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Wireless Infrastructure Analysts

5G Fixed Wireless Gigabit Services Today

An Industry Overview

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Executive Summary

This white paper discusses the advantages of using millimeter wave (mmWave) technologies, such as those being developed for the fifth generation (5G) of mobile telecommunications, to deploy fiber-like, Fixed Wireless Access (FWA). 5G FWA can provide gigabit broadband service using both licensed and unlicensed mmWave spectrum, making it an ideal option for both small and large internet service providers (ISPs). Furthermore, since the cost and speed of 5G FWA infrastructure deployment easily beats the cost and time required to extend fiber-optic cables straight to the premises (fiber-to-the-premises, FTTP, or fiber-to-the-home, FTTH), 5G FWA allows fiber networks to easily be deployed and scaled without compromising broadband speed or reliability.

The use of mmWave spectrum offers service providers an excellent opportunity to stay competitive considering ineffective, monopolistic broadband services in the U.S. In 2016, the U.S. Federal Communications Commission (FCC) released a report that concluded that “advanced telecommunications capability is not being deployed to all Americans in a reasonable and timely fashion.” A large contributing factor to this problem is the domination of spectrum by large ISPs like Verizon and AT&T. While these companies have managed to purchase a significant portion of licensed mmWave spectrum, such as the 28 GHz band, the FCC has allocated 14 GHz of contiguous unlicensed spectrum in the 60 GHz V-Band. This gives small ISPs the chance to utilize mmWave technology without the large cost needed to purchase licensed spectrum.

Using unlicensed or lightly-licensed mmWave frequencies, such as the 60 GHz V-Band or 70/80 GHz E-Band, is therefore a cost-effective choice for deploying fiber-like 5G FWA. Commercial mmWave radios are capable of operating in a point-to-point (PtP) or point-to-multipoint (PtMP) topology to deliver gigabit broadband to businesses, Multiple Dwelling Units (MDUs), and single-family homes and are currently available for deploying 5G FWA. In addition to the cost, time, and scalability advantages of 5G FWA (as opposed to FTTH), a multitude of 5G trials and deployments have validated the technology for 5G FWA. Even though the final 5G standard isn’t expected until 2020, many service providers around the world plan to roll out pre-standard 5G networks as early as 2017. As the technology has been demonstrated and offers several advantages, including gigabit throughput and inexpensive infrastructure, 5G FWA solutions present an appealing option for service providers looking to extend their coverage and compete with larger ISPs.

As demonstrated in the business cases presented in this white paper, mmWave is the most cost-effective solution in both single units and multi dwelling units – deployment scenarios. But carriers don't have to choose between mmWave and fiber, they need both since these technologies complement each other to provide the most cost-effective solution under the Hybrid Fiber-Wireless (HFW) model.

The HFW is a disruptive model for providing GTTH built on proven technology. This model adds high frequency wireless radios to a fiber network, drastically reducing deployment costs, time to install and offers the potential to provide multiple gigabits directly to the consumer. Simply put: by using HFW, providers can deploy gigabit first and for much cheaper than competitors. Using an HFW connectivity model in a residential market will result in a quantum leap in profitability.

1. Background

1.1 Broadband Access Challenges in the US

Broadband internet service in the U.S. has been plagued by uncompetitive practices. Large, nationwide internet service providers (ISPs) have built monopolies that prohibit innovation, drive down levels of service, and block competitors from entering the market. In their 2016 Broadband Progress Report[1], the Federal Communications Commission (FCC) found that only 38% of Americans have more than one choice of broadband provider, and only 10% of Americans have access to broadband speeds of up to 25 Mbps downlink/3 Mbps uplink. Many Americans lack access to broadband internet entirely, especially in rural areas: 39% of rural Americans, 4% of urban Americans, and 41% of Americans living on Tribal lands do not have access to broadband services. Considering these factors, the FCC concluded that "advanced telecommunications capability is not being deployed to all Americans in a reasonable and timely fashion."

Compounding this issue is the ever-increasing consumer demand for broadband access. Online media continues to grow in popularity, and as a result, many wireline and cable service providers are experiencing customer churn. In the first quarter of 2017, 612,000 Americans cancelled their pay-tv subscriptions (referred to as "cutting the cord"), and an additional 10.8 million pay-tv subscribers are predicted to cut the cord by 2021[2]. As pay-tv gives way to online subscription services, the need for fast and reliable broadband internet is vital as slow internet with and low capacity results in buffering that is unacceptable by customers when watching online TV programs.

1.2 A Growing Opportunity

Some organizations have attempted to provide a better broadband option to consumers through the deployment of fiber-optic networks. For example, Google Fiber, announced in 2010, offers fiber-to-the-home (FTTH) high-speed broadband internet with downlink speeds of up to 1 Gbps[3]. Verizon Fios is another FTTH fiber solution that offers high speed broadband, up to a “Fios Gigabit Connection” of 940 Mbps down/880 Mbps up[4]. Such networks serve to raise consumer expectations of broadband internet, pressuring ISPs to improve service. However, deploying fiber networks is a slow and expensive process, with an installation cost estimated to be approximately $1000 per home[5]. Accordingly, despite the high speeds available with fiber, time and cost expenses prohibit fiber as a practical broad band remedy.

Therefore, to overcome the problems of anti-competitive ISPs and increasing demand for high speed broadband services, a new solution is required. A promising option is to adopt millimeter wave (mmWave) technology, which covers the spectrum from 30 – 300 GHz, to deploy fixed broadband wireless solutions. In 2015, the FCC proposed licensing for spectrum bands in the mmWave range, including 27.5 – 28.35 GHz, 37 – 38.6 GHz, 38.6 – 40 GHz, 57 – 64 GHz, and 64 – 71 GHz to prepare for future Fifth Generation (5G) mobile services[6]. Though mmWave bands show potential for future broadband services, many of them suffer from the existing problem of ISP monopolies. With recent multi-billion-dollar acquisitions of smaller providers, large ISPs like AT&T and Verizon have already begun dominating ownership of mmWave bands. Together, these two companies own over 50% of available licensed mmWave spectrum in the U.S.7 [8].

However, service providers that can’t afford the cost of licensed mmWave bands have another option: the use of unlicensed mmWave bands, such as the 60 GHz V-Band. With 14 GHz of contiguous spectrum available, and commercial chipsets and products already developed for this band, providers can deploy gigabit-to-the-home (GTTH), fixed wireless access (FWA) for nothing more than a minimal cost of infrastructure[7].

Thus, the unlicensed 60 GHz V-Band offers service providers an excellent opportunity to offer competitive gigabit services.

1.3 Market Potential

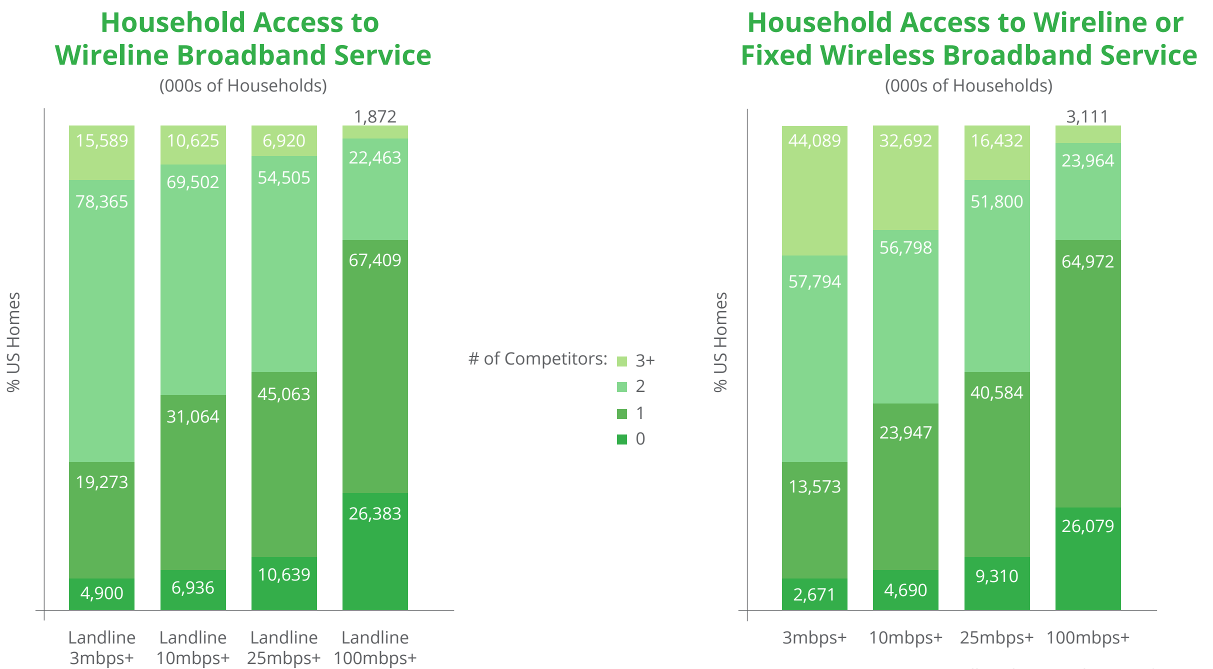
There are close to 126 million households in the US, out of which 106 million have some form of broadband. However, as we saw previously, only a very small fraction have access to 21th century broadband above 100 Mbps which is required to empower users with the emerging applications in the connected home including 4K and 8K televisions, virtual reality, IoT, and the proliferation of user devices. In other words, homes are rapidly becoming high density wireless environments which require way beyond 100 Mbps connectivity.

