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Program on Technology Innovation: Telecommunication Support for Extended Reality Wearables in the Field

An Introduction to 5G and WiFi 6 Wireless Field Communication Solutions for Extended Reality Wearables

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Technical Update, July 2020

EPRI Project Managers

T. Godfrey
J. Estrada

ELECTRIC POWER RESEARCH INSTITUTE
3420 Hillview Avenue, Palo Alto, California 94304-1338 ▪ PO Box 10412, Palo Alto, California 94303-0813 ▪ USA
800.313.3774 ▪ 650.855.2121 ▪ askepri@epri.com ▪ www.epri.com

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Principal Investigators
T. Godfrey
J. Estrada
M. Tinklepaugh

Contributor
N. McCollough

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ABSTRACT

Extended reality (XR) is a technology solution that might provide a benefit to the utility industry by enabling more efficient work practices. However, the communication requirements for such applications are not well known. In addition, the forecasted requirements indicate a need for 5G technology. This report examines currently available, 5G telecommunication technologies for the field. It also describes the fundamentals of WiFi 6 and its ability to support XR applications in the field. Also, relevant XR applications are identified and a use case for XR in the field is presented. Last, next steps in the research are presented with an action plan for future work in 2020.

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PRIMARY AUDIENCE: Wireless field-area network solution providers and engineers

SECONDARY AUDIENCE: Extended reality (XR) software and hardware developers

KEY RESEARCH QUESTION

As utility companies consider deploying XR solutions in the field, in what ways can telecommunications support these solutions, and what equipment is necessary to realize XR applications that require 5G communication requirements?

RESEARCH OVERVIEW

This research examined head-mounted, XR devices from two vendors and their capabilities to interface with wireless field-area network solutions. The approach of the research was to describe the features in the XR devices and to describe the features in emerging 5G and WiFi 6 technologies. In addition, 5G solutions from vendors already in use by the utility industry were documented, along with emerging chipsets.

KEY FINDINGS

- WiFi 6 and 5G technologies use a combination of advanced multiple-input-multiple-output techniques and beamforming to achieve increased network performance.
- Most of the vendor solutions examined use proprietary chip designs for their base station solutions.
- Many interoperable chip designs are intended for user equipment (UE), which is the edge device in a 5G network.
- XR equipment might have the capability to integrate cellular functionality into its design by using the existing modem chips.
- XR applications might not need full 5G functionality to operate effectively, and testing is required to validate this.

WHY THIS MATTERS

Because XR is a use case for 5G and WiFi 6, this report informs the utility industry of emerging 5G technologies that might support XR applications that have such a requirement. Furthermore, because current XR devices do not have 5G or WiFi 6 capabilities, the examination of their onboard modem chipsets informs a utility of the engineering effort required to design field-based, XR applications. Last, the information regarding 5G UE chips provides utility companies with information that they can use to engage existing XR device manufacturers to facilitate the production of devices that have the proper connectivity tools to fit their use case needs. Through the second half of this research, the Electric Power Research Institute (EPRI) will identify which currently deployed, XR applications require 5G or WiFi 6 connectivity and what possible applications could benefit from it.

HOW TO APPLY RESULTS

This report can be referenced for 5G communication parts, including many but not all 5G base station technologies, 5G UE chipsets, 5G base station chipsets, and 5G fixed wireless access parts. In addition to these, XR technologies are documented as well as some of their parts. Through this work, an improvised, low cost, scavenged approach to an XR field solution can be made possible by leveraging the components listed in the report with a telecommunications strategy to facilitate the build. This is especially relevant for low-budget telecommunication departments.

LEARNING AND ENGAGEMENT OPPORTUNITIES

- EPRI Technology Innovation Project: In-Plant CIM for XR.
- EPRI 161G Telecommunications Project: Network Management Systems

EPRI CONTACTS: Tim Godfrey, Program Manager, tgodfrey@epri.com; Joseph Estrada, Engineer/ Scientist II, jestrada@epri.com

PROGRAM: Information and Communication Technology, P161

Electric Power Research Institute
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com

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INTRODUCTION

Extended reality (XR) is beginning to solve several problems faced by industry participants. These include remote conferencing, maintenance support, and problem-solving applications for particular use cases. As more XR devices are connected to the network, utility telecommunication engineers will need to understand how the additional network traffic from these devices could affect their network operations, and they will need to understand whether their current equipment can support the network requirements of the devices. Furthermore, with the advent of 5G technology and the increased demand for network resources from newer XR applications, are utility telecommunication networks equipped to handle the extra traffic, and is 5G the only solution capable of delivering connectivity to XR devices in need of high throughput and low latency? This report introduces upcoming Electric Power Research Institute (EPRI) research on the topic, discusses the communication abilities of current, XR, head-mounted wearables, and identifies several emerging technologies that may enable the future of XR connectivity in the field.

Technology Innovation Research: XR Wearables in the Field

As utilities continue to deploy field-area networks to support their operations and their field staff, the communication requirements of the gear needed for field operations must be well understood in order to ensure the availability of an adequate amount of network resources. For some XR applications, these requirements may only be fulfilled by using a 5G network; however, with the emergence of WiFi 6, there may be other solutions available to utilities. This work will examine some of the network requirements of relevant, utility-focused XR applications to identify whether 5G technology is required for a successful operation of field-based XR applications. In addition to this, WiFi 6 will be examined as well in order to provide a comprehensive examination of the candidate telecommunication technologies. Last, as utilities consider the use of XR devices in the field, connectivity to the corporate network may provide challenges. Through this research, EPRI will attempt to identify any challenges that may arise from integrating these systems with a corporate network.

