The Business Case for Fixed Wireless Access

Key Market Drivers and a Framework for Evaluation

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Executive Summary

Over the next few years, hundreds of millions of consumers worldwide will have a new option for broadband access: fixed wireless. A combination of additional spectrum, advances in network equipment and CPE, and the advent of 5G are helping to transform fixed wireless access (FWA) from a broadband option of last resort into a viable competitive alternative in certain markets. In some countries already served by fiber- and cable- based fixed broadband (FBB) systems, FWA could offer a competitive alternative, possibly with faster service and lower prices. In areas that are un-served or under-served, FWA has the opportunity to provide communities with the type of broadband service they require for the 21st century.

Even with all the spectrum, technology, and policy elements coming together, we find that FWA is not a "one size fits all" solution. The business case for FWA varies not only from country to country but literally by city and neighborhood. Among the key factors: the prevailing FBB situation; the existence and cost of fiber-based systems (FTTH and FTTdp); population density; topography; and available/planned spectrum capacity.

In this White Paper, Mobile Ecosystem provides a detailed analysis of the business case for FWA. The focus is on developed country markets, principally the United States, Canada, Western Europe, Australia, and New Zealand. Recognizing that 'one size does not fit all', we look at scenarios in urban, suburban, and rural markets, comparing 5G mmWave and 5G/LTE sub- 6 GHz based options. In these cases, we also compare the FWA option to fiber to the home (FTTH) and fiber to the distribution point (FTTdp) solutions. Our model accounts for capex, opex, CPE, and installation variables, plotted against key market factors such as density, spectrum breadth and depth, and topography. We then develop a revenue model — mainly a combination of household penetration and price — clearly considering the prevailing FBB market and competitive situation in each case.

Our principle findings are that the business case for FWA is most favorable in the following situations:

- In **dense urban markets**, mmWave provides a good alternative, especially in cities with only one good FBB provider, and where FTTH is under-built and/or costs are high. We find the opportunities tilt toward the United States more than most countries in Western Europe, where fiber-based solutions are less expensive to build and broadband services are more competitive and less expensive. In markets with two or more good FBB providers, the FWA case is more challenging, as taking subscribers would have to come from a significantly better service or lower price.

- In **lower density urban/dense suburban scenarios**, mmWave falls off where it's not economically viable to build sites within 0.5 km of the household. But the expected availability of 3.5 GHz spectrum (which can reach up to 14 km when using the right CPE) will make FWA viable in sub- 6 GHz spectrum for both 5G and LTE in many markets. The best markets for FWA based on mid-band spectrum are where there is decent density and the MNO has the opportunity to achieve 40% or greater penetration of households in the served area, given the prevailing FBB situation.

- **Low density suburban/rural markets**. Historically, these are the areas traditionally underserved or unserved by FBB. Wireless Internet Service Providers (WISPs), using unlicensed spectrum, have been successful in some of these areas. The opportunity for licensed FWA in these areas is more case by case. The service must work with mainly lower band LTE spectrum, in conjunction with some mid-band build out in areas where there is a 'cluster' of homes, such as a village. Clearly the case for wireless is most compelling in areas where the existing FBB infrastructure is sub-par and/or lacks a compelling roadmap.

There are some more qualitative factors that could also affect the business case. For example, in some countries, there are government subsidies for wireless broadband (such as CAF funding), or, conversely, a smoother path for fiber builds. We've also found that there some benefits to the MNO's mobility business that helps 'subsidize' the FWA case. This is true for Verizon in some markets, where the FWA build and densification are providing needed coverage and capacity for its core cellular business, especially along the path to 5G.

Our objective with this study is not to size the market for FWA, or to proclaim that it will work in a *specific* City A but not City B or C. Rather, we hope this provides a framework for operators and other ecosystem players to assess whether FWA provides a viable option for broadband in a particular geography, market situation, or context.