FCC reports have found that about three-quarters of the country's developed census blocks lack any high-speed broadband choice. The household analysis found a slightly better, but still troubling, situation, with nearly half of the 118 million US households lacking any wired internet choice at the FCC's broadband standard of 25 Mbps. (One caveat: this new analysis examined only download speeds, whereas FCC reports define broadband as services offering both 25 Mbps download speeds and at least 3 Mbps uploads). With the growing popularity of 4k streaming which requires up to 25Mbps for single TV, the 25Mbps connectivity is increasingly becoming insufficient to cover the connectivity needs of users and inside the US home.

Deloitte Global predicts that the number of Gigabit per second (Gbps) Internet connections will surge to 10 million by year-end, a tenfold increase, of which about 70 percent will be residential connections. Looking further ahead, analysts forecast about 600 million subscribers may be on networks that offer a Gigabit tariff as of 2020, representing most connected homes in the world.

Gbit/s Internet connection might appear frivolous, but a decade ago some commentators may have questioned the need for a touchscreen-based device capable of transmitting data at 150 Mbps, with storage for tens of thousands of HD photos, video quality sufficient for broadcast, a pixel density superior to most TV sets, a secure finger-print reader, and billions of transistors within a 64-bit eight core processor. While this prediction focuses on the near term, and the Gbps era, it is most likely that the speed race will not conclude upon reaching this speed.

Figure 1: Broadband Access by Speed and Competition



Broadband access data as of June 2016

Note that these statistics represent the minimum broadband speeds – faster broadband of up to 1 Gbps will come to represent the new normal. Therefore, there is quite a large market opportunity to offer higher speed services to both urban, suburban, and rural areas in the US. In fact, mmWave could also be deployed in complement to existing fiber deployments in case an operator wishes to serve new customers in its existing footprint but does not wish to dig for fiber in older neighborhoods.

Table 1: 2015 fixed broadband and FTTx houshold penetration rates

Category	Country (examples)	2015 houshold broadband penetration	2015 houshold FTTx penetration	FTTx CAGR (2013-2015)
Category 1 High broadband penetration & low FFTx penetration or growth	Australia	76%	7%	40%
	Canada	90%	6%	38%
	France	89%	5%	56%
	Germany	77%	1%	32%
	Russia	54%	26%	11%
	UK	88%	0.20%	–
	US	83%	10%	20%
Category 2 Low broadband penetration & high FFTx penetration or growth	Brazil	37%	2%	41%
	China	49%	37%	63%
	Vietnam	40%	20%	260%

Source: Ovum

2. 5G 101

Despite being ill defined, 5G is becoming a priority for telecom operators as it comes with the promise of unseen services as well as a broad range of new use cases and business models, ranging from enabling autonomous vehicles to smart agriculture and factories. 5G is expected to push the digitization of the economy further due to its ability to handle large volumes of data with low latency in real time.

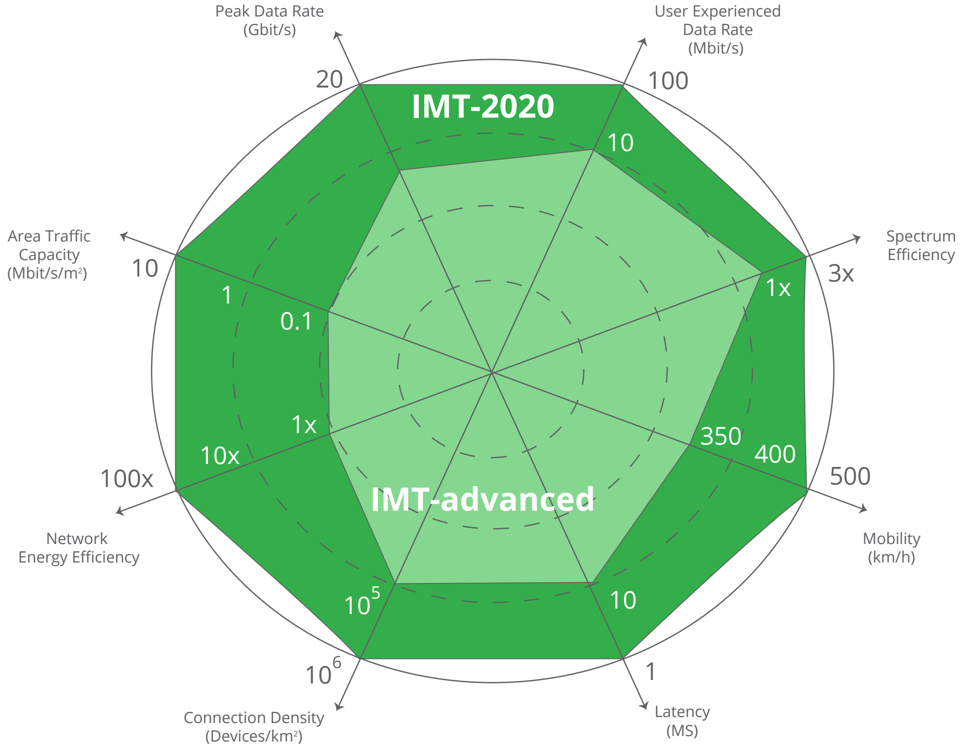
2.1 What is 5G?

The next generation of mobile telecommunications systems, IMT-2020 (commonly known as 5G), has yet to be standardized. However, much progress has already been made in developing 5G specifications. In February 2017, the International Telecommunications Union (ITU) published an early draft of what the specifications are likely to be, with the expectation that the final standard will be available by 2020[9].

Some of the key minimum technical performance requirements for 5G, as outlined in the ITU draft, are:

- A peak data rate of 20 Gbps downlink/10 Gbps uplink
- A peak spectral efficiency of 30 bps/Hz downlink and 15 bps/Hz up link
- A user experienced data rate of 100 Mbps downlink/50 Mbps uplink (in a Dense Urban test environment)

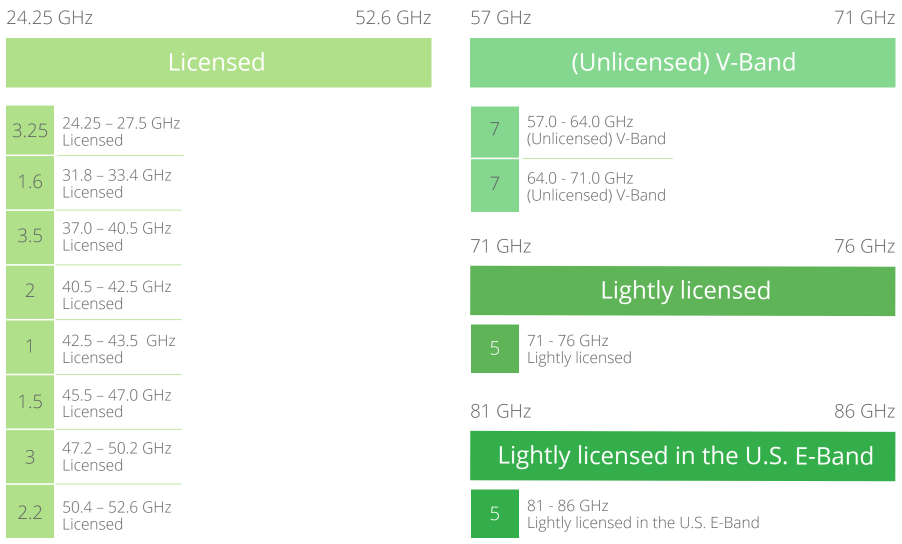
Figure 2: Comparison of key capabilities between IMT-Advanced and IMT-2020 [10]



Communication standards such as 5G must describe the frequency (or range of frequencies) at which signals are broadcast. To avoid unwanted interference, frequencies are regulated by governing bodies, such as the FCC in the U.S. This regulation can take the form of licensed spectrum, in which a user pays for exclusive use of a band; or unlicensed spectrum, in which the band is accessible to anyone (with certain restrictions). With the 5G standard yet to be finalized, a 5G frequency has not yet been determined. However, the ITU has proposed several globally viable bands in the mmWave spectrum[11]:

- 24.25 – 27.5 GHz
- 31.8 – 33.4 GHz
- 37.0 – 40.5 GHz
- 40.5 – 42.5 GHz
- 42.5 – 43.5 GHz
- 45.5 – 47.0 GHz
- 47.2 – 50.2 GHz
- 50.4 – 52.6 GHz

Table 2: Globally viable bands in the mmWave spectrum



24.25 GHz – 52.6 GHz: Licensed

3.25	24.25 – 27.5 GHz Licensed
1.6	31.8 – 33.4 GHz Licensed
3.5	37.0 – 40.5 GHz Licensed
2	40.5 – 42.5 GHz Licensed
1	42.5 – 43.5 GHz Licensed
1.5	45.5 – 47.0 GHz Licensed
3	47.2 – 50.2 GHz Licensed
2.2	50.4 – 52.6 GHz Licensed

57 GHz – 71 GHz: (Unlicensed) V-Band

7	57.0 - 64.0 GHz (Unlicensed) V-Band
7	64.0 - 71.0 GHz (Unlicensed) V-Band

71 GHz – 76 GHz: Lightly licensed

5	71 - 76 GHz Lightly licensed

81 GHz – 86 GHz: Lightly licensed in the U.S. E-Band

5	81 - 86 GHz Lightly licensed in the U.S. E-Band

The following are the bands available to wireline and cable operators at no or little cost:

- 57GHz to 64GHz plus 64GHz to 71GHz – V-Band unlicensed
- 71GHz – 76GHz; 81GHz to 86GHz lightly licensed in the US and called E-Band
- 72GHz is not part of the spectrum owned by large ISPs. It is affordable and open for all

Of these, three frequencies have emerged as leading candidates for 5G. These include the 28 GHz, 39 GHz, and 72 GHz bands, which have achieved popularity due to a concentration of research and prototyping at these frequencies.

