

The Impact of 5G Telecommunications Technology on US Grid Modernization 2017–2025

April 2019

JD Taft

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1.0 Communication Technology Evolution – A Challenge for Utilities

Grid Modernization is the name commonly used to encompass a variety of activities in the electric power industry including integration of Distributed Energy Resources and improvements in grid flexibility and reliability. There are many excellent references on various aspects of Grid Modernization including the DSPx Modern Distribution Grid Report sponsored by the Department of Energy¹ and the DOE Quadrennial Energy Review.² Every Grid Modernization application or solution requires substantial deployment of ubiquitous connectivity with security, reliability and manageability. Specific performance criteria must be developed to match the application to appropriate communication technologies and services.

The paper provides a discussion of the considerations involved in the communication needs of the electric power industry and some of the challenges and opportunities of present and future communication technologies and communication service providers.

1.1 Why 5G is Not the Answer to Utility Communication Dreams

Even as the mobile telecommunication service providers (SPs) are completing their rollouts of 4G/LTE, the industry is hard at work developing and finalizing standards for 5G that will pave the way for early pilots by 2020. As is typical of this stage of high tech development, many discussions around 5G describe everything it *might do* as what it *will do*. And since the industry is at the stage of throwing features against the wall to see what might stick, any new brainstorm is promptly added to the “well, it might be able to do that” list which almost instantly gets repeated out of context as the committed feature list.

Despite the present conversation suggesting that 5G will massively transform electric utilities, there are a number of reasons why it will not be significant for electric utility operations until after 2025 and therefore will not play a major role in the current phase of grid modernization.

This paper examines the reasons for this conclusion.³

1.2 Some Useful Background

There are a number of common terms frequently used in discussing communications that are often misused or misconstrued. Here we provide a few key definitions to support the later parts of this paper.

Bandwidth – usually described in terms of bits per second, bandwidth, unless specifically defined otherwise, generally refers to the raw, physical or theoretical data rate of the communication medium. This is not the number of bits per second seen by applications or communicating devices. It does not take

¹ <http://doe-dsp.org/>

² <https://www.energy.gov/epsa/initiatives/quadrennial-energy-review-qer>

³ Two examples of utility planning for timeframes overlapping early 5G rollouts: SCE 2018 Rate Case Filing, <http://docs.cpuc.ca.gov/>, proposes a hybrid communications infrastructure including significant utility build-out of private infrastructure for grid modernization; the HECO draft grid modernization plan mentions 5G in the context of needing reliable power from the grid, but not as a solution for utility communication requirements.

into account overhead of managing the communications path which includes bits used for framing (the start and stop of a packet), timing, addressing or routing, encryption, error detection and recovery, retransmission, etc.

Throughput – is also usually described in terms of bits per second, which means that bandwidth and throughput are often mistakenly used interchangeably. Throughput should mean the realistic number of bits per second seen by the applications or communicating devices. If the description of throughput is rigorous, it should not be a single number, but a range of numbers reflecting the range of the error rate of the communication medium.

Discussions of throughput also rarely distinguish between data rates that can be achieved for streaming versus data rates for more interactive communication. For example, satellite communications can achieve bit rates high enough to support HD video transmission, as commonly experienced by satellite TV service providers. But maintaining adequate performance for more interactive data like web browsing requires continual back and forth upstream and downstream messaging; long delays are continually incurred for each such message, unlike with download streaming. The implications for utility control are even more constrained in that interaction is between real time sensor data and real time control data which cannot be cached as the control applications require that data may be unique with every transmission.

Every communication medium has an error rate. For some, like coaxial cable or optical fiber, the error rate may be extremely low, as low as 10^{-15} .⁴ Yet even for a low error rate medium like optical fiber, error rates may vary depending on attenuation due to small radius bending, nicks or cracks in the cable sheathing, poor quality couplers and connectors, etc. Consequently, an essential part of a communication protocol is detection of errors. Error detection involves applying one or more of a variety of algorithms to the data to develop additional error checking data bits that are transmitted with the original data. When the data payload is received, complementary algorithms compare the received data with the error checking data bits to see whether any data errors have occurred.

Radio communication may experience very high error rates due to natural phenomena such as lightning or solar emissions, radio noise from other radio transmitters, interference from physical barriers and signals bouncing off of materials that reflect radio signals. Depending on the measured error rate taken in a field propagation study, it may be necessary or practical to employ techniques like forward error correction and automatic retransmission which take both extra time and extra bits to make sure that data can be successfully delivered even though the error rate may be high and may vary over several orders of magnitude during operation. The resulting throughput may be very much lower than the bandwidth depending on the error rate of the communication medium and the techniques used to deliver error free data.

Latency – is generally understood to mean the time between the transmission of a message and the receipt of that message at the other end of the communication link. With an understanding of error rates and how error rates may vary dramatically, latency should always be qualified to a specific error rate or range of error rates. Other sources of latency include the time required to encode and decode the modulated signal and all the places in the communication path where that may occur including not only the transmitter and receiver, but also any repeaters, routers, switches, and any other signal processing equipment.

⁴ Practical Bit Error Rate Measurements on Fibre Optic Communications Links in Student Teaching Laboratories, Walsh, Moodie, et al., OptoSci Ltd, 2005. https://spie.org/etop/ETOP2005_021.pdf

1.3 Typical Utility Communications

Utilities use multiple communications technologies and hybrid private/SP infrastructure.

From the earliest pioneering work of Edison, Tesla, and Westinghouse, rapidly growing electric power networks required rapid and reliable communications to give the reliable electric power service that became essential to customers.⁵ Lacking the availability of appropriate communications technologies, utilities had no choice but to develop their own, leaving a legacy of protocols and devices that shaped operational models and helped promote the development of industrial control systems as a discipline and an industry of products and technologies that has been core to the industrial revolution.⁶

Utility engineers utilized technologies, products, and services from telecommunication service providers wherever those met with their requirements. Where their needs were not met, utilities have constructed their own communication infrastructure.

Figure 1 below illustrates the evolving wide range of timing requirements for electric utility applications. As the diagram illustrates, Grid Modernization is driving a need for massive numbers of sensing and control endpoints.