Best Opportunities for Fixed Wireless Access

	FWA mmWave	FWA < 6 GHz	FTTH	FTTdp/ G.Fast	Situations Where Wireless Solution Preferable
Dense Urban					Where fiber cost/home passed >$1,000 and one good FBB provider
Urban					mmWave viable to HH w/in 0.5 km or < 6 GHz. Need 30%+ penetration
Suburban					Sub- 6 GHz viable where ~ 500 hh/mi^2 & only 1 good FBB provider
Ex-Urban					Possible using mix of sub-6 GHz/LTE and where FBB underserved
Rural					Generally unlicensed and perhaps LTE where there are 'clusters'

Optimal	Good	OK	Possible	More Challenging

I. Introduction

The market for broadband access is poised to become more competitive. Until recently, wireless could not physically or economically offer a viable alternative to fixed broadband access, with the exception of select markets where there was no viable broadband service. As a result, in most developed markets, there was the fixed broadband access market, and the mobile/wireless access market, with a quite significant gap between the two.[1]

But this is about to change. A combination of forces — vastly more spectrum, the advent of 5G, a host of new technologies, more favorable economics, and improved CPE — are coming together to make enhanced mobile broadband a viable alternative to fixed broadband in a larger number of market situations and contexts. The result, over time, will be:

- A narrowing of the gap between the fixed and mobile broadband markets
- More competition in broadband, and greater choice for consumers
- Expanded market opportunities for service providers: both mobile operators and telcos/fixed broadband providers

In some market situations and contexts, it is possible that consumers, who today pay some $400+ per month per household for separate fixed and mobile service, could consolidate their spend and relationship into one umbrella 'broadband' service.

All that said, we are still in the early days of this 'new era' for FWA. In developed economies, FWA remains a niche service, offered primarily by Wireless Internet Service Providers (WISPs) over unlicensed spectrum in areas that are un-served or under-served by broadband.[1] We estimate there are fewer than 1 million subscribers of WISP-based FWA in North America today. But the market is starting to expand. Major MNOs, such as AT&T in select rural markets, and NBN in Australia, have rolled out FWA in rural areas. And of course, all eyes are on Verizon's planned launch of FWA over 5G mmWave spectrum in several major U.S. cities in 2018, with more planned for 2019. Numerous additional commercial FWA initiatives and trial have been announced by other MNOs in North America, western Europe, and other developed economy markets.

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[1] *For the purposes of this report, we use the minimum standard for broadband service as defined by the FCC: 25 Mbps download/3 Mbps upload in urban/suburban markets, and 10/1 in rural/underserved markets.*

Even so, the economic viability and potential size of the FWA market remains an issue of intense debate and uncertainty. We find, as have numerous other studies and reports on FWA from suppliers, Wall Street analysts, and industry analysts, that the potential for FWA is largely dependent on *context*. There are many variables that feed into this, and they can vary not just by country or city, but even by neighborhood.

Recognizing that this is not the first report to be published on FWA, we thought long and hard about how to give this opportunity both a fresh look and a new framework for analysis. In this report, we attempt to do three things:

1) Discuss the technology and market drivers that are creating new opportunities for FWA;

2) Present the key variables/factors that should be considered when determining the viability of FWA for a given context;

3) Present several scenarios where we apply the FWA Model: a mix of urban/suburban/rural areas, for both sub- 6 GHz and mmWave spectrum. The emphasis is on *licensed* services, and developed country markets in North America, Europe, and Australia/New Zealand. For these scenarios, we describe the types of cities/market profiles that might correlate with the business case (i.e. downtown Chicago, suburban Paris).

II. Project Objective & Methodology

The objective of this study is to present the business case for fixed wireless access (FWA) in developed country markets, compared to other broadband deployment alternatives such as fiber to the home (FTTH) and fiber to the distribution point (FTTdp). The idea is to test whether FWA is becoming a viable alternative in some situations. The emphasis is on *licensed* (LTE and 5G) solutions for both sub- 6 GHz and mmWave scenarios, in urban, suburban, and rural markets. We focus developed country markets in North America, Western Europe, Australia, and New Zealand. We find that in certain Asia-Pacific countries such as South Korea and Japan, FWA is less relevant due to the extensive fiber deployment and lower cost of providing fixed broadband.