One reason for this concentration is that these bands are owned in part by large ISPs, thus, offering a commercial incentive to utilize them in 5G networks. Mobile providers including Samsung, Verizon, Nokia, and others have built prototypes and conducted field trials utilizing these bands (especially 28 GHz). In the U.S., Verizon and AT&T plan to deploy 5G as early as 2017 ahead of the 2020 release of an official 5G standard[12]. However, those are still technology trials rather than commercial deployments since 28GHz radios are not commercially available yet. Providers from several other countries including Russia, Brazil, China, South Korea, and more also have plans to deploy pre-standard (pre-2020) 5G networks[13].

In the U.S., unlicensed mmWave frequencies available for 5G primarily cover the band from 57 – 71 GHz, called the V-Band, or 60 GHz band. This band offers 14 GHz of contiguous spectrum, which is more than all other licensed and unlicensed bands combined[7]. This makes the 60 GHz band an excellent alternative to licensed mmWave frequencies for smaller providers, as it can be used to deliver 5G performance for the minimal cost of available 60 GHz infrastructure products.

2.2 Early “5G” use cases

5G is expected to serve a large variety of use cases, made possible by the increased capacity of mmWave technology. With data speeds greatly exceeding current broadband solutions in the U.S., 5G will allow for data-intensive applications ranging from 8K video streaming to augmented and virtual reality (AR/VR). Furthermore, the reduced latency of 5G communications makes it promising for real-time control of connected machines and devices, such as factory assets, autonomous vehicles, and smart city technology (including smart street lighting, air quality sensors, and real-time traffic management). Together, networked devices of this kind are referred to as the Internet of Things (IoT), and IoT applications are poised to benefit immensely from 5G technology[14].

In addition to mobile broadband, 5G will also enable fixed wireless broadband, delivering gigabit throughput to a variety of end users without the need for costly fiber-to-the-premises (FTTP) installations. For example, single family homes in a suburban region could be serviced with a point-to-multipoint (PtMP) topology by using existing V-band products. Similarly, multiple dwelling units (MDUs) in both urban and suburban environments could be serviced with a point-to-point (PtP) topology, using the same currently available technology. Such networks are easily scalable and much quicker than fiber to deploy, yet provide the same gigabit throughput as fiber. Thus, with its fiber-like capacity, ease of deployment, and currently available solutions, 5G fixed wireless is an excellent option for the so-called “last mile” of fiber networks.

2.3 “5G” Timeline

3GPP is currently standardizing 5G in Release 15, which will complete the no standalone version of 5G in March 2018. Based on a typical minimum period of 18 months to build and deploy the technology, initial 5G NSA deployments could occur toward the end of 2019 or the beginning of 2020. 3GPP will complete the full Release 15 specifications in September 2018, enabling deployments in 2020. Release 16, which is the second phase of 5G, will be complete at the end of 2019, and Release 16 deployments could occur in 2021. In 2020, 3GPP will begin work on Release 17 which will include yet unknown capabilities.

Supporting Gigabit to the home services for every single-family home requires that the customer premises equipment (CPE) price be at the right price point (meaning, inexpensive enough). In order to meet an aggressive price point, a highly integrated chipset is a must; however, the standardized 5G chipset for CPE will be only be available in 2020 (and that might be wishful thinking). The most compelling proposition for 60GHz is that it has a full commercial Ecosystem that can deliver 5G services at the right price point – today!

User devices capable of 5G operation have not yet been announced, but availability will likely follow the trends of previous generations of networks. Initial devices, possibly in the 2019 timeframe, will likely include routers that have a 5G radio and use Wi-Fi for local Hotspot capability and USB modems. Handset vendors are in the early stages of designing mmWave support into smartphones. These devices could come online in the 2021 timeframe, although this estimate could tighten or lengthen depending on chipset availability and handset vendor plans.

We provide more details on devices in section 3.

3. mmWaves 101

3.1 mmWave Spectrum

Millimeter waves (mmWaves) refer to the range of the electromagnetic spectrum which includes wavelengths from 1 – 10 mm, corresponding to a frequency range of 30 –300 GHz. However, in the context of 5G, the term mmWave often stretches to include slightly lower frequencies (down to about 24 GHz, which corresponds to a wavelength of 12.5 mm), to incorporate all viable 5G frequency bands. 5G networks are not expected to employ mmWaves higher than 100 GHz (i.e., lower than 3 mm).

Most current wireless technology utilizes significantly longer wavelengths than mmWaves. For example, Wi-Fi and Bluetooth both employ the 2.4 GHz ISM (Industrial, Scientific, and Medical) band to broadcast signals, meaning they use wavelengths of 125 mm. Even longer wavelengths are used in AM radio broadcasting, which can utilize waves as long as 2 km.

3.2 mmWave is Fiber-Like Wireless

The relatively unexplored use of mmWave-scale wavelengths offers both advantages and disadvantages. Because this portion of the spectrum has previously gone mostly unused, there is plenty of untapped bandwidth available[14]. Additionally, mmWave frequencies allow for fiber-like wireless capacity, enabling gigabit broadband internet with a fixed wireless infrastructure. However, the high frequency of mmWaves results in a shorter signal range because of greater signal attenuation[15]. The differences between mmWaves and more commonly used spectrum necessitate novel system research and design.

Fortunately, because of its promise for 5G networks and other applications, mmWave research is well underway. In the past several years, many proof-of-concept mmWave systems have been designed and prototyped, and have demonstrated the effectiveness of mmWave systems in the field. For example, at Mobile World Congress 2015, Nokia demonstrated a bidirectional 73 GHz mmWave system prototype that achieved a peak speed of 2.3 Gbps with a range of 160 – 200 m. The next year, at Mobile World Congress 2016, Nokia presented a unidirectional 15 Gbps version of the system[14]. In addition to research of mmWave systems, mmWave technology (such as integrated circuits and antennas) has advanced to the point that wireless mmWave products can be manufactured cheaply and reliably[12 14]. For this reason, mmWaves are starting to be used in real-world applications ranging from automotive radars to touchless gesture sensors and medical imaging technologies [16].

3.3 The Case for 60 GHz Spectrum

The downside of mmWaves' promise for future 5G networks is that licensed mmWave spectrum has begun to be dominated by large ISPs, like Verizon and AT&T in the U.S. Viable 5G mmWave bands are unfairly dominated by these providers; collectively, they own 55% and 66% of the popular 28 and 39 GHz bands, respectively. In total, these two companies own 58% of licensed mmWave spectrum in the U.S. [8]. However, the good news is that unlicensed and lightly-licensed mmWave spectrum, such as the 60 GHz V-Band and 70/80 GHz E-Band, can provide the benefits of mmWaves without the prohibitive costs of licensed spectrum. This allows smaller ISPs to stay competitive amidst the monopolistic practices of larger providers.

For example, San Francisco-based Webpass, a gigabit ISP acquired by Google Fiber in 2016, is using commercially available mmWave technology to provide broadband service[17]. Webpass uses a combination of fiber networks and PtP mmWave radios to deliver gigabit broadband to residential and business customers. These radios operate in the inexpensive, lightly licensed 70/80 GHz E-Band, avoiding the licensed mmWave spectrum owned largely by Verizon and AT&T[18]. Another service provider using mmWave wireless solutions is UK-based Metronet, which also utilizes the 70/80 GHz E-Band for last mile broadband infrastructure. Like Webpass in the U.S., Metronet can deliver gigabit fiber-like wireless to U.K. customers using mmWave radios [19]. In addition to the comparatively low cost of fiber-like wireless infrastructure (as opposed to FTTH), a further advantage of mmWave fixed gigabit wireless networks is the ease of deployment and scaling. Networks of this kind, utilizing the lightly licensed 70/80 GHz E-band or unlicensed 60 GHz V-Band for last mile wireless broadband, are an affordable and appealing option for many wireline and cable service providers.

Of these, the 60 GHz V-Band is a particularly appealing option for FWA service providers. Unlike the lightly licensed 70/80 GHz E-Band, the 60 GHz band is unlicensed, and therefore, is accessible to a wider range of providers. Additionally, the 14 GHz of contiguous spectrum in this band offers more bandwidth than any other licensed or unlicensed mmWave band. Further, the 60 GHz band has chipsets and technology currently available on the commercial market. In order to deliver gigabit-to-the-home (GTTH) service, it will be necessary to achieve the right price point for customer-premises equipment (CPE). Thus, the most compelling case for the 60 GHz band is that it uniquely achieves this CPE price point with a full ecosystem of commercial technology - other mmWave bands do not yet have standardized chipsets available.

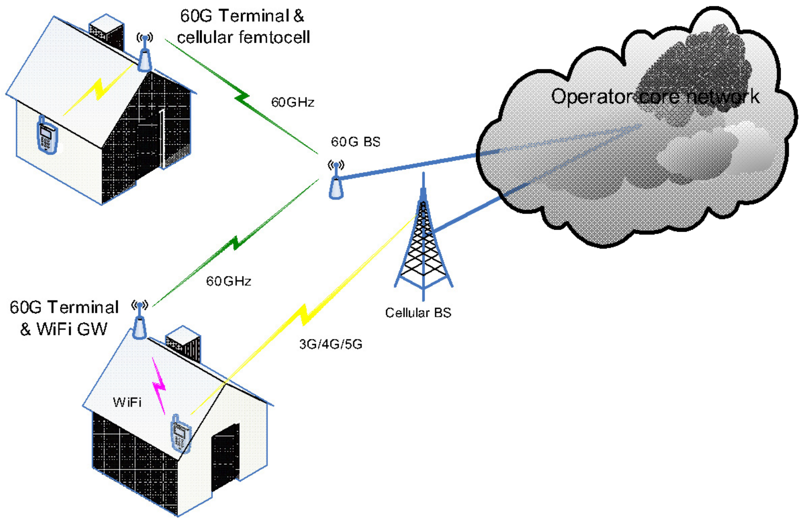
In Table 3, the properties of 60 GHz are contrasted with those of the 28 and 39 GHz licensed bands.

