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Introduction

In the recent years, as Operators continued to trial various technologies, it has become clear that initial 5G deployments will begin with fixed broadband wireless access in the mmWave band. This is partly driven by the large amount of spectrum available in both licensed and unlicensed bands and the maturity of technologies that facilitate the mmWave solutions. The expected increase in capacity and the enhancement in QoS resulting from this situation, will benefit the Operators by generating additional revenue from new business models built around various 5G use cases such as virtual reality, real-time distributed UHD gaming, and tactile internet for remote surgery.

Fixed Wireless Broadband Access Overview

Operators today offer fixed wireless access primarily using Fiber-DSL, Cable, Wireless, and Satellite mediums that have a limited data rate between a few megabit/sec to hundreds of Mbps depending on the location and the access technology in use. For example, xDSL based fixed access technology offers a data rate in the range of hundreds of Mbps. However, the services are geographically challenged and cannot be guaranteed uniformly over distance in both urban and suburban areas with the required quality of service or throughput.

Satellite based access technology, on the other hand, can cover remote areas and reach 100s of Mbps based on the DVB-S2x specification. However, due to the inherent delay in GEO based Satellite networks, this type of fixed access service will always have limitations.

Among the available technologies, an end-to-end fiber based network has the potential to offer multi-gigabit fixed access to end users. A fiber network's biggest hurdle is the delivery of that fiber access to the end user. In communities where fiber is non-existent, it can be time-consuming and very costly to deploy resulting in Operators experiencing a long delay in realizing a return on their investment. In most cases, the fiber is never seen at the end user location, however, the fiber based link is terminated at a central hub and the last mile access is provided by either xDSL, copper, or wireless technologies limiting the last mile throughput significantly.

In the last several years, wireless technologies and the spectrum allocation has gone through radical changes. In particular, the availability of mmWave spectrum from 26 to 90GHz has opened significant opportunity to deliver multi-gigabit wireless access to users. For example, recently the FCC has opened up around 3.85GHz of licensed spectrum between 27.5 to 40GHz band (27.5–28.35GHz, 37–38.6GHz, 38.6–40GHz) [1]. Furthermore, 7GHz of spectrum in the unlicensed V-band (64–71 GHz) was added to the existing unlicensed V-band (57–66GHz) spectrum, and there exists 10GHz of spectrum in the lightly licensed E-band (71–76GHz and 81–86GHz). In total, this uniquely provides nearly 28GHz of spectrum for use in wireless technologies.

The access to spectrum is an important first step to enabling wireless technology as a solution to fixed access networks. The second "wave" or step is the significant technology advancement that has happened in antenna design and wireless communication protocols based on beamforming, MIMO, and phased array targeted to mmWave channels. And lastly, fueled by an industry-driven ecosystem and standardization bodies such as WiFi Certified WiGig [2], IEEE 802.11, ETSI ISG mWT, and 3GPP, there have been considerable improvements in signal processing techniques that opened opportunities to create mmWave solutions that are commercially feasible.

Fixed Wireless Access Deployment Model and Solution Approach

Figure 1 shows an example fixed wireless broadband access and transport network in a typical urban deployment. The access nodes could be installed at the roof-top or near the window or inside the home, while the aggregation nodes could be installed on the street-side lamp-post as shown in Figure 2. To support redundancy and mitigate interference the aggregation nodes could be connected with mesh topology.

Figure 1. Example Fixed Wireless Broadband Access and Aggregation Link in an Urban Environment