The approach in this study is from the perspective of an operator's TCO: the cost of deployment, against expected penetration and revenue. In the business cases, we present both known fixed costs, and other variables that might affect the business case, such as the state of the broadband market in that context, quality of service, expected penetration, pricing, and so on. We also take into account, but don't specifically model for 'market lift' factors, such as the benefits that infrastructure built for FWA might bring to the mobile bring to the mobile business.

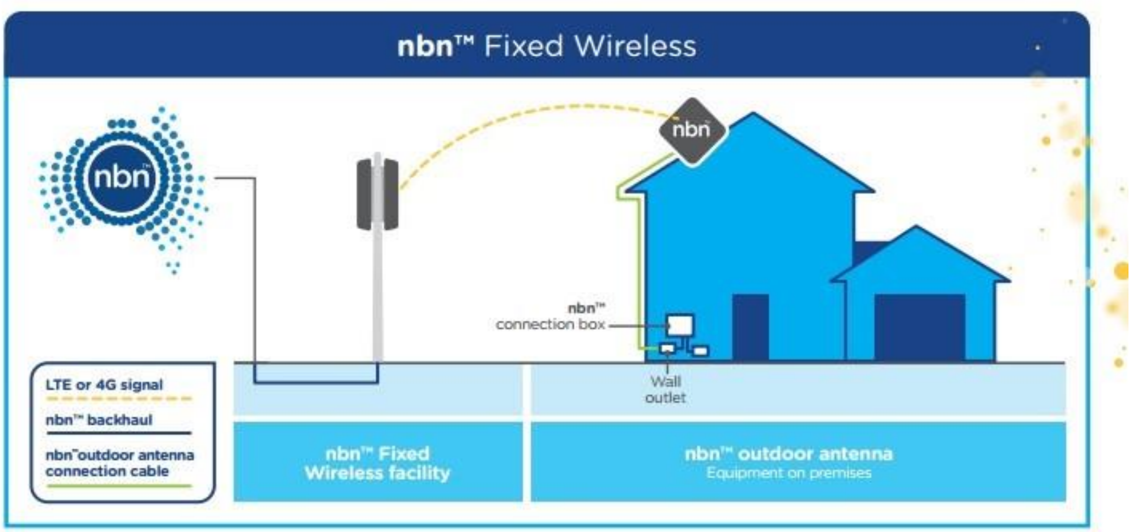
In preparing this research, we had more than 30 discussions with ecosystem players: operators, network equipment suppliers, CPE and chipset suppliers, regulatory agencies and trade associations. We also consulted our previous work on this topic, plus existing published research, trade press articles, vendor white papers, and select financial analyst reports. We believe a unique aspect of our approach compared to some others we have seen is that it accounts for particular market conditions (such as the current state of broadband competition --- it is not exclusively a cost-based model).

III. Definitions

Fixed wireless access (FWA) uses the cellular network to deliver broadband access to the home. It is a separate offering from an MNO's standard mobile service. FWA usually involves deploying dedicated equipment on the tower/node that broadcasts a wireless signal to a receiver (CPE) that sits outside or inside the home, with the signal in the home or business radiated via Wi-Fi using a standard router.

While DSL and cable bridge this gap using wired phone and television connections, fixed wireless accomplishes the same outcome by broadcasting the connection via radio waves from an access point (usually mounted on a tower) to reception dishes at consumer residences.

Exhibit 1 Simplified FWA Schematic: NBN Australia Example
Source: NBN



There are two flavors of FWA:

- **Unlicensed FWA**. This uses unlicensed spectrum, often in or adjacent to the Wi-Fi bands. These solutions are most typically offered by the Wireless

Internet Service Providers (WISPs).