2
COMMUNICATION CHARACTERISTICS OF CURRENT, XR, HEAD-MOUNTED WEARABLES

For many applications, specific devices must be used due to environmental or ergonomic constraints. These can include hands-free requirements, financial requirements, or technical requirements. This work will examine the communication capabilities for head-mounted, XR wearables in order to identify solutions that may resolve the inability to use applicable, XR field applications. EPRI has previously identified several head-mounted, wearable, XR devices that are used in the augmented reality domain: Microsoft HoloLens and HoloLens 2; and RealWear HMT-1 and HMT-1Z1.

Since the focus of this research is to identify communication capabilities of current, XR, head-mounted, wearables, the information contained in this section will focus on the operating system, the input/output (I/O) capabilities, and the hardware architecture in order to focus on solutions that provide remote digital worker capabilities. Furthermore, EPRI will test and examine XR applications on these head-mounted wearables.

Microsoft HoloLens

Microsoft has been working on developing an augmented reality platform for several years. Their recent HoloLens platform is being updated into a HoloLens 2 platform that contains additional features. The HoloLens 2 is not widely available; however, the original HoloLens has seen wider deployment.

Windows Holographic Operating System

The Windows Holographic operating system can be purchased in a developer form or a commercial form, referred to as Windows Holographic for Business. These can be obtained by either purchasing the developer license, which is the standard operating system for the HoloLens series, or by purchasing a commercial license, which can be obtained by buying the Windows Holographic Commercial Suite.

Many utilities rely on secured remote connectivity for work processes. In order to be a fully secure, company asset, utilities may have to consider an operating system's compatibility with their existing corporate network solutions. In order to ensure that the HoloLens series of devices are capable of being integrated into existing networks, Microsoft has included features in Windows Holographic for Business that can enable successful integration into a Windows-based device and network management environment.

Windows Holographic for Business contains several key features that distinguish it from the developer version. These include VPN connectivity, device management capabilities using Windows Intune, a private app store for company applications, and an app access control mechanism, called *Kiosk Mode*. The HoloLens 2 ships with these commercial features and the ability to run Win32 applications, such as Word and Excel [1]. If these can be used with VBA, system-level communication functions can possibly be accessed.

Input/Output

The I/O hardware of the HoloLens varies between the models. The most notable of these, for field use cases, is the ability to connect Ethernet devices to the USB-C port on the HoloLens 2. The original HoloLens does not come with this capability. Because HoloLens literature explicitly mentions Ethernet usage with the USB-C port on the HoloLens 2 [2], it is possible that cellular support could be integrated without much internal work required on the HoloLens 2. This would enable the use of the HoloLens 2 in the field, where WiFi connectivity is not present.

However, WiFi connectivity is a means to provide field connectivity. Both the original HoloLens and the HoloLens 2 come with IEEE 802.11ac wireless communication modules; however, the HoloLens 2 uses a 2x2 multiple-input-multiple-output (MIMO) radio frequency (RF) channel scheme.

Computing Hardware

The main processing elements in the HoloLens series are the Holographic processing units (HPUs) and either the Qualcomm Snapdragon 850 computing platform (HoloLens 2) or an Intel Atom processor (original HoloLens).

Holographic Processing Unit

The HPU is a proprietary processing element within the HoloLens series of devices, and it is responsible for processing information obtained from sensors. The first version of the HPU, found in the original HoloLens, contains 24 Tensilica digital signal processing (DSP) cores. These cores are arranged in 12 clusters and created by a company, called *Cadence*, that makes intellectual property solutions for system-on-chip designs. The HPU also contains PCIe and serial interfaces for communicating with other components. The inclusion of a PCIe communication lane in the HPU may permit swappable PCIe components. Microsoft has stated in 2017 that the HPU 2.0 would include an artificial intelligence (AI) co-processor in order to natively implement Deep Neural Networks and provide AI processing [3]. However, exact details on how this is accomplished or which tools were used are being investigated.

Qualcomm Snapdragon 850 Mobile Computing Platform

The HoloLens 2 uses a Qualcomm Snapdragon 850 mobile computing platform, which differs from the original HoloLens Intel Atom processor in many ways. Most significant is that it is ARM-based (Advanced RISC Machines) and uses a heterogeneous computing architecture. Furthermore, the Snapdragon 850 contains an LTE modem: the Snapdragon X20. This modem can provide speeds of 1.2 Gbps in the downlink and 150 Mbps in the uplink. It provides WiFi connectivity through IEEE 802.11ad, 802.11ac Wave 2, 802.11a/b/g, and 802.11n [4]. However, it does not provide WiFi 6 connectivity. Nevertheless, Microsoft has released a Windows 10 Software Development Kit for ARM64 programs. Because of this, it would be possible to use the Snapdragon X20 to provide 4G LTE connectivity to the device but not 5G new radio (5G-NR) or 5G standalone (SA) connectivity; however, there are other Qualcomm products that do and they are discussed in more detail in Section 3.

RealWear HMT Series

RealWear has developed two head-mounted, XR systems: the HMT-1 and the HMT-1Z1. The HMT-1Z1 contains the same computing resources as the HMT-1, except the HMT-1Z1 contains additional ruggedization certifications and no longer has a USB Type-C port [5]. Also, the HMT-1Z1 contains software specific to operating in work environments where employees must use their hands more.