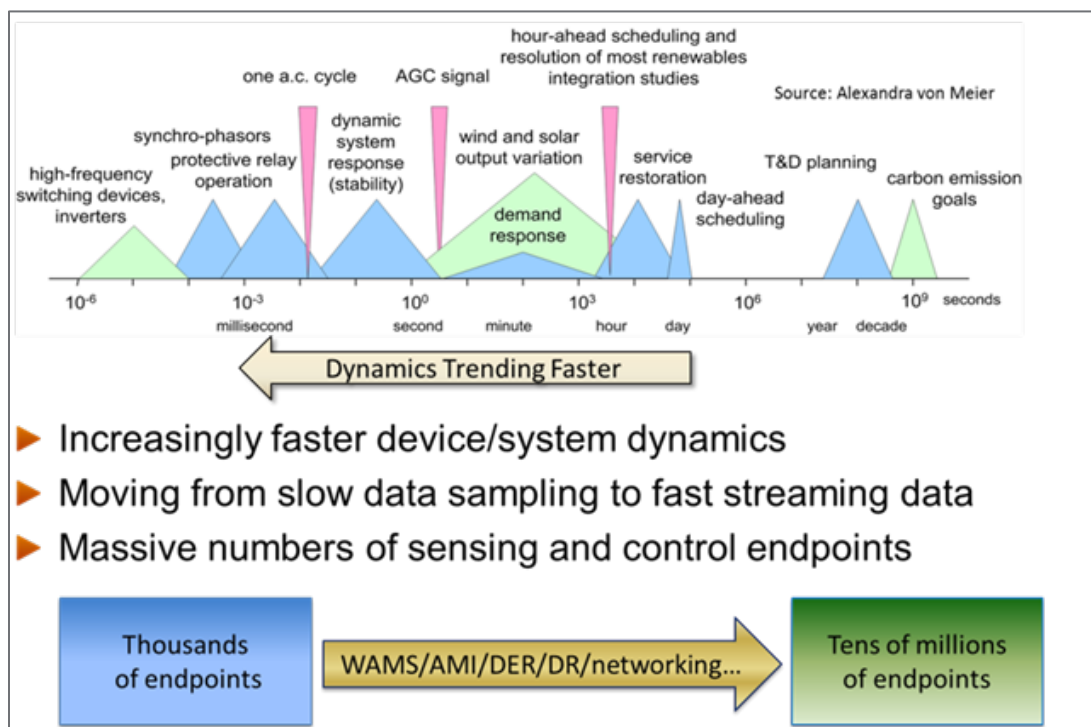


Figure 1. Utility Data Trends

⁵ The Grid: A Journey Through the Heart of Our Electrified World, Phillip F. Schewe, 2007

⁶ An Abbreviated History of Automation & Industrial Controls Systems and Cybersecurity, Hayden, Assante, Conway, 2014

<https://ics.sans.org/media/An-Abbreviated-History-of-Automation-and-ICS-Cybersecurity.pdf>

1.4 Substation Connectivity

Many electric utilities have a mix of different generations of telecommunications technologies and services for communications to substations, including simple two and four wire twisted pairs, PSTN, cellular links, and microwave for remote locations where other communication infrastructure is not available. Even satellite communication has been used for remote access. Some utilities have deployed optical fiber to connect substations and control centers.

1.5 Distribution Grid Communications

The distribution grid has a legacy of very sparse communication due to both the sheer size of the distribution grid with its connection to millions of customers and the cost/benefit of the improvements possible with better instrumentation and control. Distribution communication has been dominated by protection systems and smart switches. These challenges are exacerbated for rural utilities that have many fewer customers per mile of distribution infrastructure and may also have much longer distribution feeders. Some of these utilities continue to rely on legacy power line communication technologies where “high speed” may mean data rates of 5 to 60 bits per second.⁷

The requirements for integration of distributed energy resources (DER) described in the DSPx reports have created the need for near real-time information and dynamic control of distribution grid operations.

1.6 Advanced Metering Infrastructure (AMI)

AMI systems are typically hybrid systems consisting of RF meshed endpoints connecting to a backhaul collector/concentrator with utility private backhaul or service provider communication backhaul from collector/concentrator to the utility backbone network or data center. Utility private backhaul may aggregate at a substation or other utility infrastructure where there is a point-of-presence (POP) for connection to the utility backbone network.

1.7 SP Backhaul – 3G, 4G, LTE

Although telecommunication service providers have a number of different digital network services, cellular technologies are the most attractive for AMI due to their wide coverage, eliminating the need for any utility infrastructure build-out projects. Rate case filings widely document the business case for AMI. It is notable that almost all presently operational systems have business cases built around applications that could be supported by 15-minute interval data recording with 12-hour collection cycles and on-demand reads with latencies measured in tens of seconds or even minutes for outage verification, starting service and ending service reads and customer service needs.

As discussed in the DOE reports, dynamic distribution grid control requires much more frequent distribution grid information. There have been several studies and commercial products deployed that try to co-opt existing AMI systems to that task.⁸ While some level of functionality can be achieved this way, communication performance of existing AMI systems was specifically constrained to limit cost.

⁷ Electric Power Substations Engineering, 2nd Edition, McDonald, CRC Press, 2016, Chapter 15.11.11 Power Line Carrier

⁸ Lightning Strikes Twice: AMI Finds New Life as Outage, Voltage Tool, Rod Walton, Electric Light & Power, December 2016

This is reflected in both the performance characteristics of mesh networks and the typical performance of cellular communication.

1.8 Performance Characteristics of Mesh Networks

AMI mesh networks have as their primary design goal addressing the RF propagation issues that result from typical meter locations, physical objects that attenuate or reflect RF signals, and maximizing the number of meters per collector or concentrator which is the point of presence for backhaul communication, generally cellular. This goal is accomplished through having every meter serve as a store-and-forward device able to receive a transmission from other meters and forward that message on until it reaches the concentrator. In this way, a meter message can be passed from one meter to the next, routing around obstacles. The number of times a message is retransmitted before it reaches the concentrator is referred to as the number of hops. Every mesh system attempts to minimize the number of hops and let each meter know whether the message it has received needs to be forwarded or may have already been forwarded by another meter. In some cases, repeaters are also used to provide hopping around obstacles when no appropriately located meters are available.

The specific routing of messages, i.e. which meters receive and retransmit any given message, is never fixed, but is dynamically adjusted as conditions change due to construction, transient vehicle presence, foliage growth, noise sources, and many other factors. Even though a “typical path” with a reasonable latency may exist, the very nature of mesh networks is intended to accommodate failure of a hop by rerouting along a different path with retries until transmission is successful.

Despite the dynamic nature of mesh network routing, successful operation of a mesh network system depends on a large percentage of routes persisting through time.⁹ Initial establishment and retention of a default route for each mesh network node is called convergence. Along with updating of route information that occurs whenever the initial route fails, every mesh network has means to periodically test for a more efficient (i.e. fewer hops) route to improve performance and also address any traffic congestion (bottle-necking) that may occur if many routes start to go through a particular node.

After an extended outage, the entire mesh network may require re-convergence. For a mesh network of a million or more meters and other devices, this is a process that may take an extended period of time (hours to days) before data communication can begin. The issue here is whether the network maintains routing information during a persistent power outage. If not, the network must rediscover the routes when power returns.

Of course, there may arise conditions such that at any given time, a message cannot be forwarded successfully. Such errors are logged and reported at the next successful transmission. If a meter message is sent as the result of a request, the requestor will recognize when a reply has not been received within a designated time. This usually results in one or more retries depending on how the system is configured and will include attempts using alternate paths. If the meter is the originator of the message, unless there is a preconfigured expectation of arrival time, there is no system information available concerning message failure until a successful communication path is found.

The obvious lack of determinacy of mesh networks is of little consequence to the primary applications of 15-minute interval data which include time-of-use billing. Meters are capable of storing information for

⁹ Performance Study of Routing Protocols for Wireless Mesh Networks, Zakrzewska, Koszalka, Systems Engineering, 2008. ICS-ENG '08. 19th International Conference, <http://ieeexplore.ieee.org/document/4616659/>

extended periods of time, some for 30 days or more, and the data remains useful and relevant as long as transmission is eventually successful.