- **Licensed FWA**. These FWA services are offered over the same spectrum used by mobile network operators for traditional mobile/wireless services. In theory, FWA can be offered over any licensed spectrum held by an MNO. For the purposes of this report, we are focused on two segments of the licensed spectrum:
    - ***Sub- 6 GHz***. This is an emerging swath of spectrum being considered for FWA. Generally, this is in the 2.5 GHz to 4.2 GHz range, and most commonly now in the 3.5 GHz band globally (CBRS in the U.S.). Coverage can be several km depending on the case and geography. We consider 40 MHz as the minimum requirement for FWA – especially if that spectrum is being shared with traditional mobile services.
    - ***mmWave.*** mmWave is any spectrum above 24 GHz and is the high frequency spectrum being considered for 5G in some countries. The range is typically less than 500m, but channel bandwidths of 200 MHz or more deliver the type of speed and capacity that support a competitive, if not a superior, broadband offering. FWA is one of the leading early business cases for 5G.

The viability of FWA, and of which band of spectrum can be used, depends on geography and density profiles. The schematic below is a helpful guideline.

Exhibit 2 Flavors of FWA By Density

	Density (hh/*mi²*)	Example	Sub- 6 GHz	mmWave
Dense Urban	1,500	Barcelona		
Urban	1,000	Chicago downtown		
Suburban	500	Evanston, IL		
Ex-Urban	Under 200	St. Charles, IL		
Rural	Under 100	Freeport, IL		

Optimal	Good	OK	Possible	More Challenging

Type of dwelling

- **Multiple Dwelling Unit**. Either a condo of more than 5 units, or an apartment building.
- **Single family home**. A unit for a single family, or multi-family home that still looks like a 'home'.

CPE

In FWA networks, the CPE is part of the solution as it is the operator's asset in the end-users' home. Having the right device to allow for the highest speed, reliability and support is of utmost importance. There are 2 options that need to be considered when choosing a Fixed Wireless CPE: outdoor or indoor.

In currently deployed FWA networks, which are mainly targeting rural areas, operators have typically chosen an outdoor CPE. In this set-up, a dedicated receiver antenna that looks like a small pizza box is installed on the roof of the end-user premise. From there, the outdoor CPE is connected via a wire through a hole to home equipment (such as a router), or in some cases wirelessly to an indoor CPE unit. Installation of the CPE on the roof allows for directional antennas and guarantees that the device can be installed with the best the Line of Sight (LoS) to the base station. This increases the signal-to-noise ratio (SNR) and therefore also the performance as a higher QAM modulation can be used.

In situations where the performance is of lower importance, operators are currently deploying indoor CPEs as they can offer a quick fix. The installation is done by the end-user without optimization, therefore the performance is of best effort and connectivity can't be guaranteed, resulting in a higher return ratio than when using outdoor devices.

With the advent of 5G, the number of end-users connected to the Fixed Wireless network will be much greater than in current rural deployments. Outdoor CPE require professional installation and will therefore be challenging and costly. Therefore, new solutions are being developed that include both an indoor and outdoor component to allow for optimal LoS and performance while ensuring easy installation so the end-user can do it themselves.

We have emphasized CPEs with an outdoor component in our analysis, given its 15–25 dB better signal quality, which is generally needed for mmWave and sub- 6 GHz solutions

IV. FWA Market Drivers

Numerous factors are coalescing to enhance the market opportunity for FWA. In addition to some key developments on the technology front, we find that there are a host of new market and business drivers that are compelling operators to take a fresh look.

A. Technology Drivers

Several of the key developments on the technology front that are enabling a new look at licensed FWA in developed economies are captured in the table below.

Area	Key Developments
Spectrum	• mmWave spectrum and channel bandwidths for 5G provide for significantly greater speed and capacity • Significant swaths of mid-band spectrum are becoming available, expanding MNO capacity potential
Antennas & Site Technology	• Massive MIMO & MU-MIMO enhance spectral efficiency and expand capacity for FWA applications, especially for 5G • Beam forming capabilities in the LTE-A and 5G roadmap allow for more precision service to households
Vendor Equipment	• Major network equipment suppliers have developed a new wave of FWA-optimized solutions
CPE	• A new wave of improved CPE has become available. They feature integrated antennas delivering up to 19 db gain, and can deliver gigabit speeds by supporting carrier aggregation, 4x4 MIM0, and 256 QAM. • New CPE for indoor has technology to reduce path loss and optimize the installation process to guarantee the best performance possible

B. Market Drivers

At a high level, good quality, reasonably priced broadband service is a requirement in developed economies --- close to being a 'utility' on a par with electricity and water. Any location where broadband is 'sub-par' in any way — level of competition, speed/latency, service price, investment roadmap, and so on — is open season for at least considering FWA. This includes locations that are 'unserved' or 'underserved' by FBB.

