# The Future of Wireless

Electronic Design
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In a nutshell: More wireless IS the future.

Electronics is all about communications. It all started with the telegraph in 1845, followed by the telephone in 1876, but communications really took off at the turn of the century with wireless and the vacuum tube. Today it dominates the electronics industry, and wireless is the largest part of it. And you can expect the wireless sector to continue its growth thanks to the evolving cellular infrastructure and movements like the Internet of Things (IoT). Here is a snapshot of what to expect in the years to come.

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## The State of 4G

4G means Long Term Evolution (LTE). And LTE is the OFDM technology that is the dominant framework of the cellular system today. 2G and 3G systems are still around, but 4G was initially implemented in the 2011-2012 timeframe. LTE became a competitive race by the carriers to see who could expand 4G the fastest. Today, LTE is mostly implemented by the major carriers in the U.S., Asia, and Europe. Its rollout is not yet complete—varying considerably by carrier—but nearing that point. LTE has been wildly successful, with most smartphone owners rely upon it for fast downloads and video streaming. Still, all is not perfect.


While LTE promised download speeds up to 100 Mb/s, that has not been achieved in practice. Rates of up to 40 or 50 Mb/s can be achieved, but only under special circumstances. With a full five-bar connection and minimal traffic, such speeds can be seen occasionally. A more normal rate is probably in the 10 to 15 Mb/s range. At peak business hours during the day, you are probably lucky to get more than a few megabits per second. That hardly makes LTE a failure, but it does mean that it has yet to live up to its potential.

One reason why LTE is not delivering the promised performance is too many subscribers. LTE has been oversold, and today everyone has a smartphone and expects fast access. But with such heavy use, download speeds decrease in order to serve the many.

There is hope for LTE, though. Most carriers have not yet implemented LTE-Advanced, an enhancement that promises greater speeds. LTE-A uses carrier aggregation (CA) to boost speed. CA combines LTE's standard 20 MHz bandwidths into 40, 80, or 100 MHz chunks, either contiguous or not, to enable higher data rates. LTE-A also specifies MIMO configurations to 8 x 8. Most carriers have not implemented the 4 x 4 MIMO configurations specified by plain-old LTE. So as carriers enable these advanced features, there is potential for download speeds up to 1 Gb/s. Market data firm ABI Research forecasts that LTE carrier aggregation will power 61% of smartphones in 2020.

This LTE-CA effort is generally known as LTE-Advanced Pro or 4.5G LTE. This is a mix of technologies defined by the 3GPP standards development group as Release 13. It includes carrier aggregation as well as Licensed Assisted Access (LAA), a technique that uses LTE within the 5 GHz unlicensed Wi-Fi spectrum. It also deploys LTE-Wi-Fi Link Aggregation (LWA) and dual connectivity, allowing a smartphone to talk simultaneously with a small cell site and an Wi-Fi access point. Other features are too numerous to detail here, but the overall goal is to extend the life of LTE by lowering latency and boosting data rate to 1 Gb/s.

But that's not all. LTE will be able to deliver greater performance as carriers begin to facilitate their small-cell strategy, delivering higher data rates to more subscribers. Small cells are simply miniature cellular basestations that can be installed anywhere to fill in the gaps of macro cell site coverage, adding capacity where needed.

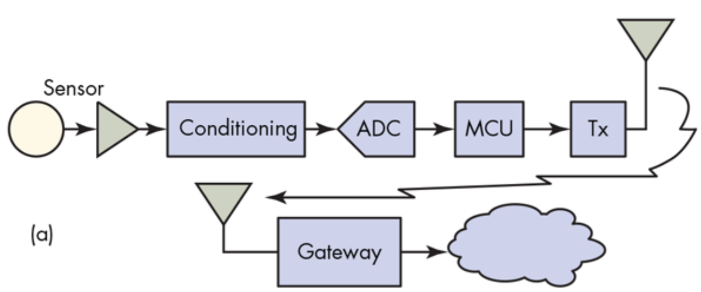
Another method of boosting performance is to use Wi-Fi offload. This technique transfers a fast download to a nearby Wi-Fi access point (AP) when available. Only a few carriers have made this available, but most are considering an LTE improvement called LTE-U (U for unlicensed). This is a technique similar to LAA that uses the 5 GHz unlicensed band for fast downloads when the network cannot handle it. This presents a spectrum conflict with the latest version of Wi-Fi 802.11ac that uses the 5 GHz band. Compromises have been worked out to make this happen.

So yes, there is plenty of life left in 4G. Carriers will eventually put into service all or some of these improvements over the next few years. For example, we have yet to see voice-over-LTE (VoLTE) deployed extensively. Just remember that the smartphone manufacturers will also make hardware and/or software upgrades to make these advanced LTE improvements work. These improvements will probably finally occur just about the time we begin to see 5G systems come on line.