Additional data can be recorded by the latest generation meters, including line voltage and reactive power flow at the load. While the average “fair weather” performance of a mesh network may provide data that is marginally useful from a determinacy, latency and availability perspective, it is difficult to imagine this as the basis of critical control of a dynamic distribution grid with a high penetration of DER having the normal fluctuations of varying loads and passing cloud cover.

1.9 Performance Characteristics of Cellular Networks

There are some characteristics of cellular communications, even in the most recent LTE systems and nascent 5G systems, which are often overlooked. While data rates have increased, the underlying architecture of all cellular systems is based on sharing or multiplexing communication demands over a limited number of RF channels. Even data services presented as “always on” or “always connected” have the underlying structure of queuing and allocation over available channels. This entails variable channel setup and queuing delays.¹⁰

SP architecture requires routing through packet data network (PDN) gateway, generally located at a SP central office, prior to routing to utility control center.¹¹ Such a gateway may be quite remote from the utility infrastructure it is serving, to the point of even being located in another state. The resultant latency can be both long and if the SP network allows for multiple possible PDN routings, the latency may also be variable and unpredictable.

Figure 2 below illustrates the major elements of the LTE architecture.

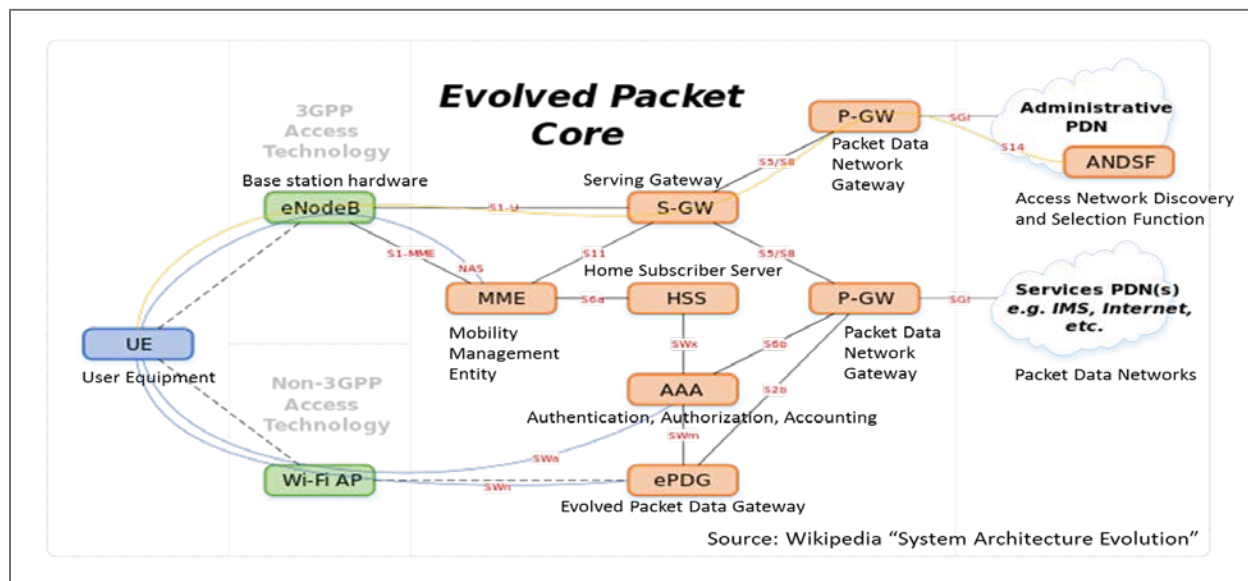


Figure 2. LTE Architecture

¹⁰ Latency in HSPA Data Networks, Mohan, Kapoor, Mohanty, Qualcomm, July 2013, <https://www.qualcomm.com/media/documents/files/qualcomm-research-latency-in-hspa-data-networks.pdf>

¹¹ Master LTE with the Help of an LTE Network Diagram, RCR Wireless News, May 9, 2014, <https://www.rcrwireless.com/20140509/evolved-packet-core-epc/lte-network-diagram#prettyPhoto>

Once resource allocation is accomplished, ever increasing bandwidths, now up to 1 Gigabit per second for LTE Advanced, with ambitions of 10 Gbps for 5G, means latency within multi-packet data streams may be as low as 1 millisecond. However, your mileage may vary. Dropped calls, intermittent connections, call failure, etc. remain common occurrences in everyone's experience with mobile communications. Reflexive movement to a location with better signal is almost unnoticed, but obviously unavailable to fixed machines or devices.

1.10 What about LTE Peer-to-Peer?

While often discussed as obtainable with LTE, peer-to-peer is not available in any current SP network.

Proposals for peer-to-peer are part of the discussion for LTE Advanced and 5G but challenges remain with SP management of their network and revenue models for peer-to-peer support.

Proposals for peer-to-peer describe it as "best efforts" for device-to-device (D2D) communication, avoiding the overhead and latency of cell queuing and routing. The reason for the characterization of such services as best efforts is that not only do they bypass the normal means by which service providers measure traffic to collect revenue, but may use resources (radio frequency channels) that should be prioritized for tariffed data.

2.0 Device Connectivity and the Internet of Things (IoT)

A number of communications technologies have been used to enable device-to-device communication for consumer uses. Not all of these have fared equally well in the marketplace, thus challenging the utility industry to choose well, so as to avoid early obsolescence and stranded investments.

2.1 WiFi

WiFi has benefitted greatly from the immense investment in development of digital signal processing, antennas, and RF system-on-a-chip (SoC) technologies, all driven by smart phones. Technologies such as OFDM¹² and MIMO¹³ underlie both 4G/LTE and the latest WiFi standards. The huge quantities of devices that include computers, tablets, smart phones, and consumer devices such as smart televisions, smart thermostats, and a variety of home automation and home control devices, have powered the enormous investment and astonishingly low price points that are seen in today's products.

2.2 Bluetooth

Bluetooth thrives on its mission for exchanging data over very short distances, giving rise to applications for computer peripheral interconnections like the ubiquitous Bluetooth mouse and keyboard, and the highest volume use: wireless interconnection for cordless headphones.

2.3 Also-Rans: Zigbee, Z-wave, CEBus

During the mid to late 1980s, WiFi did not yet have the benefit of leveraging smart phone development and appeared like it would never be suitable for battery powered operation. The need for low power communication suitable for battery power and consumer devices lead to the development of a number of different communication technologies to address the potential of the consumer and home automation market. Despite some initial success, they have been overwhelmed in price, performance and commercial acceptance by WiFi in most cases and Bluetooth in the rest.

2.3.1 Zigbee

There remains some persistent interest in Zigbee for energy management systems and due to its presence in several million utility electric meters in the United States, most notably in California and Texas. The original vision was to provide access to the meter data for energy management systems within the customer premise. The reality has turned out to be that, other than in pilots, the Zigbee capabilities of AMI meters is virtually unused - a stranded investment of tens of millions of dollars.