We define underserved as any combination of the following:

- Sub-par service quality. In urban/suburban, we consider this to be a service below the minimum of 25/3, and in rural 10/1 (the FCC's definition)
- Inordinately high prices or lack of meaningful competition
- A less than compelling investment roadmap from incumbent fixed broadband providers. For example, are they continuing to build FTTH? Upgrading to DOCSIS 3.1, G.fast, or other means of improving service over time?

Given this, the opportunity for FWA is a function of the following market factors in a particular location:

- Level of competition.
- Quality, pricing, and penetration of fixed broadband service

- Cost of providing broadband service (i.e. cost of fiber to the home)

The state of each of these, or a combination thereof, figures prominently in the potential for FWA to offer a competitive alternative, from the standpoint of cost, quality or price. We also need to consider that there will be a need for better broadband in the coming years: faster speeds, lower latency, and greater capacity, driven the growth of video, 4K, OTT television, and augmented/virtual reality, One must consider, in a particular market, not just the 'mobile' evolution to LTE-A and 5G, but also broadband providers' planned improvements to their networks.

These are the key market variables that figure prominently in our market model. Put simply, many locations in developed economies need better broadband, in the form of more competition, faster speeds, and lower prices. The United States is a good example. Some 50% of households only have a choice of one broadband provider. And in some 50% of households that that have a choice of more than one provider, the second offers a sub-bar service (i.e. under 25 Mbps download speeds). Additionally, broadband services in many developed economies are comparatively expensive. In the U.S., the cable providers (who own 70% of broadband market share) generally require a pay TV and telecom bundle (so-called 'Triple Play') for the best price. A customer who wants to take broadband as a standalone service often has to pay more.

C. Business Drivers

We must also take into account changes in the business landscape that contribute to the FWA business case.

Mobile market subscriber and revenue growth in most developed economies has flattened, due to a maturing market. Subscriber penetration is near 100% (or exceeds it). Revenue growth has been flat – in fact, prices continue to be under pressure in many countries, even though mobile data consumption continues to increase by 30-50% per year. These realities are contributing to greater pressure on the MNOs to find additional sources of revenue. This is why they're investing in IoT, private LTE, and so on. FWA, in the proper context, represents a significant incremental revenue opportunity.

Verizon's commitment to FWA represents an excellent example: even though they lead the U.S. mobile market in terms of subscribers and revenues, growth has flattened of late. In broadband, they are a regional rather than a national player. And, expanding the footprint of their FiOS (broadband and TV) service has become too expensive, and they have little avenue or appetite to improve their legacy DSL offerings.

One must also consider the 'market lift' benefits of an FWA investment. Any upgrade to the network for FWA — additional cell sites, densification, capacity increase, upgrade to 5G — also likely benefits the mobile network as well. This clearly translates into higher potential revenues, lower churn, and so on. So in many cases, FWA investments results in a virtuous circle.

V. Business Case Overview

It is *technically* possible to bring FWA to nearly any location. But whether it makes market or business sense is highly dependent on context -- it must meet one of the three criteria:

- *The area is either un-served or under-served by FBB*. Either there is no decent broadband in the area, or the broadband that does exist is either inadequate, overly expensive, or both.
- *Providing an FWA solution is economically more feasible than FBB*. In some rural areas, it is too expensive to build fiber, cable, or copper based FBB solutions. In some urban areas, FWA is more economically feasible than FTTH or other wired access solutions.
- *There are prevailing FBB quality of service or pricing issues*. It's possible in some markets than an MNO can viably offer a FWA-based solution for less than the prevailing FBB price. In some cases, the MNO might break even or lose money specifically on the FWA component, but accrue other benefits to their mobile business, such as higher capacity, better coverage, lower churn, or FWA as part of a bundle.