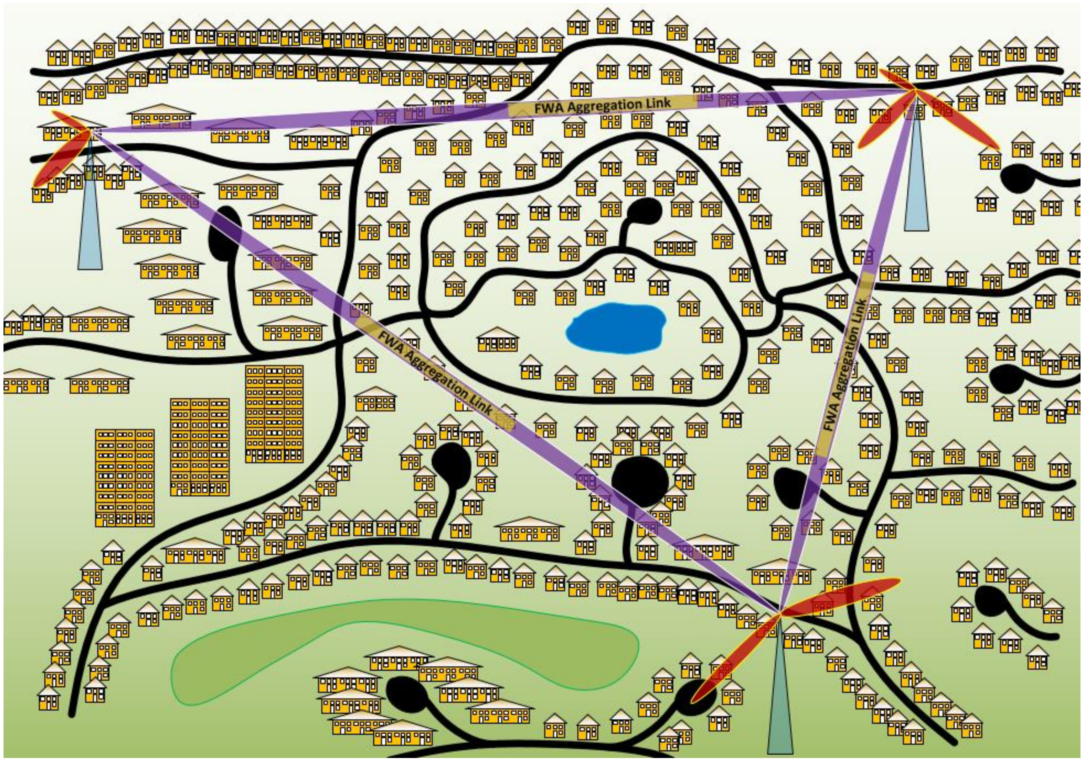


Figure 2. Example Access Nodes Deployment Options

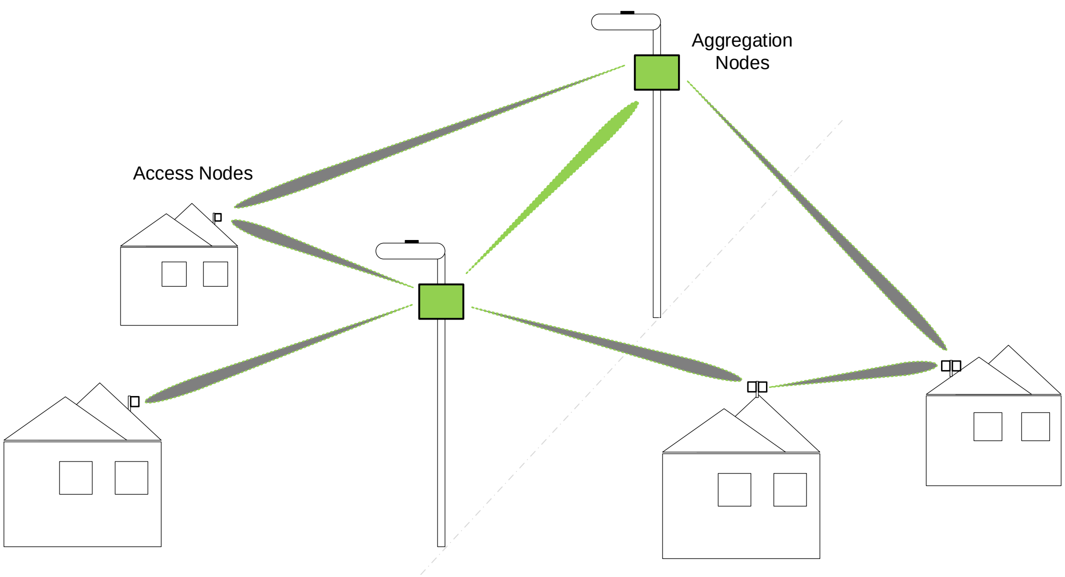
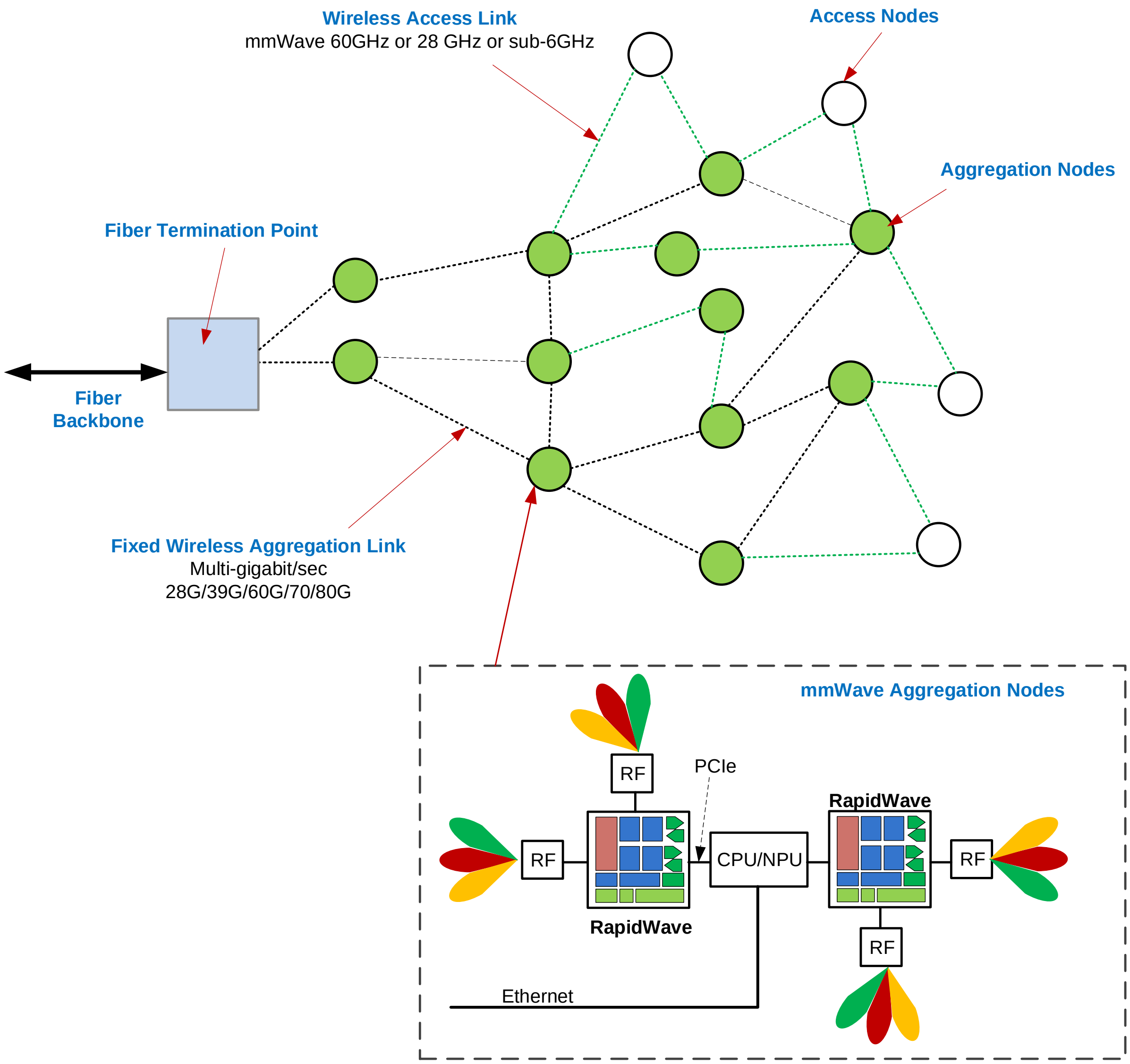


Figure 3 illustrates an example topology of the mmWave fixed wireless access network. In this example, the access portion of the network could be serviced by either an IEEE 802.11ad or an emerging 802.11ax based wireless access point using the mmWave or the sub-6GHz frequency bands depending on the choice of air interface protocol. Alternatively, the access portion of the network could be serviced by the emerging 5G New Radio (NR) access module using the 28GHz frequency band.