Security issues and concerns have been part of the reason for the slow adoption of Zigbee.¹⁴ Another has been the practicalities of communication from the utility meter to the customer premise. The meter is located to facilitate electrical connectivity, not communication. Many types of construction,

¹² OFDM Orthogonal Frequency Division Multiplexing Tutorial, Poole, Radio-Electronics, <http://www.radio-electronics.com/info/rf-technology-design/ofdm/ofdm-basics-tutorial.php>

¹³ What is MIMO? Multiple Input Multiple Output Tutorial, Poole, Radio-Electronics, <http://www.radio-electronics.com/info/antennas/mimo/multiple-input-multiple-output-technology-tutorial.php>

¹⁴ Zigbee Exploited, Zillner, August 2015, <https://www.blackhat.com/docs/us-15/materials/us-15-Zillner-ZigBee-Exploited-The-Good-The-Bad-And-The-Ugly-wp.pdf>

especially stucco, aluminum siding, and masonry severely impair RF propagation. High rise and multi-unit premises typically have meter rooms or meter banks that also represent substantial impediments to RF communication.

It has generally proven by Green Button¹⁵ and others that for applications which can add value to the consumption meter reading, it is more practical to obtain that information from the utility company via the Internet. Despite the argument that not all customers have internet access, a realistic study will generally show that the percentage of meters that cannot communicate into the customer premise may be even larger than the number of customers without internet access.

At the end of the day, debate over technical merits has been completely overwhelmed by the commercial success of WiFi, resulting in enormous development investment, low prices, and proliferation into almost every consumer device where there's a value proposition for communication, with the complementary success of Bluetooth taking up most of the rest.

Consumer products that have chosen WiFi over Zigbee include smart TVs, audio systems, home video surveillance and security systems, and even a few washing machines, dryers, and refrigerators. Smart thermostats are the most widely deployed home energy management devices and were once widely expected to be the beachhead for Zigbee in the home automation and energy management market but have succumbed to WiFi.

Some market statistics from 2015:

- 233,450 Zigbee enabled smart thermostats from eight companies sold in 2015¹⁶
- Nest is estimated to sell 100,000 WiFi thermostats per month¹⁷
- Ecobee,¹⁸ 2nd in the market behind Nest, sold 1 million thermostats in 2015¹⁹

Clearly, only about 10% of the smart thermostats sold in 2015 were ZigBee. Almost 90% were WiFi, a market share that has only grown larger since 2015.

2.3.2 Z-wave and CEBus

CEBus serves primarily as an example of a consumer electronics communication standard that has faded to obscurity. Introduced with much fanfare in 1992, almost all the consumer electronics companies signed on to what was standardized as EIA-600 and promoted as the "...foundation for future growth in consumer electronics."²⁰

¹⁵ Green Button, Department of Energy, <https://energy.gov/data/green-button>

¹⁶ 8 companies in the ZigBee-enabled smart thermostat market, Technavio, March 2016, <https://www.technavio.com/blog/8-companies-making-waves-zigbee-enabled-smart-thermostat-market>

¹⁷ Nest, Google's New Thermostat Company, Is Generating A Stunning \$300 Million In Annual Revenue, Yarrow, Business Insider, January 2014, <http://www.businessinsider.com/nest-revenue-2014-1>

¹⁸ About Ecobee, <https://www.ecobee.com/about/>

¹⁹ Thermostat Wars: With Help From Apple HomeKit, Ecobee Takes Number Two Place Behind Nest, Tilley, Forbes, September 2015, <http://www.forbes.com/sites/aarontilley/2015/09/28/thermostat-wars-with-help-from-apple-ecobee-takes-number-two-place-behind-nest/#57346ade1940>

²⁰ Interoperability Of CEBus Consumer Electronic Products, Gary, IEEE ICCE 1992, <http://ieeexplore.ieee.org/document/697224/>

Z-wave began as a proprietary technology developed by Danish company Zensys, later acquired by Sigma Designs in 2008. Z-wave has achieved notable adoption, boasting of more than 1700 products certified by May 2017.²¹ However, as with Zigbee, Z-wave is being challenged by the explosive growth of consumer products dominated by WiFi and is having to resort to hubs and gateways for interoperation.

Initial inroads to electrical device control by Zigbee and Z-wave devices from companies like Leviton have been challenged by devices like Belkin's Wemo® that operate via WiFi. The challenge has grown sufficiently that competitive pressures have lead companies Like Philips (Hue lighting) that started with Zigbee to offer hubs or gateways to WiFi and induced Leviton to introduce its Decora Smart™ product line with WiFi technology.

Beyond smart thermostats, the home automation leaders today are clearly Amazon Echo and Google Home, being closely chased by Apple's HomeKit – all WiFi-based, with no direct Zigbee or Z-wave support.

3.0 Communication Technology Time Horizons – A Challenge for Utilities

Legacy utility business models of a fixed return on assets for investor owned utilities are experiencing pressure for change from deregulation to distributed energy resources.²² Nevertheless, the industry remains structured around the core model of capital assets with operational lives of 30 years or more.

Utilities are sometimes described as resistant to new technology, but when need, capability, and cost converge appropriately technology adoption is rarely an issue. What *is* an issue that severely challenges the industry is technology that becomes stranded, leaving the industry with equipment or systems that are difficult or even impossible to maintain due to lack of availability of vendor support, repair or replacement parts, and ultimately lack of trained personnel.

Technology time horizons, especially for consumer technologies (which includes mobile telephony), are driven by relentless competition for better-faster-cheaper just even to survive, let alone flourish and achieve market leadership.²³ It's not so much that technology products cease to function; it's more that their value propositions are overwhelmed by the cost/benefits of the next generation, eventually leading to wholesale abandonment as focus and adoption shifts, thus leaving no manufacturers, no replacement parts, and little or no value left in the previous generation of technology. This plays out constantly among wireless carriers as they tout their network reliability, faster speeds, better coverage, and latest unlimited plans.

A technology must be mature, secure, and widely available before utilities can begin to deploy it. Utilities may deploy thousands or even millions of devices (the PG&E smart meter deployment was 7.5 million meters). That means technology must be in volume production. For technologies whose success

²¹ ZigBee vs Z-Wave for the IoT, Pink, IEEE Electronics 360, May 2017, <http://electronics360.globalspec.com/article/8625/zigbee-vs-z-wave-for-the-iot>

²² ENERGY DARWINISM: The Evolution of the Energy Industry, Channell, et al., Citi GPS: Global Perspectives & Solutions, Oct 2013

²³ Rapid Technological Change Is The Biggest Threat To Global Business, Morrison, Forbes, February 2017, <https://www.forbes.com/sites/nickmorrison/2017/02/09/donald-trump-is-not-the-biggest-threat-to-global-business/#23943d2a1b73>

is linked to consumer markets, wide availability is reached when a technology is more than 25% through its lifecycle (see Telecommunications Service Providers Must Evolve or Die below).