Table 3: Advantages of the 60 GHz band

Band (GHz)	28	39	60
Bandwidth (MHz)	1,200	3,500	14,000
Standard	5G (3GPP)	?	WiGig
Capacity (Gbps)	→ 2	→ 1	2 → 8
Range (m)	~1,000	~1,000	~400
Chipset	2018 (?)	2018 (???)	Now
Products generally available	2020 (?)	2020 (???)	Now

Another advantage of the 60 GHz band is that it readily complements 3G/4G/5G mobile technology, and can share infrastructure with other technologies. This is illustrated in Figure 3.

Figure 3: Shared infrastructure - 60 GHz and mobile technologies



4. 5G Broadband Fixed Wireless Access (FWA)

4.1. The Case for pre-standard 5G Technology

Deploying 5G FWA gives wireline operators a head- start in working with different aspects of 5G as a practical alternative to FTTH/FTTP. Operators can become familiar with a new air interface, new spectrum, new radio form factors, and new antenna systems. An early experience in those aspects of the 5G technology can help speed up full 5G deployments once the standards are set.

Other benefits for wireline operators to test and deploy earlier version of 5G technologies is that it will allow them to exercise a more notable influence on the standard developments. MNOs will be able to reuse some of their FWA deployments to support their wireline operations. These deployments can readily take the form of hybrid fiber wireless, in which only the last mile of a network is wireless.

4.2. Early 5G Trials

One immediately accessible benefit of 5G and mmWave research is the commercial availability of mmWave solutions, such as PtP radios, which can be used to provide fixed wireless access (FWA) for gigabit broadband service. Before describing this benefit further, it is helpful to appreciate the large quantity of early 5G experiments that have helped advance mmWave technology to its current state. Table 4 presents a non-exhaustive list of both past and planned 5G research and field trials, utilizing both licensed and unlicensed mmWave spectrum.

Table 4 - A list of early 5G research, trials, and demonstrations

Year	Organization	Description
2011 – 2013	NYU Wireless	Extensive propagation measurement campaigns were conducted to develop channel models at mmWave bands including 28 GHz, 38 GHz, 60 GHz, and 73 GHz [20] [21]
2014	Nokia	Used the NYU Wireless channel measurements to research and demonstrate a 73 GHz over-the-air link [22]
2015	Nokia	At Mobile World Congress, demonstrated a 73 GHz mmWave system that achieved a peak data rate of 2.3 Gbps [14] [22]
2015	Samsung	Expanded upon earlier channel measurements to demonstrate the viability of 28 GHz for cellular communications, and began researching phased arrays for cell phones [22]
2015	Qualcomm	Conducted 28 GHz experiments in a dense urban environment to show the capacity of intelligent beamforming for Non-Line-of-Sight (NLoS) communications [23]
2016	Huawei/Deutsche Telekom	Presented a 73 GHz prototype mmWave system that used multi-user multiple-input-multiple-output (MU-MIMO) to achieve the potential for greater than 20 Gbps throughput [22]
2016	AT&T/Ericsson/Intel	Tested enterprise 5G applications using mmWave bands of 15 GHz and 28 GHz, achieving over 1 Gbps in a field trial at an Intel office [24]
2016	Nokia	At Mobile World Congress, demonstrated a 73 GHz mmWave system that achieved a data rate of 15 Gbps [14]
2016	Nokia	At Brooklyn 5G Summit, demonstrated beam scanning with a phased array for a 60 GHz system with 1 GHz of bandwidth [14]
2017	PHAZR	Conducting U.K. and U.S. trials of a hybrid 5G broadband FWA system that uses mmWave downlink (in 24 – 40 GHz licensed bands) combined with sub-6 GHz spectrum uplink [25]
2017	Siklu	Launched the MultiHaul series of plug-and-play mmWave PtMP radios operating in the unlicensed 60 GHz V-band [26]
2017	Intel	At Mobile World Congress, demonstrated a 28 GHz Radio Frequency Front-End (RFFE) 5G Mobile Trial Platform capable of up to 3 Gbps Over-The-Air (OTA) data transfer [27]
2017	SK Telekom	Plans to deploy a pre-5G network in South Korea by the end of 2017 [13]
2017	Verizon/AT&T	Both providers plan to deploy pre-standard 5G systems in the U.S. [22]

The success of these and other trials have clearly demonstrated the potential of 5G mmWave technology for both mobile and fixed broadband services. In particular, small service providers can utilize unlicensed mmWave bands (such as the 60 GHz V-Band) to provide 5G FWA with fiber-like, gigabit throughput. Not only are commercial products available to deploy 5G FWA, but providers such as Webpass in the U.S. are currently operating with this exact model [18].

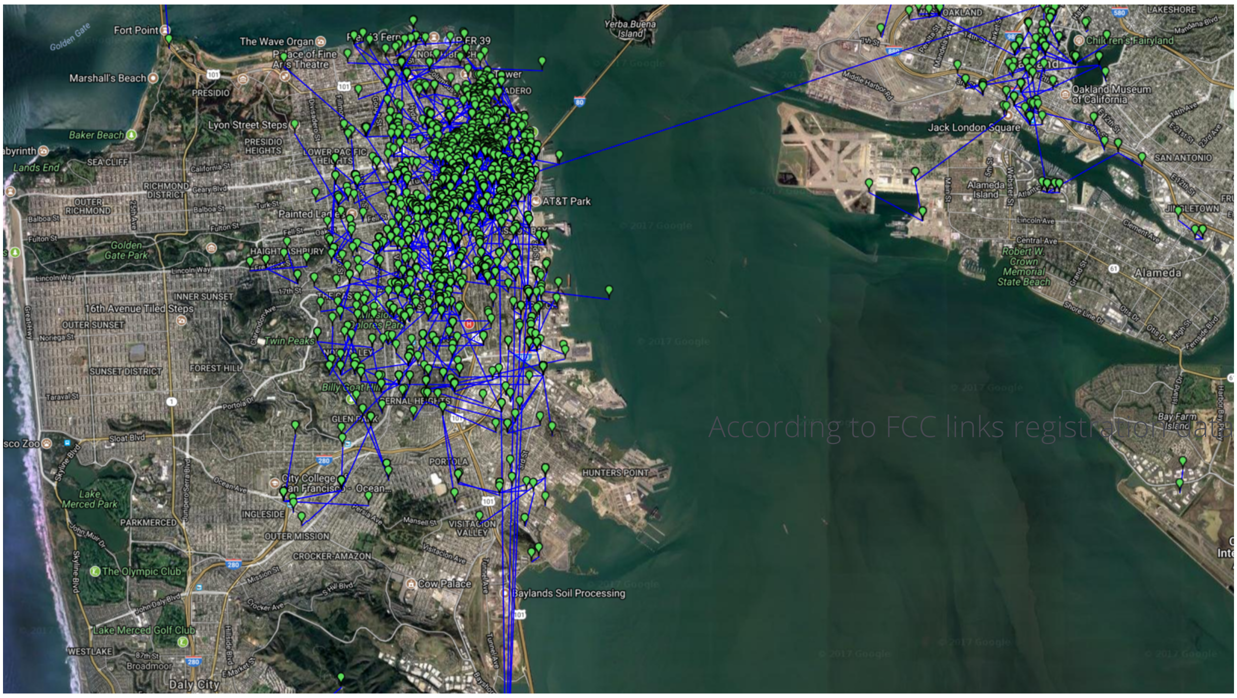
4.3. Short Term planned RFIs and Deployments

RFI/P we are aware of at least 2 RFP for pre 5G mmWave FWA solution issues by two tier 2 Wireline carriers (We cannot disclose names since we are under NDA). Currently it is in the lab and field testing phase.

However smaller regional innovative ISP already use mmWave PTP and ramping up PtMP to deliver Gig services in large scale.

4.4. Delivering the Promise

Figure 4: Deployed Active Systems in San Francisco



According to FCC links registration data

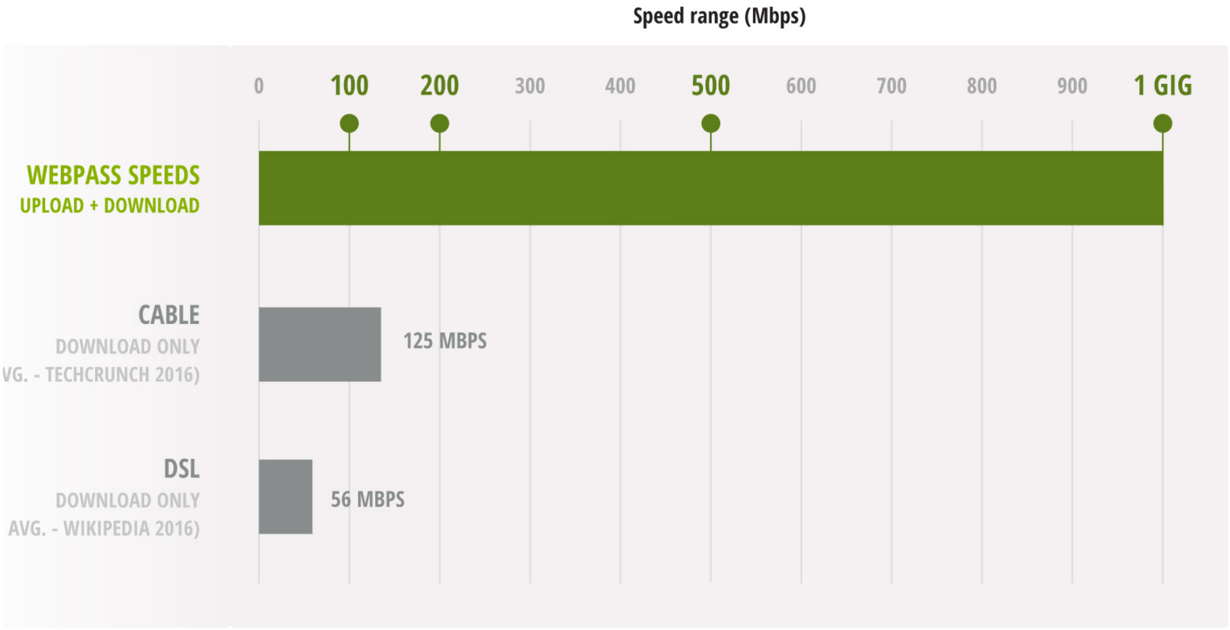
60/70/80GHz wireless systems are a reality today. This map from the interactive FCC database shows the massive number of deployed systems active today in San Francisco. A similar map can be generated for cities all over the US and UK.