A. <u>Minimum Requirements for FWA</u>

At a high level, the minimum requirement is that the FWA solution must be competitive with the prevailing (or near- to medium- term projected) FBB solution. The two consumer-facing essential components of broadband are speed (uplink/downlink) and capacity. Despite the FCC's minimum speed requirements for broadband funding vehicles, Mobile Ecosystem has modified that definition somewhat to model what we believe are real-world requirements. For example, we believe 25 Mbps is the minimum to support streaming video (not 4K), and 50 Mbps is preferred to support multiple devices connected simultaneously. We don't believe that in an urban/suburban situation that a SP will enter the FWA market unless it can offer 50 Mbps down to 80% of the households covered by FWA. In projecting out into the early 2020s, we believe FWA providers in an urban/suburban setting should be thinking about a minimum 100 Mb download service. We also define that latency must average under 5 ms.

In terms of capacity, we apply a minimum benchmark for what we believe most households in developed markets want to do. Today in the United States, average consumption in FBB households is about 250 GB/month, projected to grow to nearly 500 GB/month by 2022. This we call the average 'Netflixing' household. In a developed market urban/suburban setting, we believe a prospective FWA provider must be able to support consumption of 200 GB/month per household.

Area	*FCC* Min. Speed Requirement	*Market* Min. Speed	Min. Monthly Capacity/HH
	Downlink/Uplink	***Downlink Speed***	***GB Per Month***
Urban	25/3 Mbps	50-100 Mbps	200+
Suburban	25/3 Mbps	25-50 Mbps	150-250
Rural	10/1 Mbps	10-25 Mbps	100

B. Key Inputs to the Model

The following are the major levers for the business case --- that is, the numbers that can be adjusted to affect the business case.

Capex Costs

# of HH Reached Per Node * Cost Per Node/# of HH In Area (density) = Total Initial Capex (one-time)

- Then add annual maintenance capex, which is a % of total capex

Opex Costs

Opex Cost Per Node/Month

Home Dropped Costs

Price of CPE + Cost of Installation (one-time)

Revenue Model

Customer Penetration (% of homes passed) **+** Monthly Service Fees **=** Revenues/Month

Exhibit 3 Explanation of Key FWA Variables

Category	Definition	How Figure Into the Model
Technology & Market Variables		
Spectrum Band & Capacity	• Which band (i.e. mmWave or sub- 6 GHz) • Amount of spectrum, in MHz, needed for FWA solution • Max range of propagation in that band • Capacity per cell site. Not an issue in mmWave, but in mid-band need ~1.5 GHz per site	• ***mmWave***: 100-400 MHz in the mmWave band. Max range ~500m. *Minimum 100 MHz of spectrum* • ***Sub-6 GHz***: 40-100 MHz in mid-band is required. Range ~1-3 km urban, up to 14 km suburban with good LOS. ***Capacity***: Need ~1.5 GHz/cell site – balance w/range
Density	• # of households per mi² • Must meet 80% of HH in area • mmWave will only be competitive in urban and denser suburban markets	• Dense Urban: >1,000 HH/mi², • Urban: 750-1,000 HH/mi² • Suburban: 100-500 HH/mi² • Ex-Urban/Rural: < 100 HH/mi²
Topography & Geography	• Line-of-Sight (LOS): Generally, the HH CPE must have LOS to the nearest node • Foliage/Weather: density of foliage, rain, and humidity are factors. Denser foliage presents challenges • Type of terrain: flatter easier	• For mmWave, need LOS from AP to CPE. For mid-band, can more easily penetrate buildings • Weather/foliage more subjective – i.e. low-medium-high
Building Materials	• Urban deployments: buildings present challenges, block LOS • Brick, type of glass, other materials influence DB signal loss into buildings and location of CPE	• Not specifically incorporated in model, but impacts LOS requirements; proximity of node; whether CPE can be indoor/outdoor
Key Cost Elements		
Capex	• Generally expressed as cost per node. Elements are RAN, antennas, etc. Both build capex and maintenance capex	• **Build capex.** In *licensed* implementations, we've seen a range of $25,000-100,000 per node. • **Maintenance Capex.** Ongoing capex. We work up to ~5% of build capex
Opex	• Backhaul & power, $/node/month • Additional network opex (cost per month)	• Range is $500-1,500/node/mo. – has a big bearing on case • Can be ~3-5% of revenues
CPE Cost	• The cost of installing the CPE receiver for FWA, either inside or outside of dwelling (or both)	• Range is $150-400 for outdoor CPE
Installation Cost	• Whether must be professionally installed or self-install influences cost of solution	• Professional installation average cost is $150
Cost Per Home Passed	***Total capex divided by number of homes that could get the service. The key overall metric to compare to FTTH or other FBB alternative.***	***$1,000 per home passed is a good benchmark to compare to fiber-based solutions***