HMT Release 10

The HMT-1 and HMT-1Z1 use a software package, called *HMT Release 10*. This software package uses the Android 8.1.0 operating system and a software package, called *WearHF*, to enable hands-free usage of the HMT. In addition to this, the software can provide file management capabilities and features improved access to core Android capabilities than previous iterations. Furthermore, scrolling based on head movement is enabled as well as a menu-based and speech-based keyboard. Selection can be made with the user's voice.

In addition to the onboard software, RealWear uses a cloud service, called *Foresight*, in order to push updates. Some of the notable features of Foresight include the ability to add apps to device groups and enforce policies. Through the cloud service, administrators are able to apply policies for specific users and devices, and they are able to push specific apps to users and devices as well.

Qualcomm Snapdragon 625 Mobile Platform

The RealWear HMT devices use a Qualcomm Snapdragon 625 Mobile Platform that contains processing and communication elements. These include the utilization of an 8-core, 64-bit, ARM Cortex A53 processor in conjunction with an integrated Qualcomm Snapdragon X9 LTE modem. According to a Qualcomm 625 product brief [6], the LTE modem is capable of downlink speeds of 300 Mb/s and uplink speeds of 150 Mb/s. In addition to this, the platform enables LTE call continuity when using voice over WiFi but also supports voice over LTE. Furthermore, the Qualcomm Snapdragon 625 supports the WiFi standards: 802.11ac Wave 2, 802.11a/b/g, and 802.11n. Last, the platform can support dual subscriber identity module (SIM) capabilities and has 2x20 MHz carrier aggregation in both the uplink and downlink bands. Further details of the platform's specifications can be found in the Qualcomm 625 product brief [6].

3
5G TECHNOLOGIES

Vendor equipment to realize the next generation of wireless technologies consists of a set of similar features. These features are setting the stage for what a 5G-based field-area network may look like. Specifically, they focus on a MIMO antenna technology that can provide concurrent, different streams of traffic within the operating frequency band. Through this and advanced DSP technology, systems are able to increase their data throughput and reduce the latency for multiple users. For 5G, a specific implementation of MIMO, called *massive MIMO*, is being used to enable a larger number of streams to be used. A diagram illustrating MIMO can be seen in Figure 3-1.

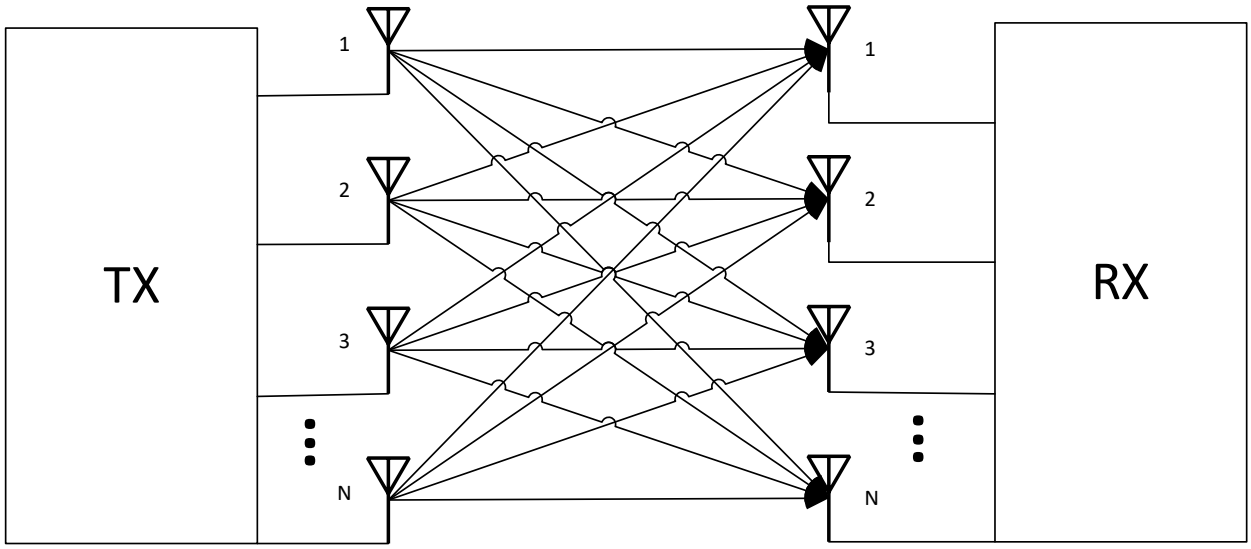

Figure 3-1
A diagram depicting a MIMO system

However, this is not the only technology enabling the future of 5G networks. A technique, called *beamforming*, is also being used by radio technologies in order to improve and receive signal level and connection reliability through the utilization of antenna arrays and phase shifted signals to create constructive or destructive interference. By enabling more users to have geographically exclusive channel access, throughput rates may be increased and latency may decrease, due to the reduction in channel access contention. A diagram depicting the functional characteristics of beamforming can be seen in Figure 3-2.