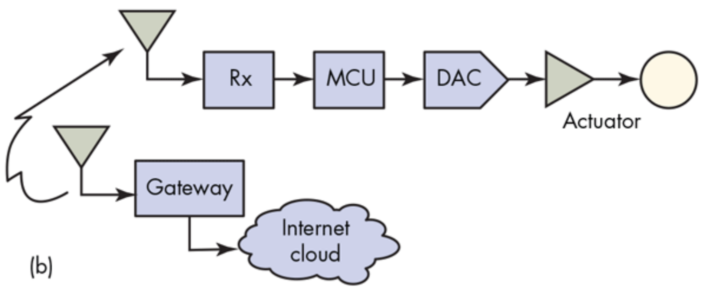
## 5G Revealed

5G is so not here yet. What you are seeing and hearing at this time is premature hype. The carriers and suppliers are already doing battle to see who can be first with 5G. Remember the 4G war of the past years? And the real 4G (LTE-A) is not even here yet. Nevertheless, work on 5G is well underway. It is still a dream in the eyes of the carriers that are endlessly seeking new applications, more subscribers, and higher profits.

The Third Generation Partnership Project (3GPP) is working on the 5G standard, which is still a few years away. The International Telecommunications Union (ITU), which will bless and administer the standard —called IMT-2020—says that the final standard should be available by 2020. Yet we will probably see some early pre-standard versions of 5G as the competitors try to out-market one another. Some claim 5G will come on line by 2017 or 2018 in some form. We shall see, as 5G will not be easy. It is clearly going to be one of the most, if not the most, complex wireless system ever. Full deployment is not expected until after 2022. Asia is expected to lead the U.S. and Europe in implementation.



: rationale for 5G is to overcome the limitations of 4G and to add capability for new applications. The itations of 4G are essentially subscriber capacity and limited data rates. The cellular networks have already transitioned from voice-centric to data-centric, but further performance improvements are needed for the future.




Furthermore, new applications are expected. These include carrying ultra HD 4K video, virtual reality content, Internet of Things (IoT) and machine-to-machine (M2M) use cases, and connected cars. Many are still forecasting 20 to 50 billion devices online, many of which will use the cellular network. While most IoT and M2M devices operate at low speed, higher network rates are needed to handle the volume. Other potential applications include smart cities and automotive safety communications.

5G will probably be more revolutionary than evolutionary. It will involve creating a new network architecture that will overlay the 4G network. This new network will use distributed small cells with fiber or millimeter wave backhaul *(Fig. 1)*, be cost- and power consumption-conscious, and be easily scalable. In addition, the 5G network will be more software than hardware. 5G will use software-defined networking (SDN), network function virtualization (NFV), and self-organizing network (SON) techniques. Here are some other key features to expect:

- Use of millimeter (mm) -wave bands. Early 5G may also use 3.5- and 5-GHz bands. Frequencies from about 14 GHz to 79 GHz are being considered. No final assignments have been made, but the FCC says it will expedite allocations as soon as possible. Testing is being done at 24, 28, 37, and 73 GHz.
- New modulation schemes are being considered. Most are some variant of OFDM. Two or more may be defined in the standard for different applications.
- Multiple-input multiple-output (MIMO) will be incorporated in some form to extend range, data rate, and link reliability.
- Antennas will be phased arrays at the chip level, with adaptive beam forming and steering.
- Lower latency is a major goal. Less than 5 ms is probably a given, but less than 1 ms is the target.
- Data rates of 1 Gb/s to 10 Gb/s are anticipated in bandwidths of 500 MHz or 1 GHz.
- Chips will be made of GaAs, SiGe, and some CMOS.

One of the biggest challenges will be integrating 5G into the handsets. Our current smartphones are already jam-packed with radios, and 5G radios will be more complex than ever. Some predict that the carriers will be ready way before the phones are sorted out. Can we even call them phones anymore?

So we will eventually get to 5G, but in the meantime, we'll have to make do with LTE. And really—do you honestly feel that you need 5G?

## What's Next for Wi-Fi?

Next to cellular, Wi-Fi is our go-to wireless link. Like Ethernet, it is one of our beloved communications "utilities". We expect to be able to access Wi-Fi anywhere, and for the most part we can. Like most of the popular wireless technologies, it is constantly in a state of development. The latest iteration being rolled out is called 802.11ac, and provides rates up to 1.3 Gb/s in the 5 GHz unlicensed band. Most access points, home routers, and smartphones do not have it yet, but it is working its way into all of them. Also underway is the process of finding applications other than video and docking stations for the ultrafast 60 GHz (57-64 GHz) 802.11ad standard. It is a proven and cost effective technology, but who needs 3 to 7 Gb/s rates up to 10 meters?

ıny given time there are multiple 802.11 development projects ongoing. Here are a few of the most ˛ıificant.