Utility rollout over an entire service territory typically takes 5+ years, including a planning cycle that selects available technology, accomplishes the feasibility testing, and obtains regulatory approval. Imagine a mythical grid device that used the original iPhone as a core component. By the time a utility would have been able to place the first purchase order the original iPhone would already have been no longer available.

4.0 Telecommunications Service Providers Must Evolve or Die

Despite the existence of extensive utility owned communication infrastructure, all utilities also use services and infrastructure from telecommunication service providers. Whether utility owned or SP owned, multiple generations of technology have been installed over many decades as need, technology capability, and cost have converged to make specific projects viable. The result is a multi-generational installed base that has obsolete elements well before the planned utility investment life cycle has completed.

SPs, of course, have their own version of the technology time challenges. SPs must build business models and operational organizations that can obtain and grow sustainable competitive advantage, competing for the individual customers that represent the majority of their business. The technology life cycle for telecommunications does not always mesh well with electric utility technology adoption and deployment life cycles, since it is mostly driven by consumer products, services, and choices.

4.1 TDM is Going Away²⁴

It's no longer news that SPs are discontinuing leased line services. Utilities are the largest installed base of analog 2/4 wire modem lines as well as TDM services like Frame Relay, SONET, etc. Equipment is obsolete, no longer manufactured, and no longer supported - without a functioning supply chain, utilities are relegated to buying spares on eBay.

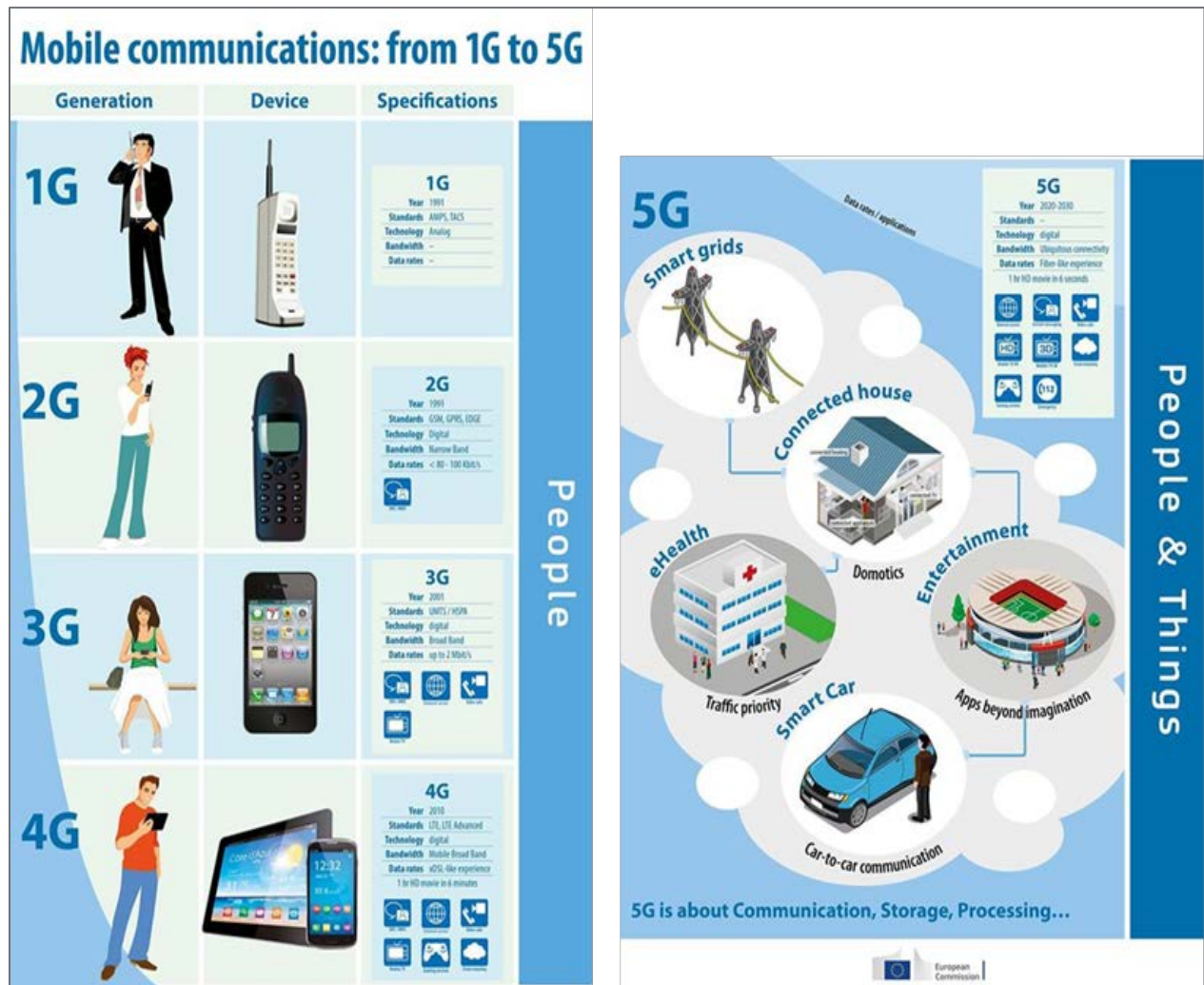
The entire telecommunication industry is at the end stages of a complete architectural transformation from circuit switched analog to packet switched digital technology. As with electric utilities, one of the major challenges has been the continuously shifting sands of technology evolution as they've tried to settle on technology and equipment that will last long enough to be deployed and not become obsolete or unavailable before a rollout is complete.

4.2 Mobile Telephony

Nowhere has the relentless shift in telecommunications technology been more dramatic than mobile telephony. It's hard to believe that mobile telephony had its introduction to the general public in the Americas with the Advanced Mobile Phone System (AMPS) in 1983.

²⁴ IP Transitions Issue Brief, Utility Technology Council, November 2016, https://utc.org/wp-content/uploads/2016/11/UTC_Issue_Brief_IP_TransitionNOV-2016.pdf

The original iPhone was introduced in 2007 and did not have 3G as service availability and chip set availability were not sufficient to enable Apple to sell and support their expectations of over a million devices, leading Apple to partner with AT&T on their earlier generation EDGE network. Figure 3 below illustrates five generations of wireless telecommunications technology.



The diagram is adapted from an infographic from One Europe that can be found at:

<http://one-europe.info/eurographics/from-1g-to-5g>

Figure 3. 1G to 5G Transition

Some observations:

- Successive generations mature about every 10 years
 - 1981 – AMPS, 1991 – 2G, 2001 – 3G, 2010 – 4G, 2020 (estimated) – 5G
- As each generation matures, equipment orders for previous generations diminish & chip vendors stop making chips
- Equipment becomes unavailable two generations back
- Service is discontinued three generations back. Examples:
 - AMPS and CDPD turned off in 2008

- 2G and GPRS turned off in January 2017
- The 5G date of 2020 is called the “early drop” in the 3GPP planning group and is the bare start of a service that will require completion of SP infrastructure buildouts for wide availability.