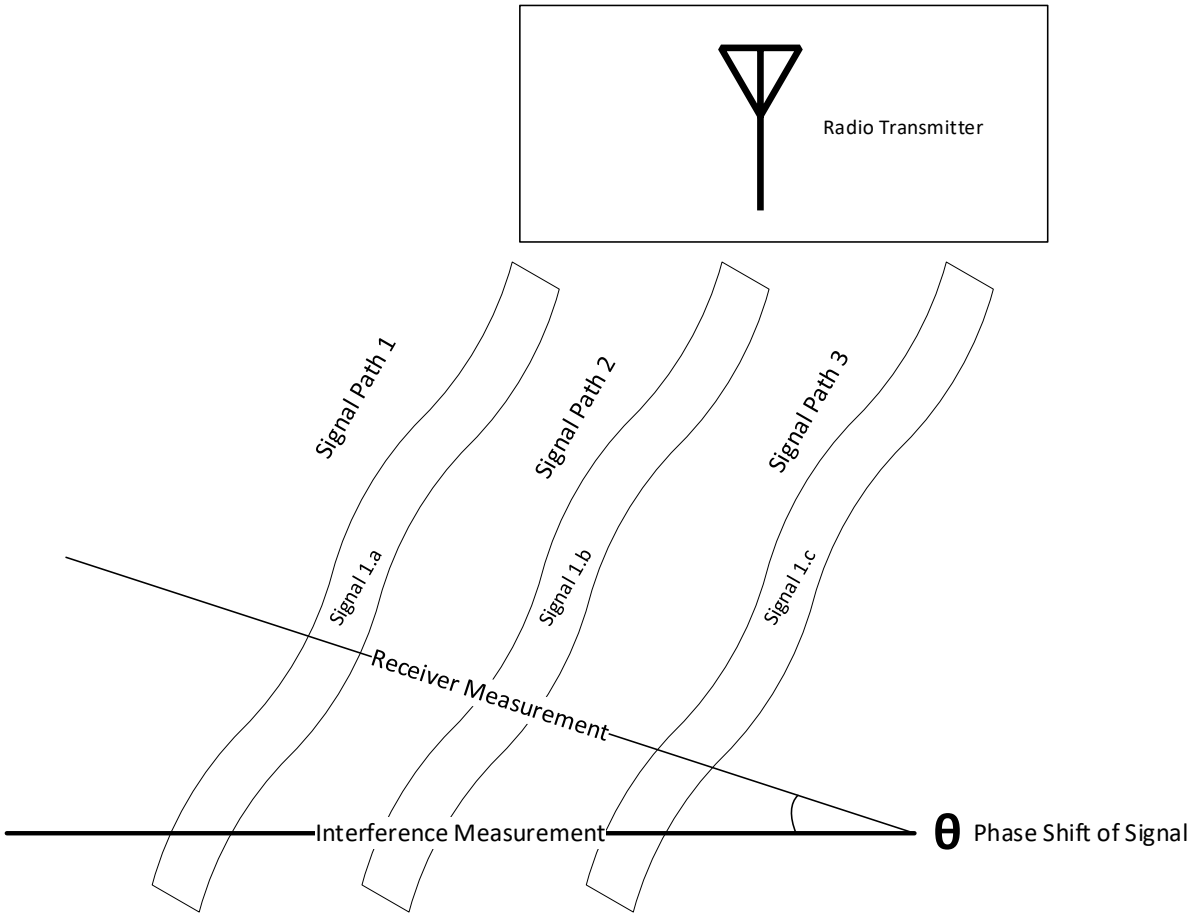

Figure 3-2
A diagram depicting the measurement method for phase shifted signals (This process is used for beamforming and distance calculations of devices.)

EPRI members are using several different vendor technologies in the field, which vary from utility to utility. Some of the vendors already in use in the utility industry have begun to create 5G equipment. This equipment may enable the use of XR applications that require a large amount of data to be transmitted over the network with reduced latency. However, XR technologies are not currently equipped with the necessary chipsets to enable 5G connectivity on the spectrum assigned for that purpose. As a result, relevant chipsets were also investigated in order to provide a picture of the future state of mobile 5G connectivity for XR devices. In addition to this, vendor technologies' 5G equipment has been examined, and specifics of their implementation can be found in the following sections. Ultimately, lab and field performance tests will guarantee their effectiveness for utility use cases.

Technologies with 5G Access

A 5G access is an important element for utilities who may consider migrating over to a 5G network in the future. Many of the technologies documented here have mechanisms in place to enable a transition from LTE to 5G. Furthermore, many of the fundamental radio access elements of the network, also known as the *radio access network (RAN)*, are still the same. For example, with both LTE and 5G, mobile UE and consumer premises equipment both communicate with a base station element. These base station elements, through innovative research, can take on many different forms. Specifically, a base station is composed of the analog radio element, called the *remote radio head (RRH)*, and the digital processing unit, called the *baseband unit (BBU)*. These elements were within one unit at one time; however, in order to enable a cloud-based RAN, they have been separated to provide a centralized digital processing element for many RRHs. This has been accomplished through advancements in optical networking through the utilization of standards, such as common public radio interface (CPRI) and enhanced CPRI (eCPRI). This technique is referred to as *fronthaul networking*.

The following technologies use fronthaul networking, and a vast array of different vendor technologies that use fronthaul networking are available. However, this report focuses on 5G technologies and the means by which they can enable XR applications that demand more resources from the field-area network than the current LTE technology that has already been deployed in commercial networks.

Nokia

Nokia is a vendor that has been used by the utility industry for several years. Their wireless products have also been widely deployed. Interestingly, they have leveraged their existing LTE technology implementations in their 5G equipment in order to enable backwards compatibility. Although they offer many components of the core network, this report focuses on the components within the 5G RAN. This is because utilities are positioned to leverage their LTE core with a 5G RAN. Doing so enables the earliest form of 5G (5G-NR), which comprises a 5G RAN and an LTE-based core network.