Webpass is a high-profile example of early 5G deployments focused on providing fixed wireless used to complement fiber networks without the need to run fiber all the way to the home.

About WebPass

Webpass, which was acquired by Google in 2016, uses point-to-point wireless technology to connect businesses and multi-unit residential buildings in densely populated areas. Webpass strategy is to use wireless in complement to fiber deployments where it makes more sense to deploy wireless mmWave. Webpass's residential service offers speeds of up to 1Gbps for $60 a month including in San Francisco, Denver, Seattle, San Diego, Miami, Chicago, and Boston. Webpass claims more than 25,000 active customers and over 1,000 buildings connected.

Figure 5: Speed range(Mbps) comparison



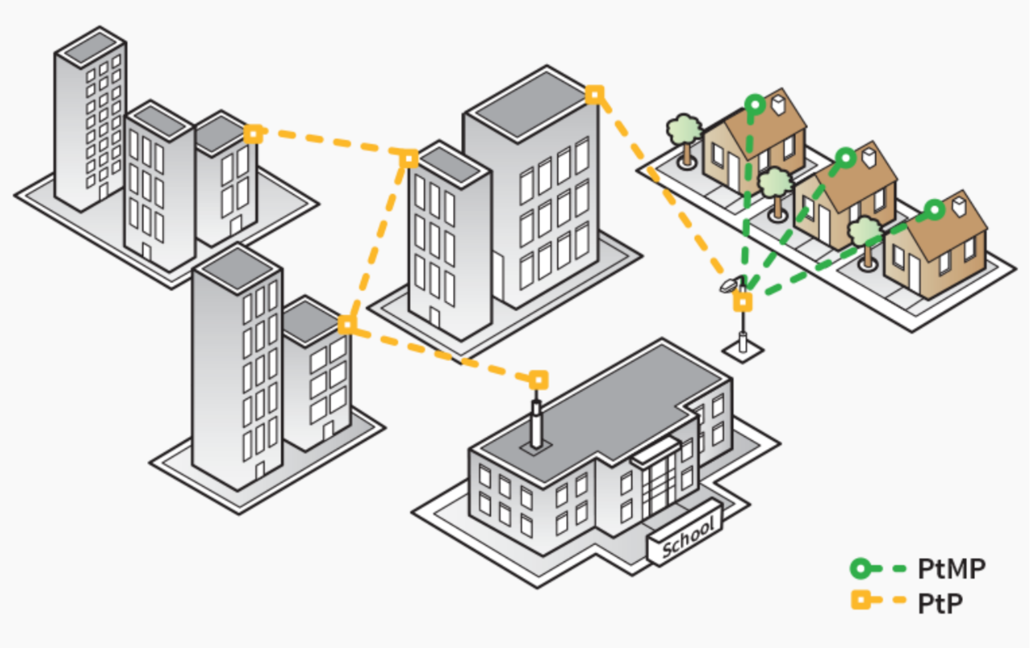
5. The Business Case for 5G FWA

5.1. Network Architecture

To better understand 5G FWA, an overview of the network architecture is warranted. 5G FWA is well-suited to serve as an alternative to expensive and slow FTTH deployments, specifically in the so-called last mile (i.e., the final infrastructure connection to homes, MDUs, or businesses). Instead of deploying fiber directly to the premises (FTTP), the last mile can instead be replaced with fiber-like wireless networks. By using high capacity mmWave technologies for these networks, the gigabit throughput of fiber can be maintained despite the lack of a physical fiber connection.

5G FWA can be provided using either point-to-point (PtP) or point-to-multi-point (PtMP) topologies. In the case of PtP, a base station or other network node communicates with a single other node; in PtMP, a base station can communicate with multiple end nodes. To realize either of these topologies with mmWaves, a technique called beamforming is often employed. Beamforming provides a method of directing wireless signals to require the least amount of transmit power possible, by manipulating several non-directional antennas to simulate a large directional antenna. Arrays of antennas used for this purpose are known as phased arrays. In practice, there are many methods of beamforming, including analog, digital, and hybrid architectures. However, these methods employ the same principles of constructive and destructive wave interference to focus signals in the direction of choice [28].

Figure 6: Illustration of PtMP and PtP wireless topologies



Beamforming for PtMP mmWave signals is especially important because of the high attenuation experienced by high frequency signals as they propagate. For both licensed and unlicensed mmWave bands, a combination of beamforming and short ranges (up to about 400 m) can overcome these poor propagation characteristics, even in dense urban non-line-of-sight (NLoS) environments. Increasing the number of beamforming antennas in a phased array can provide extended ranges (up to 3 miles) for high-frequency mmWave signals. However, the comparatively short range of mmWave signals can nevertheless provide full area coverage when combined with the expected densification of 5G networks. Densification refers to the number of base stations per square kilometer, which for 5G may reach a density of 40 – 50 base stations, obviating the necessity for long wireless ranges [15]. For these reasons, the best way to achieve 1 Gbps service coverage using FWA is by densifying the network and utilizing 60 GHz mmWave, which has 14 GHz of available spectrum.

With these building blocks in place, it is clear how 5G FWA can be provided to single family homes, MDUs, or businesses in urban or suburban environments. Rather than extending a fiber network directly to premises, a mmWave PtP or PtMP radio base station can be used to set up fiber-like wireless connections to each unit in the service area having the appropriate customer-premises equipment (CPE).

In the U.S., 5G FWA has emerged as the first real offering of commercial 5G services, in part because of the comparative lack of complexity compared to mobile 5G [29]. This is exemplified by Google Fiber's loss of momentum as the expense and time required for fiber deployments began to prove impractical, followed by the company's purchase of Webpass, a service provider employing a fiber-like wireless approach to last mile network infrastructure[17]. Other providers in the U.S., such as PHAZR, are poised to begin offering 5G FWA as early as this year. Currently, 5G FWA is not possible with mmWave bands such as 28 and 39 GHz, because commercial chipsets are only available for the 60 GHz band. 5G over mmWave is a promise, but 5G over 60 GHz is a reality.

For fixed broadband service providers, there are several clear advantages to a 5G FWA approach. To begin, fiber-like wireless is both cheaper and easier to deploy than FTTH. These advantages beget further advantages, in that fiber-like wireless can be deployed more quickly than fiber, and scaled more easily. Without having to spend the massive upfront investment of FTTP infrastructure, service providers can cover a service area with the minimal infrastructure cost of mmWave base stations and CPE. An additional benefit of this paradigm is that no investment is wasted in connecting customers who won't sign up for broadband services [29].

Of course, these advantages would be frivolous if 5G FWA could not meet the growing consumer need for fast and reliable broadband access articulated by the FCC [1]. As we've seen, mmWave technology is perfectly capable of matching the gigabit throughput of FTTH connections. This has been clearly demonstrated (see Table 1) for both licensed and unlicensed mmWave bands. Additionally, with intelligent beamforming solutions, pencil-thin mmWave beams can be broadcast to minimize interference and provide strong wireless reliability. Finally, the availability of commercial mmWave PtP and PtMP radios that can achieve these required properties (gigabit throughput and strong reliability) at unlicensed or lightly-licensed mmWave bands (the 60 GHz V-Band and/or 70/80 GHz E-Band) makes 5G FWA a viable service option for all service providers[26].

5G FWA is suitable for businesses, multiple dwelling units (MDUs), gated communities, and single-family homes, ideally for residential densities of around 1,000 households per square mile [29]. With the ease of 5G FWA deployment, area coverage can be extended quickly and the number of broadband subscribers can be easily scaled. For broadband customers, the combination of quick access (no waiting for fiber installations) and reliable, gigabit speeds is an appealing incentive to switch from larger providers, who dominate the market while offering poor service. And for the millions of Americans who have no broadband access at all, 5G FWA is perhaps the best option for providing broadband coverage.

As 5G becomes standardized and mmWave technology matures, there will undoubtedly be new broadband solutions that arise. However, just as FTTH solutions will continue to exist alongside 5G FWA, so too will 5G FWA exist alongside whatever new solutions enter the market. As long as 5G FWA continues to provide reliable, gigabit broadband, it will continue to serve broadband customers. In fact, with peak 5G adoption predicted to occur around 2040 [15], it's a safe bet that 5G FWA solutions will endure for at least the next couple of decades. Together, the flexibility, scalability, and survivability of 5G FWA make a strong case for service providers to invest in this growing technology. This being the case, small providers should not wait for mmWave technologies for the 28 and 39 GHz band to mature, considering the commercial availability of 60 GHz chipsets. By waiting until these other mmWave bands mature, small providers will be unable to afford the licensing of their spectrum, and will lose the 5G battle to larger providers.