4.3 An Example from the Automotive Industry

Technology must be mature before automobile manufacturers make it available since they need high volume parts availability, reliable equipment suppliers and a stable, fully deployed infrastructure before they can equip hundreds of thousands or millions of vehicles. By the time automobile connectivity on a cellular network can be made available for sale, there will only be about five years left before the next generation of technology is introduced.

Utilities have the same issue but with a need for even longer time horizons.

4.4 Specific Utility Example

Just as the first digital PCS (2G) systems were being introduced (Sprint 1995), Cellular Digital Packet Data (CDPD) was being developed to take advantage of under-utilized spectrum in the 1G AMPS system. CDPD was heavily promoted to utilities and regulators for utility use in telemetry and automated meter reading. Offered by several AMR vendors, hundreds of thousands of CDPD meters were deployed in the late 1990s and early 2000s. Even before AMPS was turned off in 2008, manufacturers had already moved on to volume manufacturing of 2G and GPRS and were investing in active development of 3G.

Utility deployment of CDPD systems ended abruptly as the future discontinuation of that service became clear.

4.5 SP Drivers

Ultimately, although electric utilities are both important customers for SPs and a source of physical infrastructure for cell sites, *the primary business drivers for SPs are business and consumer mobile telephony*. They cannot afford to diminish their critical resources to sustain obsolete services for smaller customer segments. Competitive pressures for mobile telephony are intense and as the continuing merger and acquisition activity indicates, success is never assured.

Projected cellular telecomm industry revenues from the Utility vertical for 2018 are less than 0.2% of industry revenues reported in 2015.²⁵

Utilities represent a small percentage of overall SP revenue and cannot be a determining factor in SP decisions driven by technology advancement and competitive pressure.

²⁵ Estimated utility Vertical cellular revenue is projected to be \$7B in 2018, lowest in the categories presented after Healthcare at \$7.9B. To put that in perspective, a 2015 Boston Consulting Group study reported mobile industry revenue at \$3.3trillion. Sources:

- The Mobile Revolution: How Mobile Technologies Drive a Trillion-Dollar Impact, January 2015, Boston Consulting Group, https://www.bcgperspectives.com/content/articles/telecommunications_technology_business_transformation_mobile_revolution/
- Forecasted M2M (machine-to-machine) revenue by industry vertical in 2018, Statista, subscription required, <https://www.statista.com/statistics/270844/distribution-of-global-m2m-revenue/>

Similar circumstances prevail in competitive pressure for broadband service. Just as telephone companies have evolved from analog to digital, so have cable TV companies, who now deliver totally digital service at least to the neighborhood pedestal if not all the way to the customer premise. In any place that legacy technology still remains, increasing operating costs result from increasing maintenance, and scarcity of knowledgeable technicians and replacement equipment.

4.6 5G

Massive investment in R&D is being made for the next generation of mobile communications technology, 5G. METIS is a consortium of 29 partners coordinated by Ericsson and co-funded by the European Commission to lay the foundation for a future mobile and wireless communications system for 2020 and beyond. Figure 4 below is a pictorial presentation of their 5G architectural work.

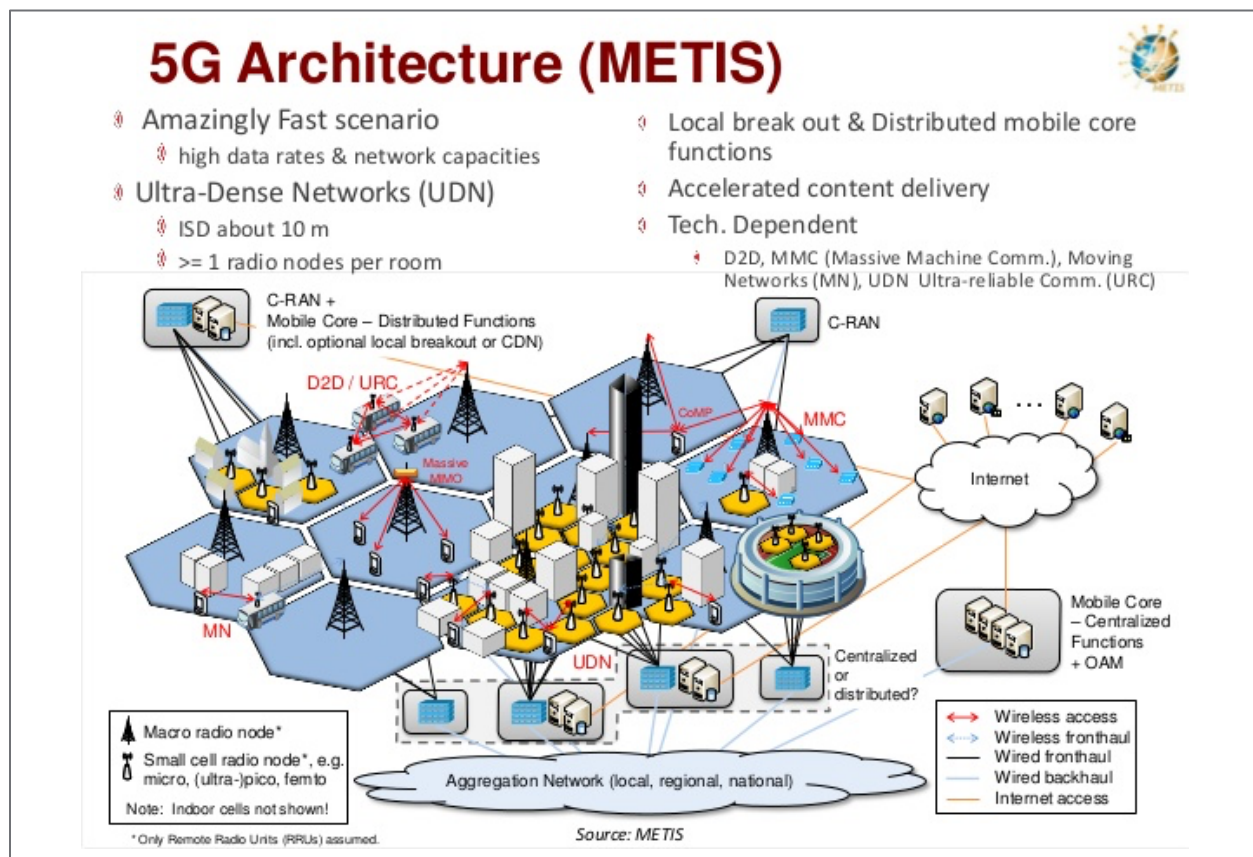


Figure 4. METIS 5G Architecture

In a June 2017 report,²⁶ Research and Markets concluded:

- “5G has not been fully standardised yet. But 5G is set to become a reality by 2020 and, for some MNOs by 2018. MNOs and equipment manufacturers are all in the starting blocks and trialling 5G.