Nokia 5G RAN Technologies

There are three main devices that make up Nokia's 5G RAN technology portfolio, called *AirScale*. These are the AirScale Active Antennas, the AirScale Base Station, and the AirScale mmWave Radio. In addition to these, Nokia has developed a chip for their 5G systems, called the *ReefShark*.

AirScale Active Antennas

The AirScale Active Antennas come in two forms: the Compact Active Antenna (CAA) and the massive MIMO Adaptive Antenna (MAA). The antennas are an aggregate form of a typical passive antenna configuration, where the electronics of the radio and powering elements, such as the power amplifier, are combined into one unit. The CAA is a compact antenna that is designed for deployment scenarios where there may not be much space. In addition to this, the antenna uses a dual band radio to increase capacity.

The MAA uses massive MIMO technology and beamforming to enable improved coverage and higher capacity [7]. By doing so, Nokia claims that the number of cell sites required is reduced. For Nokia, 64 transmit and 64 receive MIMO streams are used. Currently, the devices support LTE networks but, through a software update, they are able to provide 5G-NR capabilities. According to Nokia, the use of massive MIMO technology with these devices enables them to provide similar coverage at higher frequencies as they can provide with lower frequencies [8].

AirScale Base Station

The Nokia AirScale Base Station is a device that has been designed to be backwards compatible with many legacy technologies, such as GSM, WCDMA, and LTE. They have created it to be compatible with another base station technology, called the *Nokia Flexi Base Station*. Nokia markets this as a feature that enables the technology for integration into existing telecom deployments. Furthermore, this device's software supports several different RAN deployment techniques: distributed RAN, centralized RAN, and Cloud RAN.

Nokia claims that the baseband module can attain speeds of 84 Gbps per unit, and the modules can be chained together to reach a total data rate of 6 Tbps [9]. In addition to this, the system is a triple band radio that can support carrier aggregation, massive MIMO, and beamforming. Last, the AirScale Base Stations have a power control element that allows certain network layers to be shut off during times of low traffic.

AirScale mmWave Radio

The AirScale mmWave Radio is a system that operates in the 28 GHz or 39 GHz frequency band. Due to the propagation characteristics of the mmWave spectrum, these systems are being marketed by Nokia for areas that have a large number of UE devices in use within a smaller area. Typically, these would include airports and stadiums.

Nokia FastMile—Fixed Wireless Access

The FastMile is a solution for 5G and/or 4G LTE access by using the cellular network as a backhaul network for an indoor WiFi solution. This solution is not mobile and is called *fixed wireless access (FWA)*. FWA-based 5G technology has been increasingly selected as a technology for delivering high speed Internet access to customers. FWA offers gigabit speeds similar to fiber Internet to the home, while avoiding the higher installation cost of burying fiber.

FWA can operate in 5G sub-6 GHz bands or in millimeter-wave bands above 24 GHz. While Samsung has introduced a gateway operating in mmWave bands, the FastMile gateway operates below 6 GHz. It supports 5G SA and non-standalone (NSA) modes with carrier bandwidths between 20 and 100 MHz and 4x4 MIMO on the downlink. It also supports dual connectivity, whereby the gateway can simultaneously connect to a 5G carrier and an LTE carrier (up to 20 MHz) and aggregate the throughput.

The FastMile Gateway offers local device connectivity by WiFi 5 (802.11ac) and gigabit Ethernet ports.

Ericsson

Information regarding Ericsson hardware is available in a limited manner on their public site; however, they mention several components used for implementing their 5G solution. The first is the Fronthaul 6000 series of optical network devices. These devices are used with eCPRI and CPRI standards to enable low latency, high throughput, fronthaul connectivity. In addition to this, Ericsson provides several massive MIMO wireless systems: AIR 6488, 5121, 6468. Although it is not explicitly mentioned, these systems in combinations with Fronthaul 6000 series devices may provide the BBU and RRH functionality needed for a field-area network cell solution.

Ericsson additionally provides a software solution called the *Uplink Booster* that is used to improve channel estimation and split lower layer analysis. Last, the Ericsson Radio Dot device is a radio that can provide small cell, indoor 5G connectivity. The Hybrid Fiber IRU 1649, IRU 8848, and RFX 1110 enable the backend network needed to provide this functionality. Data sheets and additional information on these devices are not readily available from Ericsson's public site.

Samsung

Samsung has produced several base station and UE technologies for 5G networks. These include BBUs that transfer unmodulated signals to end users, radio units that transmit and receive wireless signals, and chips. As a result, Samsung has developed a completely proprietary solution, like Nokia.

According to Samsung's website, the Samsung BBU CDU50 can process LTE and 5G signals in a single unit by allowing interchangeable cards that may be either 5G cards or 4G LTE cards. In addition to this, the CDU50 supports CPRI and eCPRI standards while also supporting distributed and centralized RAN architectures. In addition to baseband processing, Samsung has developed MU-MIMO radio systems that can operate in every 5G spectrum. Furthermore, they are capable of splitting their MIMO streams between LTE usage and 5G usage.

Samsung has developed chips that they use for their radio systems. These chips are proprietary digital-to-analog converters, called *digital/analog front end, application-specific integrated circuits*, which are capable of converting from digital to analog and from analog to digital. Their UE 5G modem is the Exynos Modem 5100.

