all.” Ford declined to name the suppliers for the C-V2X technology in its vehicles.

While Japan is still studying uses of 5G for cars on its roads, says Kenji Ueki, an official at Japan’s Ministry of Economy, Trade and Industry, the risk of hacking must be taken seriously if 5G is used to control vehicles. In February, Japan’s top auto makers and other companies formed a body to gather information on cybersecurity risks for connected cars.

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▲ A car from BYD, a Chinese maker that is adopting 5G.

BYD Co. came out with C-V2X models, using equipment from Chinese suppliers.

They were followed this year by Ford with two C-V2X models in China, the Explorer and Edge Plus. Drivers of those Ford models in some areas of the cities of Wuxi and Changsha can get information such as the best cruising speed to hit green lights, according to the car maker. In the U.S., Ford says it plans to begin

5G in car-to-car communication has the potential to make driving safer and more convenient.

a driver is disabled.

In Japan, Subaru Corp. and mobile-phone operator SoftBank Corp. said last November that they successfully used the 5G version of C-V2X in tests with merging traffic.



Farmers Join the Push to Harvest the Benefits of 5G

The technology shows promise. But bringing coverage to rural areas will be a challenge.

By ASA FITCH

On a collection of adjoining fields near a university in rural western England, an ambitious farming project aims to show it’s possible to plant, grow and harvest a crop autonomously, using robotics, drones—and potentially 5G.

The case for using 5G in farming shows promise, although the superfast networking technology is only beginning to be applied in the agriculture world. And there have been some kinks in early-

▲ Kurt Steck (left) of the 5G Open Innovation Lab, with Nate Krause, owner of Swan Trail Farms in Washington state, in an apple orchard on the farm.

stage experiments.

Farmers can benefit from large amounts of data about their crops, and 5G-enabled sensors could help deliver it, measuring if soil needs watering or plants are getting too much sun. Streaming high-quality video over mobile connections could help farmers analyze crops from afar in ways that weren’t possible with earlier generations of cellular technology.

Kit Franklin, a senior lecturer in agricultural engineering at Harper Adams University in England, who co-founded the autonomous farming project, called the Hands Free Farm, says many of the possibilities 5G opened up were enticing. So he and his colleagues signed up to test the new networking technology about three years ago as part of a government-supported initiative called 5G RuralFirst.

Mr. Franklin thought 5G could streamline the farm’s communications, merging them into a single 5G link instead of relying

on a mix of Wi-Fi and other radio-transmission technology. He also thought that because of its high speed, 5G could help the farm move away from having hefty computers on board tractors and harvesters and instead do the number crunching required to automatically steer machinery on remote servers in the cloud. Those things could make robotic farming cheaper and more reliable.

“We said, let’s take the smarts off the tractor and let’s try to put the smart stuff, the decision making, into the cloud where computing is cheap,” Mr. Franklin says. “The truck in the field has a GPS receiver, it’s got a camera and it’s sending that information to the cloud and the cloud is working on it.”

About halfway around the world, on a farm in Washington state, a different kind of experiment in the intersection of 5G and farming is taking place. There, a group of big tech compa-

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JOURNAL REPORT | 5G TECHNOLOGY

It's a New Game for Esports Players And Fans

Faster networks will enhance the competition for both the gamers and spectators

By YANG JIE

In June, armed young men with the latest high-tech gear are expected to descend on Beijing to shoot at their rivals.

Fortunately, the event is just a game with play guns. But it's also a thriving business that stands to grow and change with the addition of fifth-generation mobile connections.

Esports are videogame competitions played before live and online audiences—sometimes totaling in the tens of millions—in which experienced contestants vie for cash prizes. Companies ranging from Intel Corp. to Ericsson AB say they see esports as a natural application for ultrafast 5G networks. With much faster speeds than fourth-generation technology, 5G can make a critical difference in the realism of game scenes and the action. Fast networks are needed to transfer the huge amounts of data that allow players to respond to one another's actions and keep simulated environments realistic-looking.

With faster connections, there also will be potential to involve more players from different venues in a single esports competition. The higher speeds made available in mobile devices, meanwhile, will give a big boost to competitions in virtual-reality games—both in how such games are played and how audiences experience such events.

In virtual-reality games, headsets made by companies such as Facebook Inc.'s Oculus unit allow players to immerse themselves in simulated environments. In shooting games, for example, players see themselves moving through the virtual environment, and when they pull the triggers on their faux guns to shoot at virtual enemies, bursts of gunfire appear.

Previously in virtual-reality esports, contestants at the venue could move around some, but they had to wear bulky backpacks stuffed with computers to manage data transfers and ensure uninterrupted play. 5G frees competitors to move around more, without wires or the burden of a heavy backpack containing computer power.

The technology “is revolutionizing the industry as mobile and cloud-based gaming is set to take prece-



sionally fans would see the players sitting in front of their PCs. The new ability to see the players actually moving around and testing their physical abilities provides an extra thrill, says J.C. Kuang, managing director at the U.S. research firm Greenlight Insights.

Intel has had a hand in esports for years. It sponsors a long-running professional videogame-competition tour called Intel Extreme Masters and started to experiment with virtual-reality games in 2017.

Sky Limit, Mr. Qi's company, and Intel are co-hosting a series of VR competitions using 5G. Their plan calls for tournaments in China, Thailand, South Korea and Singapore, although a recent flare-up of Covid-19 cases may cause disruptions in the events outside China.

The market for dedicated cloud-gaming services is estimated to be a \$6.3 billion opportunity by 2024, growing from \$640 million in 2020, according to New York-based research firm ABI Research.

ABI estimates the Asia-Pacific region would account for 45% of the market, followed by North America with 26%.