²⁶ 5G Plans and Investments – Approaching the Starting Blocks, Research and Markets, June 2017, http://www.researchandmarkets.com/research/6q6svf/5g_plans_and

- *MNOs are trialling 5G in a wide range of frequency bands mostly ranging from 3 to 80 GHz in a trade-off between technical feasibility and consumer/use cases needs based on propagation characteristics. The most trialled bands are the 28 and the 15 GHz.*
- *Very high data rates are expected and 35 Gbps data rates and above have been demonstrated.*
- *5G deployment requires massive investments. Billions of euros of both public and private funding are needed to be at the forefront of 5G in the 2 years to come.”*

As 5G has not been fully standardized, it is at that stage in the hype cycle where everything that 5G *can be imagined to do* is discussed *as if it will do*. Many similar discussions have been part of every mobile communication generation,²⁷ an observation that could be made about new technology development in general, and the *raison d’etre* for the Gartner Hype Cycle.²⁸ Anything that wasn’t delivered by the previous generation is almost always rolled into what the next generation will provide.

A 5G roadmap from the Digiworld 2014 conference appears in Figure 5 below.

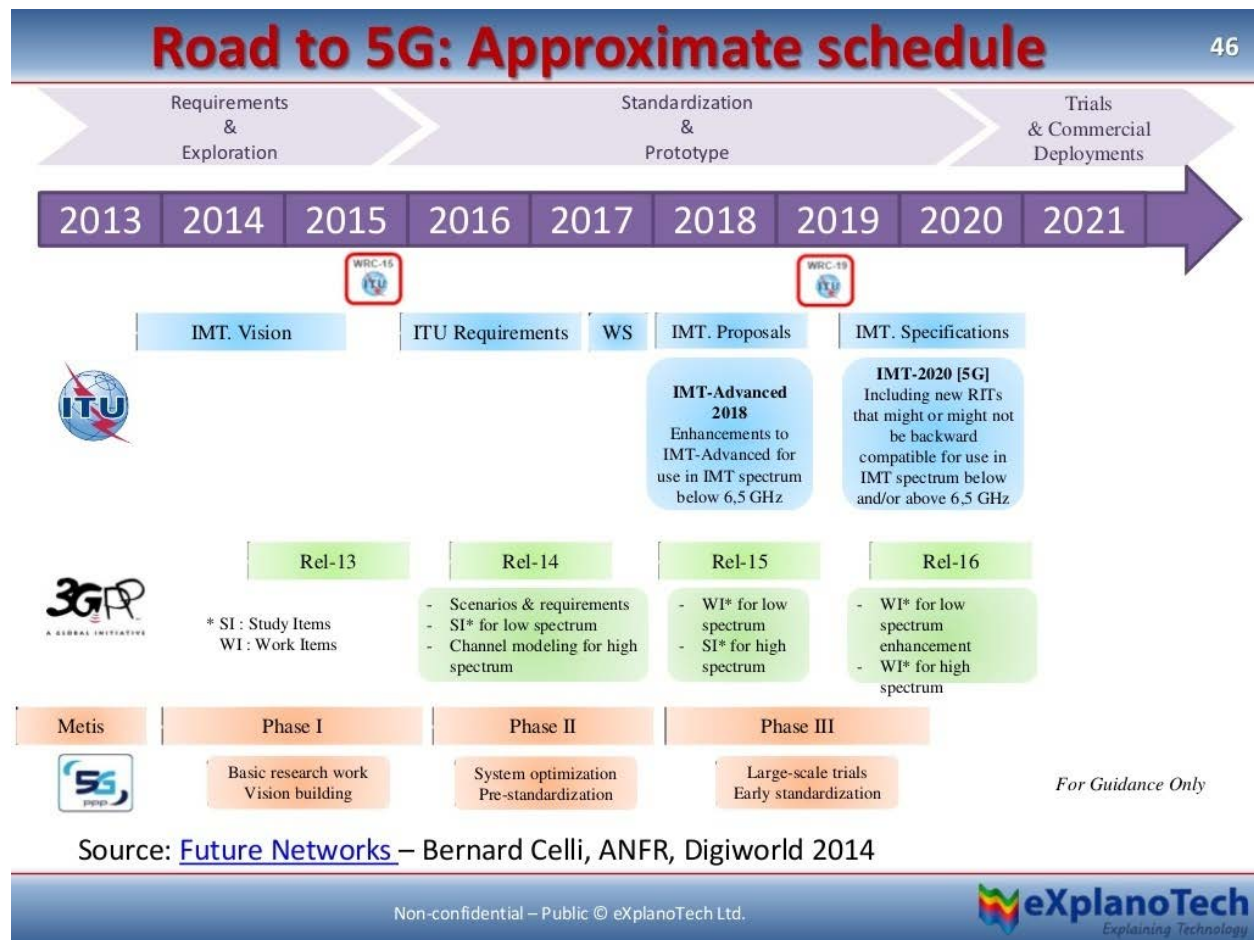


Figure 5. Roadmap for 5G

²⁷ The Evolution of Mobile Technologies, Qualcomm 2014, <https://www.qualcomm.com/documents/evolution-mobile-technologies-1g-2g-3g-4g-lte>

²⁸ Gartner Hype Cycle, <https://www.gartner.com/technology/research/methodologies/hype-cycle.jsp>

How is progress tracking that roadmap? The Mobile World Congress in March 2017 agreed to a work plan proposal for the first 3GPP²⁹ (the mobile communication industry consortium) 5G New Radio (NR) specification to be part of Release 15.³⁰ This specification is crucial to the design and manufacture of the RF integrated circuits required for 5G mobile phones. Release 15 appears to be on track to the timeline above, *but the fact that such fundamental issues as RF modulation and radio design are to be finalized in 2018 shows just how much work remains before the earliest deployments could begin in 2020.*

On their website at <http://www.3gpp.org>, 3GPP published a timeline for 5G citing early phase 1 5G deployment in 2019, shown in Figure 6 below.

At what phase will utility use of 5G become practical? Utility use of 5G must wait for production availability of 5G infrastructure wherever 5G services are required. Utilities would otherwise have to build their own 5G infrastructure and that's without even considering equipment or spectrum availability and permission or coordination with the Service Providers and their plans.

By the published schedules of 3GPP, only the earliest pilot deployments will be available in 2019. Other than pilot programs, the earliest conceivable utility deployments could not start before 2022.



Figure 6. 3GPP 5G Timeline

4.7 5G Implications for Utility Infrastructure

Beyond the necessity of waiting for the SPs to build out their 5G infrastructure, there are additional challenges for utility use of 5G. A good portion of 5G functionality – the number of devices that can be supported, support for IoT, support for peer-to-peer, high bandwidth, low latency, and connectionless services – rely on 5G's "small cell" architecture and use of high radio frequencies called "millimeter waves".³¹

²⁹ 3rd Generation Partnership Project, <http://www.3gpp.org/about-3gpp/about-3gpp>

³⁰ Ericsson touts CP-OFDM waveform for 5G NR, Allevin, Fierce Wireless, May 2017, <http://www.fiercewireless.com/wireless/ericsson-touts-cp-ofdm-waveform-for-5g-nr>

³¹ Everything You Need to Know About 5G, Nordrum, Clark, IEEE Spectrum, January 2017, <https://spectrum.ieee.org/video/telecom/wireless/everything-you-need-to-know-about-5g>

Small cells are portable, miniature base stations to be placed every 250 meters or so throughout cities. The use of millimeter wave radio spectrum means that the radio signals do not pass through walls and purposefully have very limited range so that frequencies can be reused with manageable interference.