Definition	How Figure Into the Model	How Figure Into the Model
Market Situation		
Mobile Market Competition	• How competitive is the mobile market? Influences whether FWA offers an MNO competitive advantage/differentiator; also influences capacity situation	• Higher # of mobile operators and mature market puts some pressure on MNO to pursue FWA in order to diversify and seek additional sources of revenues
Fixed Broadband Competition	• A function of the # of FBB competitors, and the quality/price of their service • Tells us whether FBB market is un-served, under-served, well-served	• 1 FBB competitor with 50 MB+ service is base case • 2+ good FBB competitors makes the business case for FWA challenging
Market Pricing	• Prevailing broadband pricing impacts case (can FWA provider match or beat price)	• Range is $50-80/month. In the U.S., we use an average unbundled price of ~$60. Europe FBB prices are lower but country dependent.
Market Objective		
Network Performance	• What does FWA provider have to offer to match/exceed incumbent FBB offerings?	• mmWave: Must be above 100 Mbps • Sub-6 GHz: Must be 50 Mbps or better unless prevailing FBB speeds are significantly less
Pricing	• What does FWA provider have to offer to be competitive on price?	• A factor of existing FBB prices and ability of FWA provide to match/exceed while offering competitive quality and capacity
Capacity/Usage Limit	• Does FWA offer Unlimited or Usage Limits? • If UNL, what capacity requirements does that drive? If usage limits, is that a competitive offering or does it limit TAM?	• In urban, competitive FBB market, must support 200 GB+/month for sub- 6 GHZ, and close to UNL in mmWave
Target Penetration	• What is the expected penetration over 5 years (% of passed HH that connect)	• Business case is challenging if <30% target penetration after 5 years • If FBB market is not competitive, then we aim for closer to 50% penetration

One can go a lot deeper, especially on some of the more individual cost components, RF elements, topography, and so on. But we've tried to strike a balance by focusing on the key components required for analysis which, in some cases, are the aggregation of some sub-components.

The Role of CPE in the Business Cases

As FWA is an alternative for a Fixed Broadband service, the CPE plays a major role in the end-to-end solution. End-users expect higher speeds, more reliability and better support from their service provider when it comes to Fixed Broadband, compared to Mobile Broadband. Therefore, to offer FWA services, the trusted zone of a mobile network (which only reaches the base station) needs to be extended to the CPE.

When extending the trusted zone, the operators takes ownership of the end-user device and can therefore better manage, maintain and monitor the service. By using the right combination of ease of installation and optimal antenna design, better performance and higher reliability can be achieved.

A new wave of outdoor CPE support gigabit speeds via carrier aggregation, 4x4 MIMO, and 256 QAM. The powerful antennas might help increase the number of households that can be reached per node. With 5G, these optimization characteristics will be adopted for indoor devices as well.