Figure 3. Example mmWave based Fixed Wireless Broadband Access Deployment Model using Mesh Networking Topology



On the other hand, the transport portion of the FWA network could use a mesh networking topology to connect the fiber termination point to the aggregation module, where each aggregation module services multiple access nodes over the 60GHz frequency band using the IEEE 802.11ad based protocol. Alternatively, the aggregation modules could connect to the access nodes over E-band, 39GHz, or 28GHz frequency band. The overall system link budget and the exact choice of frequency band may depend on a number of factors such as the availability of the spectrum in a particular region, environmental conditions, link range, available modulation and coding schemes, and the capacity/QoS requirements.

Table 1 summarizes typical system parameters for an IEEE 802.11ad based FWA network.

Table 1. Example FWA System Parameters

Key Parameters	Specification	Units
Link Topology Type	PtP and PtmP with LOS	
Number of Access Nodes per aggregation Node	4–32	Nodes
Antenna Gain and Beam Width	Depends on the maximum nodes and link range	
Wireless Protocol Standard	IEEE 802.11ad	WiGig
Frequency Band	57–71	GHz
Data Rate Tx	4.62	Gbps
Data Rate per Rx Nodes	100–300	Mbps
Link Bandwidth	1760	MHz
Modulation	QPSK, 16QAM, 64QAM	
Link Length	100–300+	m
Link Availability	99.99	%
Rain Zone	K	
Link Margin	2	dB
Beam Forming/Steering	Yes	

A typical mmWave FWA system intended to service many nodes in a Point to multi-Point (PtmP) mesh network would need to support the appropriate signal quality to cover the desired range and the desired number of receiving nodes. System designers need to trade the link range while optimizing the antenna gain or beam width, for the given number of nodes and capacity per node based on the chosen mmWave frequency band of operation and the target system parameters.

An example link budget to reach a range of 295m with 99.99% link availability is summarized in Table 2. In the example, link availability refers to the system loss that is typically associated with fading or loss in the channel and is in addition to transmission loss also specified in dB/km. Link availability in a fixed wireless system is affected by two key factors: Oxygen (O_2) absorption [4] and fading due to atmospheric moisture. The impact of other factors like foliage [5] for example should also be considered for network design as this can lead to higher signal loss than expected. Oxygen absorption specific attenuation losses limit link distance and is particularly significant in the first four WiGig frequency bands between 57 to 65 GHz. For example, the channel centered around 61GHz (Channel-2) has a peak loss of ~15.5 dB/km. This is significant and a major barrier to achieving a long range fixed wireless link (e.g., 900m to 1km). However, with the newly opened channels from 64 to 71 GHz [6], the oxygen absorption loss falls back into a reasonable 2 to 0.5 dB/km range for these upper channels, therefore increasing the potential viability of a 1km link.