- 802.11af – This is a version of Wi-Fi in the TV band white spaces (54 to 695 MHz). Data is transmitted in local 6- (or 8-) MHz bandwidth channels that are unoccupied. Cognitive radio methods are required. Data rates up to about 26 Mb/s are possible. Sometimes referred to as White-Fi, the main attraction of 11af is that the possible range at these lower frequencies is many miles, and non-line of sight (NLOS) through obstacles is possible. This version of Wi-Fi is not in use yet, but has potential for IoT applications.
- 802.11ah – Designated as HaLow, this standard is another variant of Wi-Fi that uses the unlicensed ISM 902-928 MHz band. It is a low-power, low speed (hundreds of kb/s) service with a range up to a kilometer. The target is IoT applications.
- 802.11ax – 11ax is an upgrade to 11ac. It can be used in the 2.4- and 5-GHz bands, but most likely will operate in the 5-GHz band exclusively so that it can use 80 or 160 MHz bandwidths. Along with 4 x 4 MIMO and OFDA/OFDMA, peak data rates to 10 Gb/s are expected. Final ratification is not until 2019, although pre-ax versions will probably be complete.
- 802.11ay – This is an extension of the 11ad standard. It will use the 60-GHz band, and the goal is at least a data rate of 20 Gb/s. Another goal is to extend the range to 100 meters so that it will have greater application such as backhaul for other services. This standard is not expected until 2017.

## Wireless Proliferation by IoT and M2M

Wireless is certainly the future for IoT and M2M. Though wired solutions are not being ruled out, look for both to be 99% wireless. While predictions of 20 to 50 billion connected devices still seems unreasonable, by defining IoT in the broadest terms there could already be more connected devices than people on this planet today. By the way, who is really keeping count?


The typical IoT device is a short range, low power, low data rate, battery operated device with a sensor, as shown in *Fig. 2a*. Alternately, it could be some remote actuator, as shown in *Fig. 2b*. Or the device could be a combination of the two. Both usually connect to the Internet through a wireless gateway but could also connect via a smartphone. The link to the gateway is wireless. The question is, what wireless standard will be used?

Wi-Fi is an obvious choice because it is so ubiquitous, but it is overkill for some apps and a bit too power-hungry for some. Bluetooth is another good option, especially the Bluetooth Low Energy (BLE) version. Bluetooth's new mesh and gateway additions make it even more attractive. ZigBee is another ready-and-waiting alternative. So is Z-Wave. Then there are multiple 802.15.4 variants, like 6LoWPAN.

Add to these the newest options that are part of a Low Power Wide Area Networks (LPWAN) movement. These new wireless choices offer longer-range networked connections that are usually not possible with the traditional technologies mentioned above. Most operate in unlicensed spectrum below 1 GHz. Some of the newest competitors for IoT apps are:

- LoRa – An invention of Semtech and supported by Link Labs, this technology uses FM chirp at low data rates to get a range up to 2-15 km.
- Sigfox – A French development that uses an ultra narrowband modulation scheme at low data rates to send short messages.

- Weightless – This one uses the TV white spaces with cognitive radio methods for longer ranges and data rates to 16 Mb/s.
- Nwave – This is similar to Sigfox but details minimal at this time.
- Ingenu – Unlike the others, this one uses the 2.4-GHz band and a unique random phase multiple access scheme.
- HaLow – This is 802.11ah Wi-Fi, as described earlier.
- White-Fi – This is 802.11af, as described earlier.

There are lots of choices for any developer. But there are even more options to consider.

Cellular is definitely an alternative for IoT, as it has been the mainstay of M2M for over a decade. M2M uses mostly 2G and 3G wireless data modules for monitoring remote machines or devices and tracking vehicles. While 2G (GSM) will ultimately be phased out (next year by AT&T, but T-Mobile is holding on longer), 3G will still be around.

Now a new option is available: LTE. Specifically, it is called LTE-M and uses a cut-down version of LTE in 1.4-MHz bandwidths. Another version is NB-LTE-M, which uses 200-kHz bandwidths for lower speed uses. Then there is NB-IoT, which allocates resource blocks (180-kHz chunks of 15-kHz LTE subcarriers) to low-speed data. All of these variations will be able to use the existing LTE networks with software upgrades. Modules and chips for LTE-M are already available, like those from Sequans Communications *(Fig. 3)*.

One of the greatest worries about the future of IoT is the lack of a single standard. That is probably not going to happen. Fragmentation will be rampant, especially in these early days of adoption. Perhaps there will eventually be only a few standards to emerge, but don't bet on it. It may not even really be necessary.

### 3 Things Wireless Must Have to Prosper

- Spectrum – Like real estate, they are not making any more spectrum. All the "good" spectrum (roughly 50 MHz to 6 GHz) has already been assigned. It is especially critical for the cellular carriers who never have enough to offer greater subscriber capacity or higher data rates. The FCC will auction off some available spectrum from the TV broadcasters shortly, which will help. In the meantime, look for more spectrum sharing ideas like the white spaces and LTE-U with Wi-Fi.
- Controlling EMI – Electromagnetic interference of all kinds will continue to get worse as more wireless devices and systems are deployed. Interference will mean more dropped calls and denial of service for some. Regulation now controls EMI at the device level, but does not limit the number of devices in use. No firm solutions are defined, but some will be needed soon.
- Security – Security measures are necessary to protect data and privacy. Encryption and authentication measures are available now. If only more would use them.

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