The 5G Chipsets

5G technology is being built around several different chipset technologies that have been developed by several different companies. Through this research, EPRI has identified four chip companies that have marketed 5G chipsets. These are Qualcomm, Nokia, Telit, and Samsung.

Qualcomm

Qualcomm is well-known for its communication chips and Snapdragon computing platforms, which have gained more widespread usage. For 5G, Qualcomm has developed communication chips for automotive systems and more general radio applications. These are the Snapdragon X55 5G Modem-RF System and the Snapdragon Automotive 5G platform. These systems are used in several Qualcomm solutions, such as the Snapdragon 865 Mobile Platform. Furthermore, Qualcomm antenna modules are also used with these systems to provide 5G UE radio connectivity. These include the QTM527 mmWave Antenna Module and the second generation QTM 525 mmWave Antenna Module, which are used for UE designs and mobile devices.

Snapdragon X55 5G Modem-RF System

The Snapdragon X55 Modem-RF System is a second generation 5G modem that supports mmWave spectrum and sub-6 GHz spectrum. Both spectrum configurations use MIMO technology, and the chip supports SA and NSA 5G modes. Furthermore, the chip is designed to support LTE and other legacy technologies, such as 3G and 2G, while also supporting dual SIM technology. Last, Qualcomm uses this system in its Snapdragon 8cx Compute Platform and its Snapdragon 865 Mobile Platform to build out 5G UE solutions.

Snapdragon Automotive 5G Platform

The Snapdragon Automotive 5G Platform is a 3GPP Release 15 compliant system that supports LTE, 5G SA and NSA, and concurrent, multi-frequency, multi-constellation GNSS. The system is marketed as enabling ultra-low latency below 1 ms with dual SIM capabilities and MIMO technology. Furthermore, the system has been designed to support cloud-based V2X (vehicle-to-something) technology. Although designed for automotive use cases, it may be possible to extend its capabilities to systems that require its functionality in the utility industry.

Telit FN980m

The Telit FN980m system is designed to support 5G SA and NSA, LTE, and GNSS connectivity on sub-6 GHz and mmWave spectrum. It is capable of being used on Windows and Linux operating systems while also using PCIe and M.2 technology to enable connectivity with popular computer bus systems. In addition to these, it has been designed to be compatible with the Qualcomm QTM525 and QTM 527 Antenna Modules while offering the ability for MIMO calculations. Due to its ability to interoperate with different technologies, it may be suited for more specific utility solutions. Testing would be necessary to verify this.

Nokia ReefShark

The Nokia ReefShark is a chip portfolio that contains many different chips:

- The ReefShark digital front end for LTE and 5G radio systems
- The ReefShark radio-frequency integrated circuit and transceiver
- The ReefShark integrated transceiver
- The ReefShark baseband processor

These chips are designed in accordance with the 3GPP 5G-NR specifications while providing real-time AI processing and reducing MIMO antenna size. According to Nokia's executive summary documentation, the ability of these devices to continually learn through the interpretation of live data enables them to improve beamforming capabilities, network optimization, and overall system performance [10]. Furthermore, these chips have been designed to reduce energy consumption, although it is unclear how this is accomplished and how they perform compared with Qualcomm, Telit, and others.

Samsung Exynos Modem 5100

The Samsung Exynos Modem 5100 is a 5G modem for UE devices. Specifically, Samsung has been using the chip for smartphone development. This chip supports 5G in sub-GHz and mmWave spectrum, as well as LTE, 3G, and 2G technologies. Detailed technical specification regarding the bus used on the motherboard is not well documented on their public website, and, as a result, it is unclear whether the chip is interoperable with other vendor chipsets.

4
WIFI 6 TECHNOLOGIES

WiFi 6™ is the WiFi Alliance™ brand name for the latest version of WiFi, based on IEEE 802.11ax. Instead of focusing only on increasing the raw data rate (the speed delivered to a single user), this amendment focuses on improving spectrum efficiency (the aggregate rate delivered to multiple users, and larger numbers users per unit of area). This has been accomplished while improving power efficiency. The 802.11ax defines new modes of operation similar to LTE, such as multi-user MIMO and Orthogonal Frequency Division Multiple Access (OFDMA). The benefits of 802.11ax will affect utility users of 802.11 from the enterprise to field and sensor applications. This standard defines the next generation of 802.11 devices that are widely used for both IT and operational purposes.

WiFi 6 provides throughput improvements (compared to WiFi 5/802.11ac), resulting from 1024-QAM modulation, narrower subcarrier spacing, and more flexible PHY timing parameters. WiFi 6 can achieve peak data rates of 1 Gb/s for multiple users connected to an AP. At the physical layer level, an apples-to-apples comparison between generations can be made, as shown in Table 4-1.

Table 4-1
A data rate comparison between WiFi 5 and WiFi 6

WiFi Generation	80 MHz, 1 Spatial Stream No MIMO	160 MHz, 8 Spatial Stream MIMO
WiFi 5 (802.11ac)	433 Mbps	6933 Mbps
WiFi 6 (802.11ax)	600.4 Mbps	9607.8 Mbps

Efficiency Improvements

Despite the rate increase, the primary focus is on improvements in efficiency for multiple concurrent users. The use of OFDMA allows WiFi 6 to optimize the efficient use of the spectrum. It reduces contention and overhead, thus reducing delays and latency. As seen in Figure 4-1, the use of OFDMA significantly reduces overhead due to packet headers and contention.