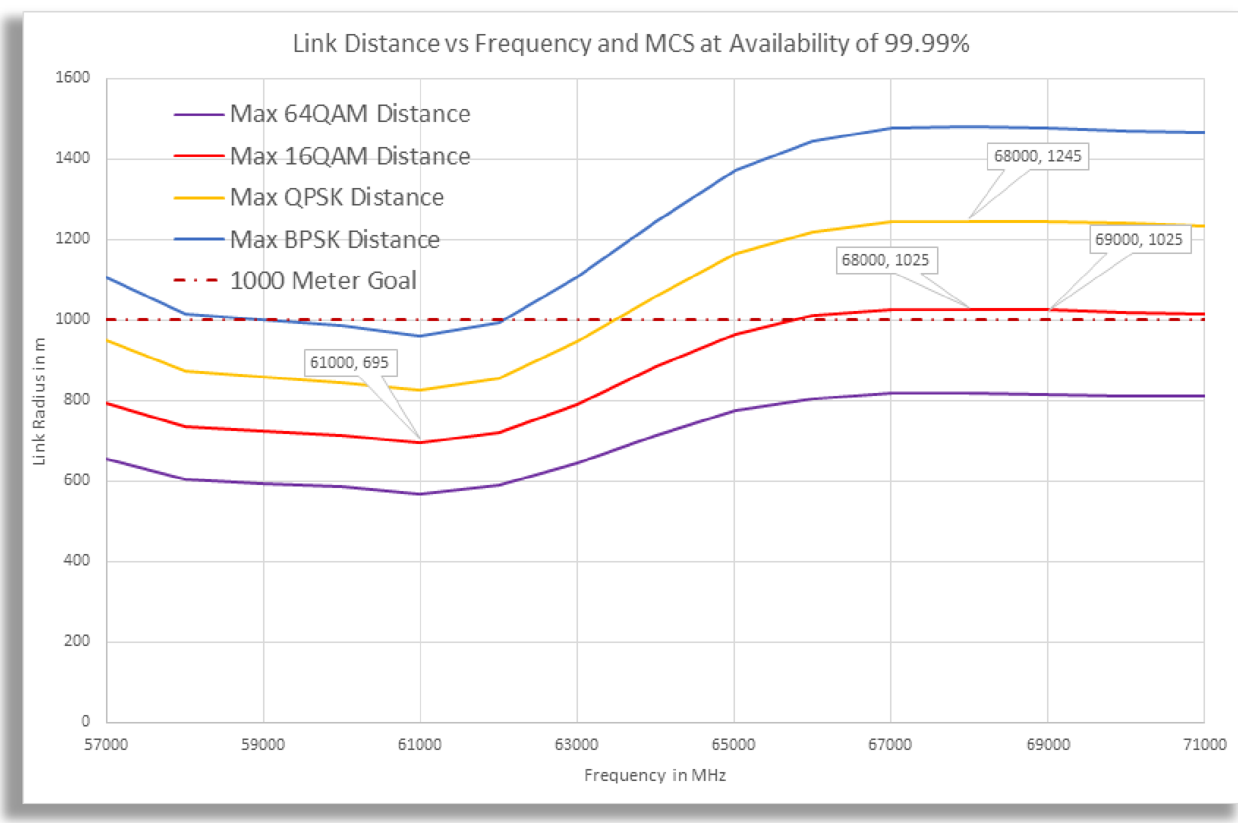
Table 2. Absorption Loss versus Frequency

Frequency [MHz]	Oxygen Absorption Loss [dB]	Frequency [MHz]	Oxygen Absorption Loss [dB]
57000	10.3	65000	2.3
58000	13.4	66000	0.8
59000	14	67000	0.2
60000	14.5	68000	0.049
61000	15.5	69000	0.01
62000	13.7	70000	0.005
63000	9.6	71000	0.003
64000	5.3		

In the example link budget, a narrower beam-width (2°) with higher antenna gain is chosen to support a link range of more than 1km. Typically, the link range for FWA may vary between 100m to 1km depending on the deployment models. In addition, the transmit power is optimized to maintain the maximum link distance while staying within the FCC power limit as defined in [7].

As demonstrated in the link budget, based on the desired network parameters and the link budget, system designers can also optimize the link range for the given modulation and coding schemes. An example of the expected link range for various modulation schemes is shown in Figure 4.