Within Asia, China is at the forefront both of esports and 5G. The leading esports platform is operated by Wuhan-based DouYu International Holdings Ltd., a publicly listed company backed by Chinese internet heavyweight Tencent Holdings Ltd. VR videogame tournaments are scheduled this summer in cities such as Beijing and Shanghai.

Arenas for esports are even part of the economic development plan in Beijing's Haidian district, the country's closest equivalent to Silicon Valley and home to several of China's leading universities. The district government's plan calls for roughly \$1.55 million in subsidies for companies hosting local esports events using 5G, virtual reality or other technologies.

Tencent Vice President Cheng Wu said in a public speech last August that the company was “hoping to bring a new, more future-oriented experience in all aspects of esports.” Next up, he said, could be virtual characters serving as tournament commentators and artificial-intelligence trainers for esports athletes.

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▲ When VR is used in esports, players are physically active, roaming around a stage.

\$6.3 billion

Estimated size of the market for dedicated cloud-gaming services in 2024, up from \$640 million in 2020, according to ABI Research

45%

Estimated market share of the Asia-Pacific region in 2024, followed by North America with 26%

dence, powered by 5G connections and higher bandwidth,” Kevin Murphy, an Ericsson vice president, wrote in a blog post in March.

Chinese entrepreneur Qi Xiao, who focuses on applications of virtual-reality technology for entertainment, is one of those working on the next generation of esports. Mr. Qi says he was inspired to take his business in this direction by the dystopian science-fiction novel “Ready Player One,” in which players of a virtual-reality game in the 2040s hunt for treasure. The 2011 novel, by Ernest Cline, was adapted by Steven Spielberg into a 2018 movie.

The 40-year-old Mr. Qi started developing his own story lines for virtual-reality videogames a few years back. In 2018, his startup, Sky Limit Entertainment, received a multimillion-dollar investment from Intel—the exact amount wasn't disclosed—and the two companies started to work on applying new technologies such as 5G to virtual reality.

One of the problems in virtual-reality esports up to now has been that contestants often experienced a sense of vertigo due to blurred images in their headsets caused by slow bandwidths. Mr. Qi's 5G connections are designed to fix the vertigo problem. He and Intel are also working on faster processing

using cloud computing, in which central servers do the heavy-duty data crunching rather than computers or devices held by the players themselves.

“The trend is to bring everything onto the cloud so even if people are far away from each other, they can still be in the same space via 5G networks for real-time battles,” says Mr. Qi.

When virtual reality is used in esports, the action is more like a traditional sporting match, in that players are physically active, roaming around a stage in a real arena, ducking down and emerging to shoot enemies.

Mobile sensors in the play guns, gloves and headsets track the players' actions—their movements and shooting—and that data is transmitted and processed into the virtual environment.

The contestants see that world in their headsets. So does the audience. Spectators at the actual event can both watch the contestants as they move about the stage and follow the battle occurring in the virtual environment shown on giant screens. Online viewers can also watch the virtual action.

In earlier esports, such as the “League of Legends” world championship, spectators mainly were shown the in-game action. Occa-

nies and cellular carrier T-Mobile US Inc. are joining forces with a county government and farmers on a 5G field lab. It aims to use 5G connectivity to process data from sensors in the field more quickly than is possible with 4G.

Nate Krause, a farmer who is taking part in the project, says his farm has been equipped with sensors that measure moisture in the soil and weather sensors that track microclimates in his apple orchard.

manufacturing have enjoyed from adopting new technology have largely eluded farms because of their remote locations. Projects like the 5G initiative, he says, are aimed at helping bring some of those gains to agriculture at a time demand for food is rising even as areas being farmed are broadly declining.

Whether investments in 5G will yield returns for farmers remains unclear. The Washington



Nate Krause trimming trees alongside a soil-moisture probe on his farm.

and the Hands Free Farm remains interested in exploring how it can use it in robotic farming operations, especially as it becomes more prevalent nationwide, Mr. Franklin says.

“It was just a technology maturity thing—it wasn't quite there yet,” he says.

Anshel Sag, an analyst at Moor Insights & Strategy, says steady growth in 5G coverage, coupled with technological advances and new standards that allow for low-power-consumption devices, bodes well for the technology's agricultural applications. The big hurdle for 5G in farming is the cost of bringing coverage to rural areas, he says.

“Maybe one of the big pushes that we do in America isn't only do we facilitate the building of 5G networks, but also the building of 5G infrastructure for agriculture specifically, because agriculture is such a big part of the American economy,” he says.

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Big gains from new technology have largely eluded farms because of their remote locations, one farmer says.

Using an app on his phone, he says he can determine when to water the trees or use sun shades to shield crops, and when to spray chemicals that target pests.

All of it is powered by a data-processing unit and an antenna in a century-old barn.

“The goal is to make agriculture more efficient,” Mr. Krause says, adding that the big gains sectors such as banking and

experiment is still under way. And Mr. Franklin's RuralFirst project in England, a collaboration between academia and private industry, ultimately produced mixed results.

The Hands Free Farm team installed fiber-optic cables near their fields to get ready for the arrival of 5G antennas, but delays in the project's rollout meant the team wasn't able to

experiment with the technology before the trial ended.

The group also realized that some of the data shuffling they wanted could be accomplished with existing 4G connections, and the project already has moved to using that older generation of telecom technology to control its robotic fleet.

More important than 5G's

speed, Mr. Franklin says, is having robust signal coverage.

“I don't need a massive amount of data transfer for my robot tractor, but what I do need is a reliable comms link,” he says. “At the moment, what's going to stop automation in the rural environment is bad communication networks.”

Still, 5G remains promising,



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