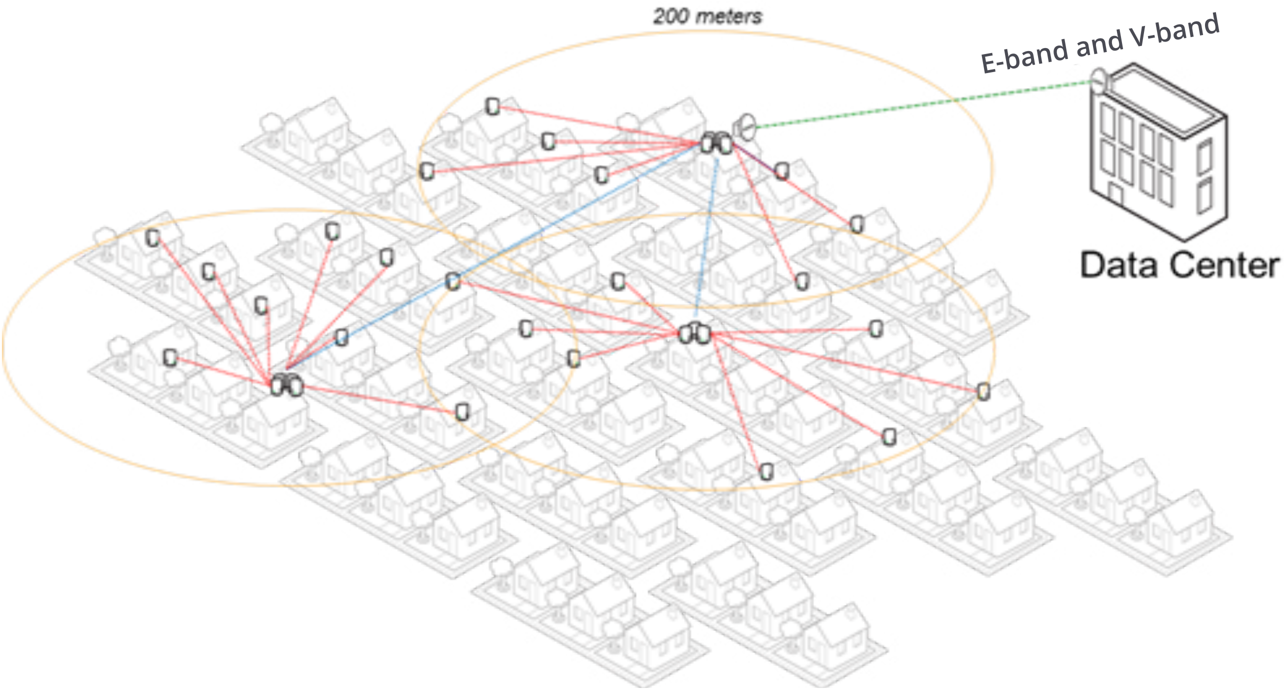
5.2. Business case Scenarios & KPIs

We know that deploying wirelessly is much faster than deploying any wireline technology including fiber. But how does mmWave compare to fiber in terms of cost when serving the same customers with the same levels of services?

We ran some cost analysis for both technologies in 2 scenarios, single family unit and multi-dwelling and assuming the most possible generous conditions for the use of fiber to make an honest and fair comparison.

5.2.1. Single Family Unit (SFU)

Figure 7: Illustration of FWA deployment in a Single family home neighborhood



In this scenario, we compare the cost of a single-family home passed (no drop) as well as connected (with drop) using mmWave vs fiber technology. We assumed a deployment covering 82 single family units in a suburban environment as illustrated in the picture above.

Our assumptions include for the mmWave solution, using 5 hubs with 4 sectors each resulting in a total of 20 base station units (BUs) and 77 terminal units (TUs) since each hub also serves as a TU for the corresponding SFU where it is mounted. We also assume the use of 2 E-band as well as 4 V-band backhaul links back to the data center. The equipment including cabling for the hubs amounts to $23,145 to which we added $1,500 in labor costs and arrive at a cost of $301 per SFU passed (no drop).

When we add the cost of the drop for the additional 77 TUs with the equipment (including mast and cabling, power supply mounting kit) and labor costs, the analysis results in cost of $500 per SFU dropped which adds to the $301 per SFU for the passing/distribution portion.

Adding both figures, we derive a total cost of $801 per connected (passed and dropped) SFU using mmWave technology.

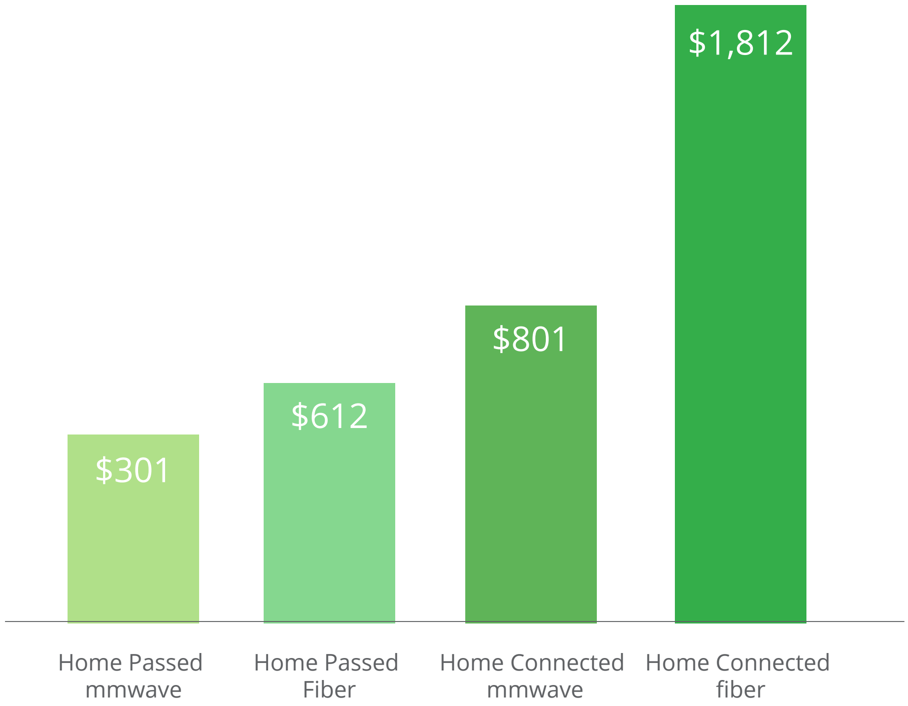
We now turn to the scenario of using aerial fiber and assuming the most possible generous conditions for the use of fiber to make an honest and fair comparison for a similar service delivery.

To cover those 82 homes, 4103 feet of fiber are needed along with 34 terminations (4 ports) and NAP (4ports) poles. We assumed the fiber is make-ready and no splicing is required. Those assumptions result in $19,506 equipment cost then we add $30,716 in labor costs which includes: fiber distribution, termination and NAP labor using industry average figures.

In this scenario, the cost per home passed is $612 with no drop. The drop equipment consisting of a NAP to terminal and ONT amounts to $17,384 for the total 82 homes dropped, on top of which we need to sum the NAP to terminal labor cost of $30,750 resulting in $1,200 per home dropped.

Thus, when we add the cost of distribution and drop, the results are $1,812 per home connected (passed and dropped) with fiber. That is over $1,000 more than the cost of connecting a SFU with mmWave and not considering speed of deployment which is must faster with mmWave.

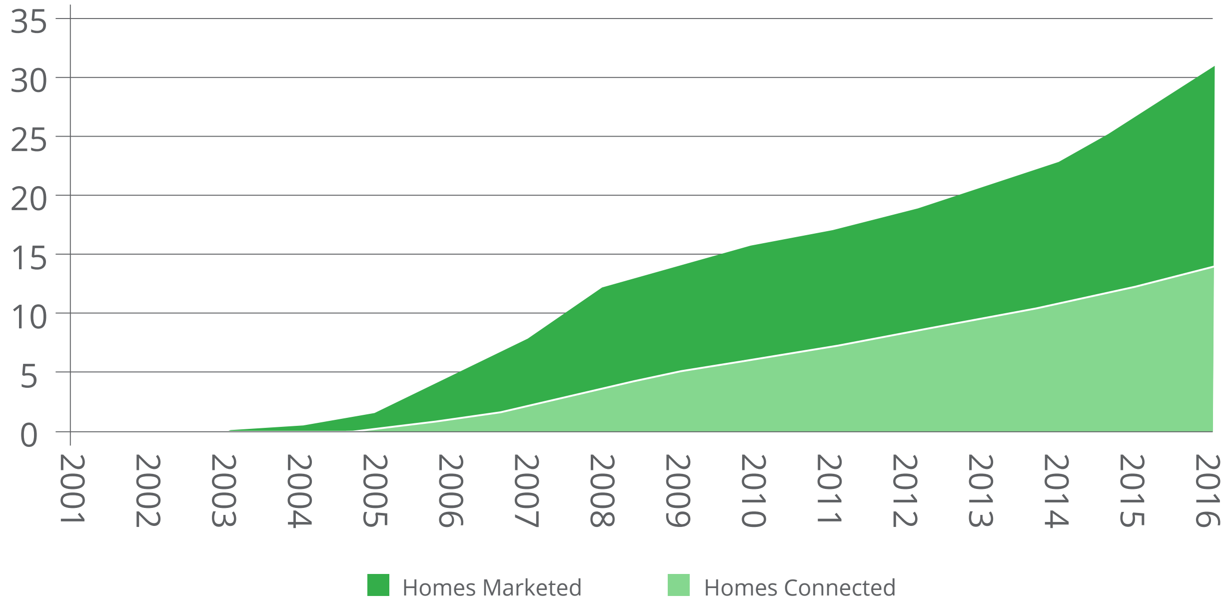
Graph 1: The Cost per Home for Distribution and Drop by Technology



As the fiber chart above clearly indicates, the additional cost of the drop for fiber is what makes fiber prohibitive for carriers compared to wireless. It also illustrates that when fiber pass is combined with wireless drop, the business case can become quite viable since the cost of a home passed with fiber remains well below the cost of the home connected with mmWave - this leaves a margin to drop with mmWave under reasonable costs and time to deploy.