Figure 4. Fixed Wireless Access Link Distance vs. Frequency Band (Availability 99.99% with Different MCS Schemes)

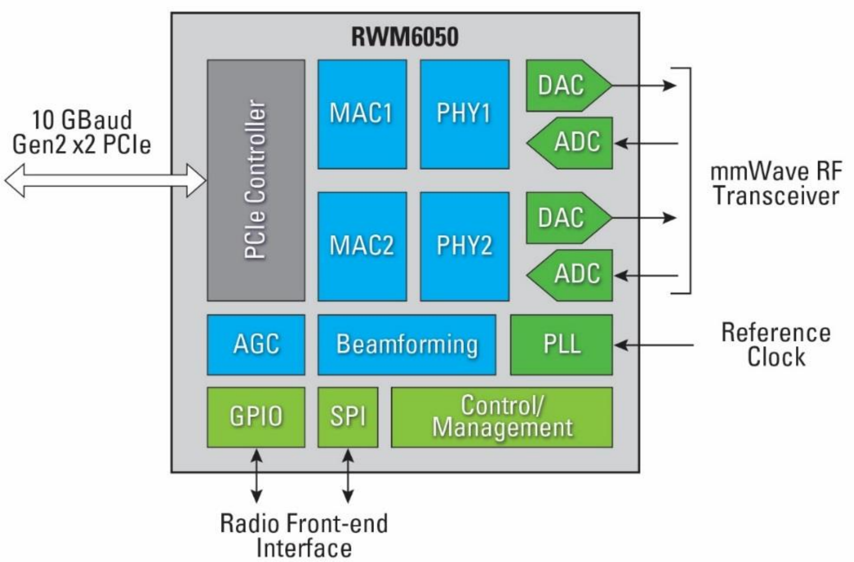


IDT has recently introduced the mmWave based wireless modem technology [3] to address the emerging fixed broadband wireless market. A high-level block diagram of the device is shown in Figure 5. The solution closes the last mile gap for pre-5G/5G systems and offers a true multi-gigabit wireless fiber experience for the end user.

The modem technology offers a range of innovative features such as beamforming, channelization, and flexible medium access control schemes. With a range of features supported by the technology, Operators and OEMs can take advantage of the large wireless spectrum available in the mmWave band and offer real-time 5G services in an interference limited environment typically expected in the unlicensed band. The solution is equally applicable to the licensed mmWave bands (e.g., Ka band) and can enable a multi-gigabit solution based on higher order modulation and strong FEC schemes, such as 64QAM with LDPC encoding.

Operators can benefit from a simplified deployment model based on a range of network topologies offered by the solution. For example, with dual modem architecture together with support for TDD and FDD, Operators can deploy a fully redundant wireless fixed broadband access for home and enterprise users in both mesh as well as hub-spoke architecture. With support for beamforming with phase array antenna, Operators can deploy a scalable sectorized cell architecture of varying sizes as the number of users grows over time.

Figure 5. IDT mmWave Modem Block Diagram (RapidWave Solution)



Conclusion

Deploying multi-gigabit speeds to the last mile needs to be practical and profitable. The greatest advantage both Operators and OEMs will experience is the rapid and low cost to deploy a RapidWave based mmWave system module. A chipset including the RapidWave modem paired with a phased array RF provides critical functionality, including digital beam alignment and sub-channelization that accelerates the deployment and simplifies the frequency planning even in densely distributed networks. The nearly 28GHz of mmWave spectrum, algorithm and antenna technology advancements and standardization, have opened new innovations such as the RapidWave modem to fuel the 5G vision of multi-gigabit fixed broadband wireless access.

References

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[3] IDT (Integrated Device Technology, Inc.), "IDT Enters mmWave Market with the Introduction of Industry's Highest Performance Integrated Modem Solutions," IDT: https://www.idt.com/about/press-room/idt-enters-mmwave-market-introduction-industry-s-highest-performance-integrated-modem-solutions, San Jose, 2017.

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[6] FCC, "Fact Sheet: Spectrum Frontiers Proposal To Identify, Open Up Vast Amounts Of New High-Band Spectrum For Next Generation (5g) Wireless Broadband," FCC: https://apps.fcc.gov/edocs_public/attachmatch/DOC-340310A1.pdf, 2016.

[7] Federal Communication Commission, "Revision of Part 15 of the Commission’s Rules," FCC, 2013.

Revision History

Revision Date	Description of Change
September 13, 2017	Initial release.
September 25, 2017	Final release.