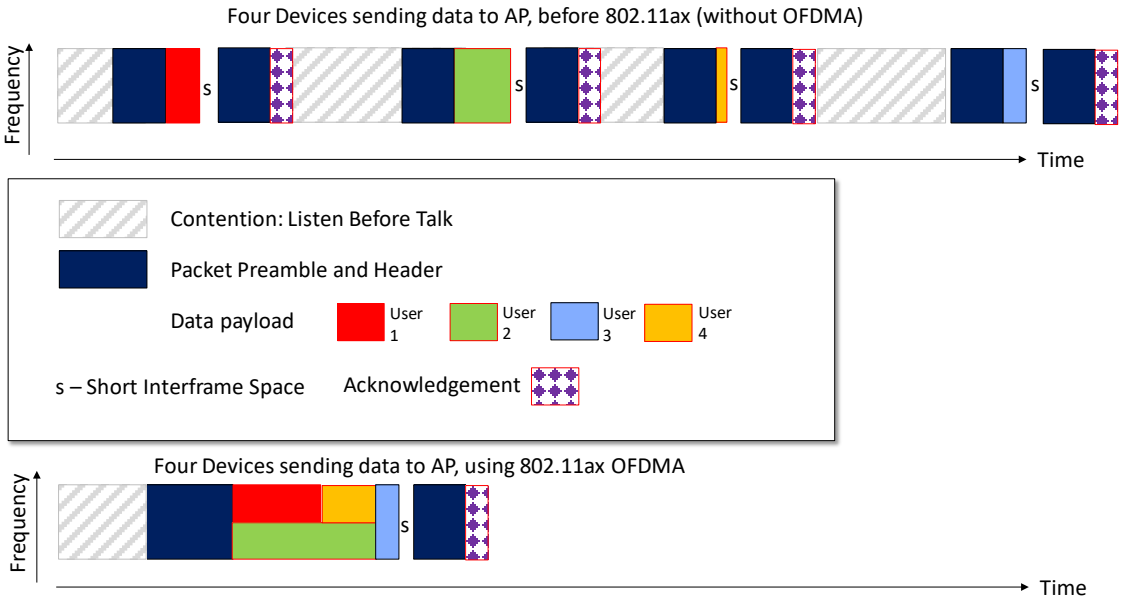

Figure 4-1
Efficiency improvement from OFDMA

In earlier versions of WiFi, each device transmission used the full frequency range of the channel. With wide channels (80 and 160 MHz wide), a large amount of data can be contained in each symbol of the OFDM waveform. For small or medium data packets, only a few symbols are needed, and time spent on contention and the frame's header and preamble dominate the total duration of the packet. This results in low efficiency.

With 802.11ax OFDMA, the channel is segmented into sub-channels that can be allocated in both the frequency domain and the time domain. The minimum unit of time and frequency is called a *resource unit*. Devices sending data to the AP are scheduled to transmit at a specific frequency range and specific time, based on the amount of data they have ready to transmit.

Multi-user, multiple-input, multiple-output (MU-MIMO) is another technique that increases spatial reuse of the spectrum. MIMO uses multiple antennas and signal processing to exploit variations in the RF environment to increase capacity. A simplification is to think of a signal taking both a direct and reflected path. With MIMO (and beamforming), different data can be sent over the direct and reflected paths, increasing the overall capacity of the same frequency band. While MIMO has been used in prior generations of WiFi, 802.11ax introduces MU-MIMO in the uplink. This provides additional spatial reuse, as MIMO can allow data from multiple devices to transmit on the same frequency at the same time and be correctly decoded by the AP.

The 802.11ax introduces new features to improve interoperation of overlapping networks or independent networks in the same area (BSS coloring mechanism). Other new features improve low power operation by extending devices' ability to sleep by defining a target wake time.

What Does WiFi 6 Mean for XR Connectivity?

WiFi 6 is optimized for live streaming and virtual/augmented reality applications that generate high volumes of traffic, particularly when that traffic is created simultaneously. The use of MU-MIMO brings further gains in capacity by allowing multiple devices to transmit simultaneously over the entire channel when they are moving larger data volumes, such as a video. Using multiple antennas to separate and receive the signals, MU-MIMO enables higher quality video streaming. OFDMA and MU-MIMO complement each other to make WiFi 6 more efficient, optimize operation with a larger number of devices, while maintaining the highest per-user throughput.

5
XR FIELD APPLICATIONS

Current Applications

There are two types of headsets that could be worn in the field. One type, such as the head-mounted table headset, presents a graphical overlay to one eye. Another type, mixed reality headset, presents graphical information to both eyes. Both types have their strengths and weaknesses in different contexts. Both types can be classified as *extended reality*, a term encompassing the placement of computer graphics on a camera feed over the human visual system. The head-mounted tablet is typically more rugged and has more components that can be plugged in. It is useful for presenting quick glance instructions, video, and data entry user interfaces. The mixed reality headset is more immersive and gives the user a sense of depth. It is useful for experiencing a lot of detail for 3D objects during training.

Examples of Head-Mounted Tablet Applications

Two comparable head-mounted tablet applications are Augmentir and Librestream. Some of the features for these two applications are checklists, notifications, and videos for the completion of procedures. The ability to capture video during work in the field may increase the documentation of common issues across various field work being performed. This transmission of video may be data intensive.