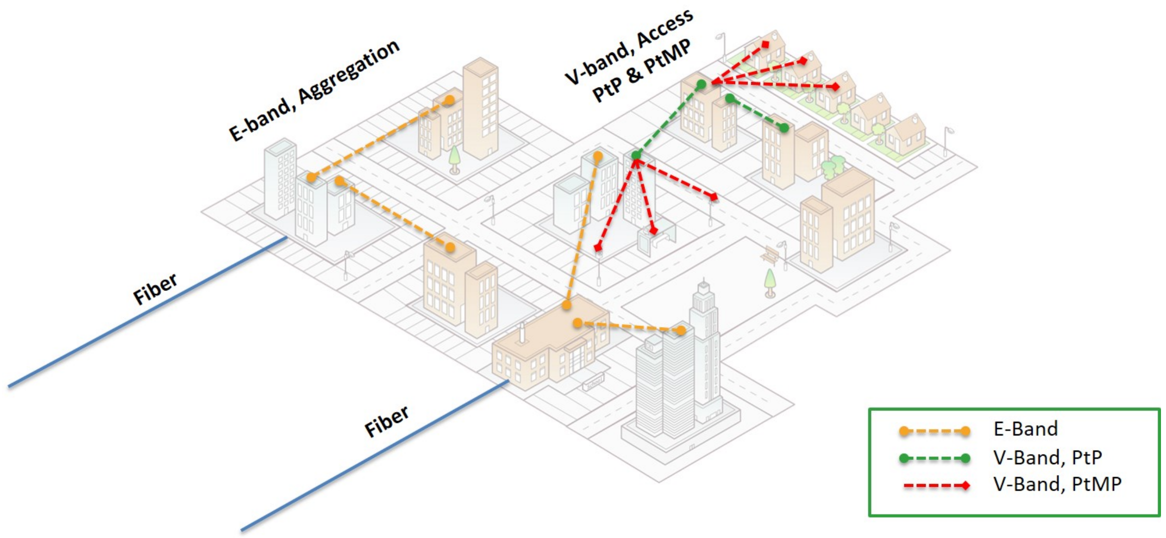
It also explains why the level of homes connected with fiber is lagging well behind the number of homes passed/marketed (not dropped) and represents a great market opportunity for carriers to fill in the gap with mmWave drop. True FTTH Now Passes Over 30 Million Homes in the U.S.

Graph 2: FTTH Now Passes Over 30 Million Homes in the U.S



5.2.2 Multi Dwelling Unit (MDU)

Figure 8: Hybrid Fiber Wireless Connectivity for MDUs



In the case of a multi-dwelling scenario, the difference with the single unit is that we need to add the cost of in-building distribution for connecting each apartment with G. Fast, Coax, Ethernet or Wi-Fi. However, the cost of passing the units will be shared among many and will therefore be much lower than in the SFU scenario.

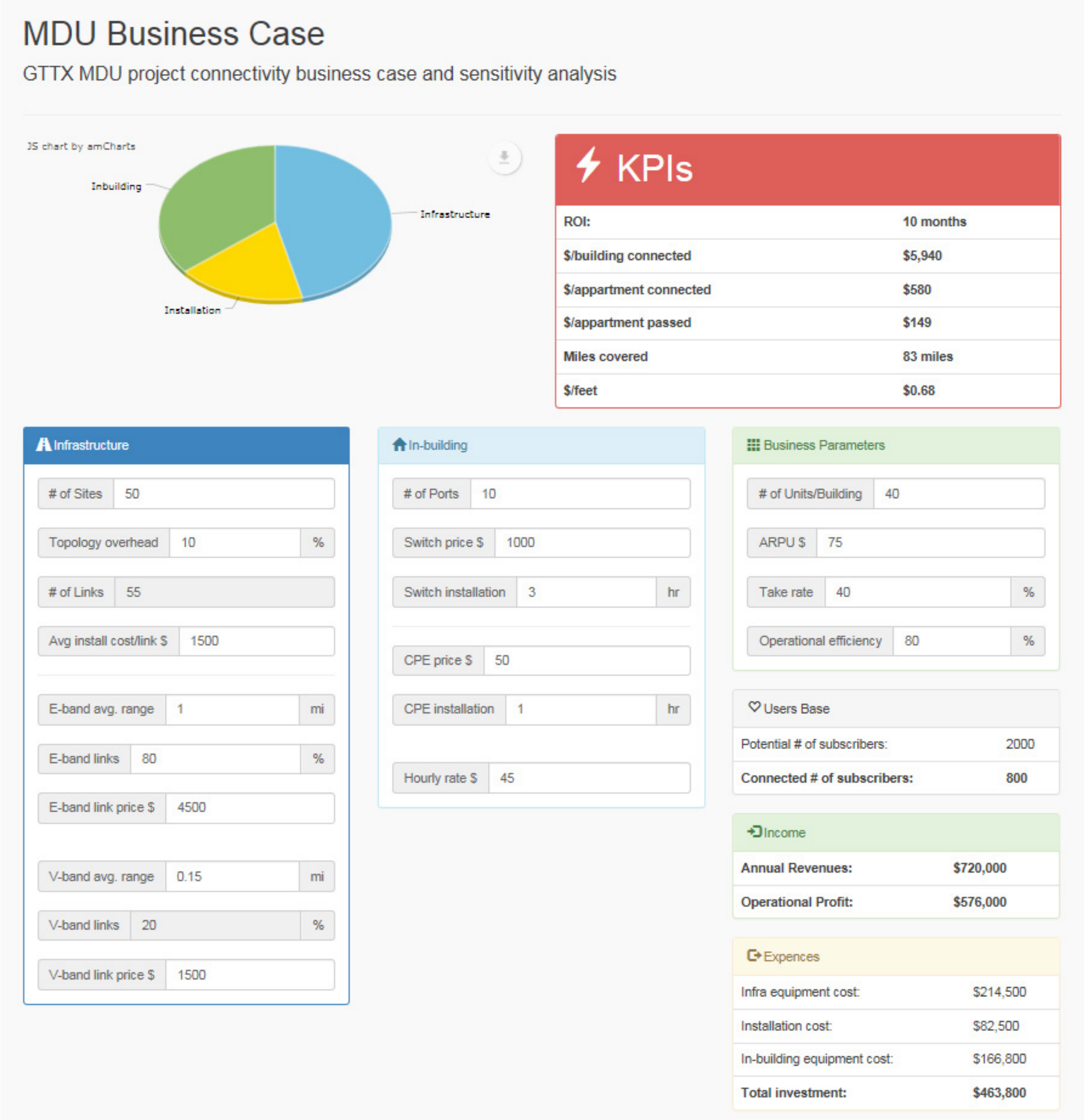
mmWave Analysis:

We assume we are providing service to 50 buildings which have either 20 or 40 units each, so either 1,000 or 2,000 units in total with a take rate of 40% which translates to eventually 400 or 800 units connected (passed and dropped). As we will see, the less units there are in a MDU, the higher the proportion of the total deployment cost is made of the infrastructure portion since there are less units to connect with inbuilding distribution. In this case, the mmWave option becomes even more attractive than fiber. In this scenario, we will need 55 point-to-point links to provide resilient topology without a single point of failure, 80% of which will be E-band and 20% V-band.

As shown in the figure below, our model indicates a total equipment cost of $214,500 and an associated installation cost of US $82,500 for a total cost of $297,000 to connect all the buildings, excluding in-building distribution. That number translates to $5,940 per building connected with mmWave. Assuming a 40% take up rate, there will be 16 units connected in each 40-unit building which results in a cost per unit connected (passed and dropped) of $580 or $951 if the building has only 20 units (with 8 connected at 40% take rate).

Please note that we assume the cost of in-building distribution is the same whether the building is connected with fiber or mmWave.

Figure 9: MDU Business Case Calculation



MDU Business Case

GTTX MDU project connectivity business case and sensitivity analysis

KPIs

ROI:	**10 months**
$/building connected	**$5,940**
$/appartment connected	**$580**
$/appartment passed	**$149**
Miles covered	**83 miles**
$/feet	**$0.68**

Infrastructure

# of Sites	50	
Topology overhead	10	%
# of Links	55	
Avg install cost/link $	1500	
E-band avg. range	1	mi
E-band links	80	%
E-band link price $	4500	
V-band avg. range	0.15	mi
V-band links	20	%
V-band link price $	1500	

In-building

# of Ports	10	
Switch price $	1000	
Switch installation	3	hr
CPE price $	50	
CPE installation	1	hr
Hourly rate $	45	

Business Parameters

# of Units/Building	40	
ARPU $	75	
Take rate	40	%
Operational efficiency	80	%

Users Base

Potential # of subscribers:	2000
Connected # of subscribers:	**800**

Income

Annual Revenues:	**$720,000**
Operational Profit:	**$576,000**

Expences

Infra equipment cost:	$214,500
Installation cost:	$82,500
In-building equipment cost:	$166,800
Total investment:	**$463,800**