One challenge for the electric utilities is that the SP deployment of cells would not be based on locations and requirements of the electric utilities and so may not provide the necessary coverage for electric utilities until late in the SP deployment cycle. Another challenge is that especially in dense urban areas, where small cells are most likely to be deployed, some of the electric utility infrastructure is below ground and inaccessible to millimeter waves from small cells.

4.8 Update on 5G as of April 2019

The foregoing analysis was done in 2017. Since then, some wireless service providers have started 5G rollouts and limitations have started to become apparent.

Access issues – Ars Technica recently conducted a test with the Verizon 5G rollout in Chicago. A key statement from the person who conducted the test: *“Even then, I still had to walk back and forth a few blocks to find the node. It's not like I automatically connected to 5G when I was in the area—I often needed line of sight to the node for the phone to connect.”*³²

“When contacted by Ars, Verizon VP of Network Engineering Mike Haberman acknowledged that coverage is limited now. But he said it will improve significantly as Verizon adds more cell sites and more spectrum and after it takes advantage of improvements in technologies such as beam-steering.

Haberman also said Verizon plans improvements in latency. Verizon in June 2018 said that 5G will bring “single-millisecond latencies,” but last week's Verizon announcement promised only that latency will be “less than 30 milliseconds.”

Coverage issues – T-Mobile and Verizon have recently commented on actual coverage plans and issues.³³ Some key quotes from the article:

“One day after T-Mobile CTO Neville Ray wrote that millimeter-wave spectrum “will never materially scale beyond small pockets of 5G hotspots in dense urban environments,” wireless industry analyst Craig Moffett asked [Verizon CEO Hans] Vestberg about Ray's statement during a Verizon earnings call. “We will need to remind ourselves, this is not a coverage spectrum,” Vestberg said.”

“Separately today, Moffett told CNBC that he thinks there is “zero chance” 5G becomes a ubiquitous technology by 2021.”

“Taken together, the T-Mobile and Verizon statements this week indicate that 5G's fastest speeds won't come to rural America and will be limited to certain areas even within big cities.”

³² J Brodtkin, In Verizon 5G launch city, reviewers have trouble even finding a signal, Ars Technica, April 8, 2019. Available online: <https://arstechnica.com/information-technology/2019/04/in-verizon-5g-launch-city-reviewers-have-trouble-even-finding-a-signal/>

³³ J Brodtkin, Millimeter-wave 5G isn't for widespread coverage, Verizon admits, Ars Technica, April 23, 2019. Available online: <https://arstechnica.com/information-technology/2019/04/millimeter-wave-5g-isnt-for-widespread-coverage-verizon-admits/>

“5G networks will use both low and high frequencies, but they're expected to offer their highest speeds on millimeter waves. These high frequencies generally haven't been used in cellular networks because they don't travel far and are easily blocked by walls and other obstacles.”

Given the above, it is clear that 5G will not have much impact on electric utilities before 2025, and in the light of the coverage statements, may never have much impact – certainly not outside of selected dense urban areas. The line-of-sight and barrier penetration issues are problematic for electric utility equipment. In dense urban areas, much of this equipment may be underground and even for above-ground devices line of sight to 5G nodes may be unavailable.

Due to the short wavelengths involved (the test referenced above used 28 GHz range spectrum), propagation and therefore connectivity can be a severe challenge. Latency involves a great many factors but while 5G should be an improvement over 4G/LTE, it is not clear what the service providers will actually achieve or guarantee. Finally, coverage by the service providers is driven by their primary customer bases, which do not include the electric utilities.

5.0 Technology Time Horizons Challenge Utilities

Technology must be mature, secure and widely available before utilities can begin to deploy. That means technology is in volume production and more than 25% through its lifecycle by the time a utility can realistically make a decision to deploy. Utility rollout typically takes 5+ years including planning cycle that selects available technology. That leaves about 10 years useful life for deployments that often have 20 year life expectations.

The major cost is not the technology hardware - it's the labor to touch each deployed unit and the organizational and customer costs of changing, perhaps even before a project is completed, leaving the utilities with a mixture of multiple technologies in deployment.

Cost points for digital electronics rely on purpose-built silicon chips in volume production. Programmable technologies such as software defined radios³⁴ (SDR) are sometimes discussed as a way to “future-proof” devices. But they are not cost effective in high volume and frequently not technically capable of meeting future generation requirements. A concrete example is the 3GPP Next Radio which specifies frequencies and signal processing that are simply beyond the capabilities of previous generation integrated circuits, programmable or not – so “software defined” is not an answer.

6.0 Conclusion

Opportunities and challenges abound in the adoption of new technologies for Grid Modernization. Specific planning and management of disparate lifecycles must be part of every utility project plan with specific risk and lifecycle analysis of products and services from any vendor. In some cases this may mean adjusting the expected lifecycle of a utility deployment. In other cases it may mean specific planning for technology end of life and transition to the next generation as an integral part of the project plan.

³⁴ Introduction to Software-Defined Radio, Keim, All About Circuits, February 2017, <https://www.allaboutcircuits.com/technical-articles/introduction-to-software-defined-radio/>

As exemplified by the Gartner Hype Cycle, we should expect that every technology up until its production deployment will be discussed as though it *will do* everything it *might do* - and then some. The realities of cost, time to market, and customer adoption ultimately dictate technology features and deployment.

The needs of Grid Modernization along with continuing increases in performance and decreases in cost of Information and Communication Technology clearly paint a future where utility usage of SP telecommunications will increase. 5G will undoubtedly have a role to play in that future, but that role will be limited to proof of concept and pilots until well after the first commercially available 5G service is announced, likely in 2019. Readers may recall advertisements for “the most reliable 4G network” and the “best LTE network coverage” as carriers invested billions in infrastructure build out that prioritizes those areas with the greatest revenue potential, i.e. dense urban populations. A 2017 study by Accenture³⁵ estimated 5G buildout to cost \$275 billion over 7 years, a massive project that is critically reliant on production equipment supply chains operating a full capacity. Given that standards are still being finalized, it is clear that this will be only in the very beginning stages by 2020 and utility usage would not occur at any significant scale before 2025. Given that many US utilities are making or are about to make commitments to modernization plans, with communications designs being one of the early decisions and roll-outs, it is clear that the timing of the SP 5G technology cycle and the 2017-2022 US distribution utility grid modernization cycle do not mesh well.

It will remain the case that utility industry needs will not drive SP technology generations or timelines and that utilities will continue to require purpose-built communication infrastructure for many of their critical needs.

³⁵ Wireless Operators in US to Invest \$275 billion to Build Out Nationwide 5G Network - Accenture Strategy, Sharma, The Fast Mode, January 2017, <https://www.thefastmode.com/technology-and-solution-trends/9791-wireless-operators-in-us-to-invest-275-billion-to-build-out-nationwide-5g-network-accenture-strategy>



902 Battelle Boulevard
P.O. Box 999
Richland, WA 99352
1-888-375-PNNL (7665)

<http://gridmodernization.labworks.org/>