Examples of Mixed Reality Applications

Two comparable mixed reality applications are Scope AR and Trimble Mixed Reality. Both allow wearers to interact with 3D models in their environment. This allows users to experience information spatially the way the might with normal everyday objects. This dynamic allows for workers to rehearse situations, such as installing or maintaining equipment in the field.

Future Applications That May Require 5G

XR enables new ways of interacting with information. Data visualization typically occupies two dimensions by virtue of the fact that flat surfaces are the main medium that humanity has had to transfer graphical analysis. This is not to say that charts should be made three-dimensional. Principally, the least amount of information required should be used to convey a quantitative difference. However, depicting graphs in three dimensions may serve as a temporary visual metaphor by which to scaffold new ways of communicating numerical data analysis. One example of this is HoloGraphing, a visualization tool that can show complex data plots. Another forward-thinking application is Real Time Operations. This application visualizes what it might look like to see information layers in three dimensions.

These are two types of applications that enable a user to walk through abstract information anywhere they go rather than sitting in front of a traditional computer. These visualizations can be physically anchored to the environment in ways that traditional computers can’t. Because of this, the opportunity for advanced XR applications that associate data with an object in physical space is possible, enabling a more informed, capable workforce when they arrive on site. Connected through a secure network, network management software can be used in conjunction

with the edge applications to provide a central database for network performance statistics. In order to react to network conditions in a timely manner, the 5G ultra-reliable low-latency communications technology would need to be developed and available. Therefore, as stakeholder participation in this research increases, identifying software and hardware sources capable of delivering this vision will continue.

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NEXT STEPS IN THE 5G FOR XR PROJECT STRATEGY

There are many options to consider when deploying a field-area network for XR applications, and, because of this, EPRI will deliver a final report detailing the various 5G and WiFi 6 deployment architectures, as well as the performance results for the applications when using these different deployment architectures. Forecasting beyond this initial project, EPRI will be positioned to isolate the minimally required network architecture to ensure reliable XR application performance while also continuing to identify and test future-state XR applications and hardware. Through this effort, the utility industry will be positioned to:

- Cut down on the purchase of expensive network equipment by focusing the research on their direct network needs for XR use cases
- Leverage EPRI's expertise to predict their future network requirements to support future-state XR applications
- Provide recommendations to the XR industry for hardware improvements that can grow the XR market and directly support utility use cases

For the remainder of 2020, this project will evaluate the network requirements of readily available XR applications in order to identify whether or not they require 5G technology. By doing so, utility companies that may want to support XR field applications will be able to pair their current field-area network technologies with the performance requirements of the applications being tested. In addition to this, EPRI will identify a set of future-state applications that may have more stringent network requirements, while also recommending improvements to the XR hardware in use. As stated earlier, this will benefit the XR and utility industry by increasing the XR market and enabling more effective performance of work tasks in the utility industry by facilitating engagement to fulfill their XR use case needs.

Because WiFi 6 is also a leading communications technology that may provide similar performance to 5G, several test scenarios are being considered with its use as well. The benefit of using 5G and WiFi 6 technology for this research is that it provides not only the highest performance wireless network for the application evaluation, but through this testing, EPRI can also provide deployment considerations for both 5G and WiFi 6 technologies in the final report.

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REFERENCES

1. Microsoft. Discover: Get Started with Mixed Reality. August 24, 2019, pg. 30. Available at: https://docs.microsoft.com/en-us/windows/mixed-reality/.
2. Microsoft. HoloLens. October 14, 2019. Available at: https://docs.microsoft.com/en-us/hololens/.
3. Microsoft. Research Blog: Second Version of HoloLens HPU Will Incorporate AI Coprocessor for Implementing DNNs. July 23, 2017. Available at: https://www.microsoft.com/en-us/research/blog/second-version-hololens-hpu-will-incorporate-ai-coprocessor-implementing-dnns/.
4. Qualcomm. Snapdragon 850 Mobile Compute Platform. 2020. Available at: https://www.qualcomm.com/products/snapdragon-850-mobile-compute-platform.
5. RealWear. RealWear Knowledge Center. HMT-1 and HMT-1Z1 Product Guides. 2020. Available at: https://www.realwear.com/knowledge-center/.
6. Qualcomm Snapdragon 625 Processor. Product Brief. 2014–2016. Available at: https://www.qualcomm.com/media/documents/files/snapdragon-625-processor-product-brief.pdf.
7. Nokia. Nokia AirScale Active Antennas Brochure. No date. Available at: https://onestore.nokia.com/asset/201018.
8. Nokia. Nokia 4.9G Massive MIMO Executive Summary. 2018. Available at: https://onestore.nokia.com/asset/201128.
9. Nokia. Nokia AirScale Base Station Brochure. 2018. Available at: https://onestore.nokia.com/asset/200024.
10. Nokia. Nokia ReefShark Executive Summary. 2018. Available at: https://onestore.nokia.com/asset/201854.

Bibliography

2019 Extended Reality Guidebook: Digital Transformation for Training and Telemetry. EPRI, Palo Alto, CA: 2019. 3002017159.

5G and Cyber Security for Utility Operational Technology Environments: Initial Assessment and Potential Outcomes. EPRI, Palo Alto, CA: 2020. 3002017835.

Knowledge Transfer Using Extended Reality. EPRI, Palo Alto, CA: 2020. 3002017905.

Quick Insights: Fifth Generation Wireless—Utility Opportunities and Challenges in the 5G Transition. EPRI, Palo Alto, CA: 2018. 3002014789.

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Electric Power Research Institute
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com