Source: Siklu GUI Business Model

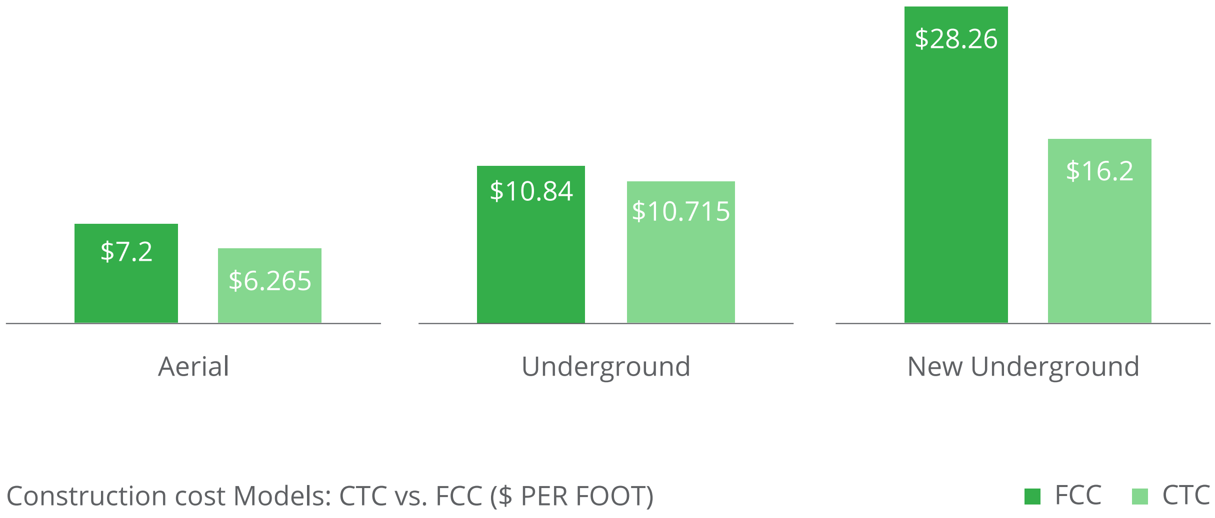
MDUs present an opportunity and a potential risk for GTTH providers. On the one hand, each MDU represents a large potential demand for services. MDUs represent about 30% of the total residential market for GTTH. But on the other, MDUs are difficult and complex to reach with fiber. More than 83% of MDUs were built before 2000 and more than 50% were built before 1980. That means providers are dealing with infrastructure that predates the internet, not just fiber. And each MDU is different, ranging from small row houses to larger, high-rise buildings with more than 100 units. So GTTH providers need to be able to handle the challenges of getting permission to enter each building or unit to install a technology, and then deal with the physical challenges of getting the fiber dropped.

Fiber Analysis

In urban and suburban areas, buildings or neighborhoods can typically access the fiber network from the closest network point. A typical fiber nod e is located between a half a mile to two miles from residential premises. Metropolitan areas typically host a variety of densification levels -- from extremely densified downtown areas to less dense residential area and suburbs.

The average cost to construct 'last mile' fiber is typically more expensive in densified metropolitan areas since labor costs for construction are higher, which increases the cost per foot to deploy. In less dense, suburban areas the distances between premises are typically larger, increasing the costs of materials. We used data that is averaged and adjusted between these different environments.

Graph 3: Construction cost Models



The above table represents 'last mile' cost analyses for the three types of fiber deployments in urban areas. Aerial and underground construction typically include a variety of parameters. The costs for each parameter may vary widely based on local environment and existing utilities.

In this scenario, we assume an average distance of .5 mile from the fiber point of presence. The cost for underground fiber in existing deployment (existing conduit etc.) according to CTC/FCC construction model is around $10/foot including labor.

So just the fiber cost in dense environment is about $26,400 (26 40 feet * $10/foot). New fiber deployed would cost at least 50% more ($16-18 $/foot). In some major cities, the cost to deploy fiber maybe up to 10x times higher than that - $300K!

Therefore, the cost for deploying fiber to the building at 0.5 mile will vary in the best case from $26,400 to $300,000 compared to $5,940 with mmWave!

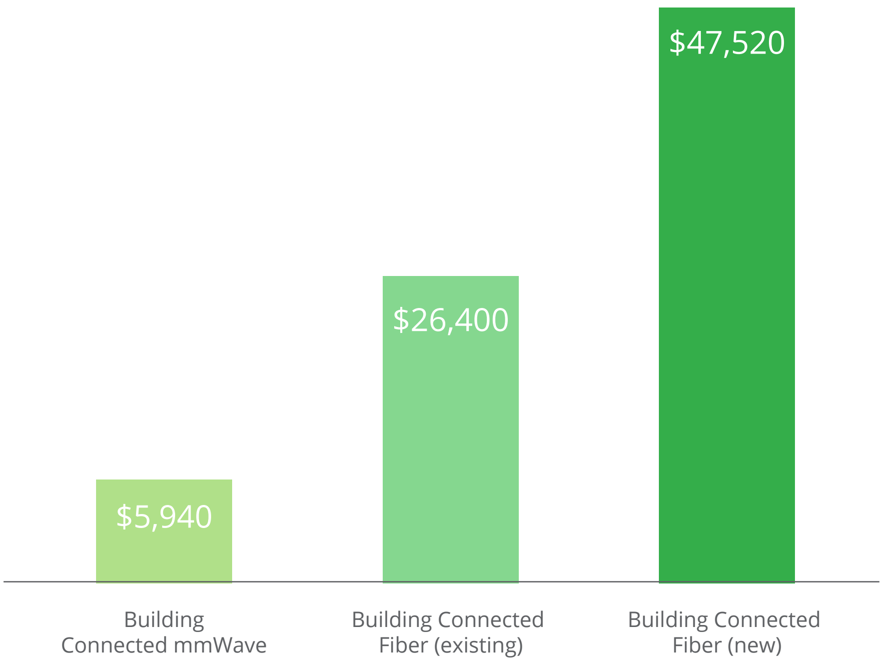
The calculations for a fiber deployment are presented below:

Table 5: Fiber Deployment Calculations

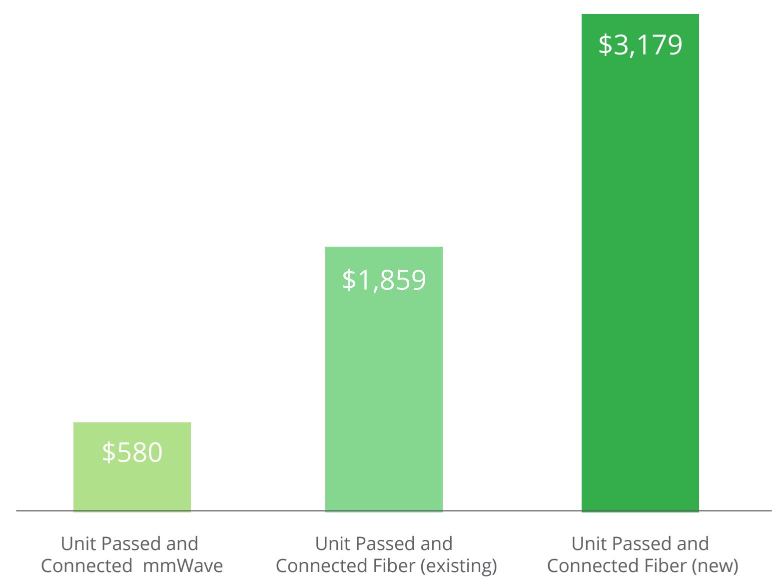
40 units per building	
units passed	40
Building Connected Fiber (existing)	$26,400
Building Connected Fiber (new)	$47,520
Unit passed and connected (existing fiber)	$1,859
Unit passed and connected (new fiber)	$3,179
In-Building Distribution (per building)	$3,336

20 units per building	
units passed	20
Building Connected Fiber (existing)	$26,400
Building Connected Fiber (new)	$47,520
Unit passed and connected (existing fiber)	$3,509
Unit passed and connected (new fiber)	$6,149
In-Building Distribution (per building)	$1,668

Graph 4: Cost of connecting an MDU Building by Technology



Graph 5: Cost of Connecting an MDU unit by Technology



5.2.3. Hybrid Fiber Wireless Proposition

Today, while FTTH projects are the favorite solution for gigabit service delivery, the timeline for these projects include a long period of network planning and design (~1 year) and even longer deployment periods (~2 years). This puts a network builder in a high-risk situation where it can only hope competition does not push prices down. And a network provider can only begin returning the investment when the last strand of fiber is deployed to the premises.

To realize infrastructure projects with high risk, a network provider may secure both a contracted subscriber base and a gigabit service much earlier using fiber-like wireless as a last mile connection technology. Fiber-like wireless installation takes less than a day. If planning and design is included, it may take anywhere from several weeks to a couple months to connect a building and begin collecting revenue to the gigabit service. So, instead of being forced to wait to deploy a gigabit while negotiations over pole attachment agreements and make-ready is in process, using fiber-like wireless, the entire construction timeline is dramatically accelerated.

Hybrid Fiber-Wireless (HFW) is a disruptive model for providing GTTH built on proven technology. This model adds high frequency wireless radios to a fiber network, drastically reducing deployment costs, time to install and possess the potential to provide multiple gigabits directly to the consumer. Simply put: by using HFW, providers can deploy a gigabit first and far cheaper than competitors. Using an HFW connectivity model in a residential market would result in a quantum leap in profitability.

About the Author

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Maravedis is a premier wireless infrastructure analyst firm. Maravedis focus on broadband wireless technologies (including 5G, LTE, Wi-Fi, Small Cells) as well as industry spectrum regulations and operator trends. Since 2002, clients have been able to access Maravedis technology, spectrum and market intelligence through research services which include disruptive reports, webinars, online databases, analyst support and briefings as well as custom consulting engagements.

About the Sponsor

Siklu delivers multi-gigabit fiber-like wireless connectivity in urban, suburban and rural areas. Operating in the millimeter wave bands, its wireless solutions are used by leading service providers and system integrators to provide gigabit services, 5G fixed wireless and in safe city and smart city projects. Thousands of carrier-grade systems are delivering interference-free performance world-wide. Easily installed on street-fixtures or rooftops, the price-competitive radios have proved to be ideal for networks requiring fast and simple deployment of secure, fiber-like and future-proof connectivity. www.siklu.com.

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