Using the right remote network management and diagnostic capabilities will make installation easier, and reduce CPE opex costs over time. To be successful in FWA, the service needs to be at the same level as other Fixed Broadband services for end-users to take on the service and the support that can be offered by these capabilities need to match the end-user expectations. We found a worthwhile tradeoff for slightly higher-priced CPE in the business cases, as it can contribute to better coverage (help serve more homes per node) and modulate at a higher rate, thereby lowering opex costs over time.

What is Not Taken Into Consideration

This is a high-level model that is meant to provide a framework for looking at the business case for FWA in different scenarios. One could go several layers deeper across numerous factors. It is more cost focused than sales and marketing focused. That said, here are some items that are not factored into this model. Most importantly, **spectrum costs are not incorporated into the model**, mainly because each situation is so different. Most operators are not acquiring specific spectrum for FWA – rather, they are allocating some portion of existing spectrum. Additionally, many of the predicted FWA implementations will be at still-to-be-auctioned 3.5 GHz or mmWave, and there is not enough data yet to consider the price of that spectrum. Plus, each country is approaching this quite differently.

Additional factors not incorporated in the model:

- Equipment Opex
- Unique costs specific to MDUs – such as cable costs from rooftop into dwelling -- we average that out to CPE & installation costs
- Operator sales and marketing expense
- Churn. Once we reach the 5-year penetration rate, we keep the subscriber number consistent…but it can be changed in the model
- "Market Lift' factors that can't be easily incorporated into an operator TCO model, such as benefits that might accrue to the *mobile* side of the business, or ancillary services than an operator might offer, such as streaming TV.

Comparing Costs

One of the objectives of this project is to compare FWA to fixed network solutions in a particular context – principally FTTH and FTTdp. Doing this for each business case is a challenge, because we find that the cost for the alternatives can vary significantly from one situation to another. For example, in Europe, the average cost of building FTTH averages €600-700, but ranges from €200 (Spain) to €2,500 (Sweden). In the United States, the costs for FTTH are a little more consistent – generally in between $1,000 and 1,500 per home, and 2-3x that for some earlier implementations (Verizon Fios, Google Fiber).

Costs for FTTN Europe are far lower – in the $150-450 range.

VI. Business Case Presentation and Analysis

The viability of the FWA business is highly situational. For this study, we have chosen several cases that we feel represent real market situations (or potentially real over the next 2-3 years for mmWave 5G NR and 3.5 GHz). This represents a mix of urban/suburban/rural, for both mmWave and sub-6 GHz. The emphasis is on *licensed* solutions, and on consumer FWA applications (single family home or MDU).

Our approach is also unique in that it goes beyond merely a cost comparison of FWA vs. fixed network alternatives. We also take into account the market situation and the state of the FBB level of service and competition.

Business Case #1: Typical Downtown Urban Area

Scenario #1: mmWave (5G)

Description. This business case is meant to test the feasibility of FWA in a typical downtown area. We model a 10,000 home neighborhood, with a density of 900 homes per square mile. There's an incumbent cable provider offering a good DOCSIS service, and a telco offering a 25 Mbps DSL service.

Markets That Reflect This Description. Some of the cities being targeted by Verizon in the United States, and some less dense cities in Europe with relatively high FTTH costs, such as Stockholm, would fit this profile.

MNO Objective & Service Proposition. Offer a competitive broadband service that at least matches cable broadband, and exceeds the DSL service, at a competitive price.

Solution. The MNO enters the market with a mmWave-based service which is equivalent or better service than the incumbent cable provider, for approximately the same price. Because the system is based on mmWave, only 80 customers are reached per node and the per-node price is high.

Results. The MNO achieves 40% penetration – mainly by taking share from the DSL provider. Net revenues are a loss of -$6.7 million after 5 years, and a profit of $1.5 million in Year 10.

Key Levers

Capex	The high equipment cost per node and the low # of HH reached per node is the biggest challenge in the business case
Cost Per Home Dropped	We find that self-install and cost of CPE do not make a dramatic difference compared to increasing penetration to 40%. But if CPE is expensive, the 10-year case is substantially less profitable
Opex	We modeled a modest $500/month
Penetration	The difference between 30% penetration and 40% penetration makes this profitable for the MNO, at $60 per month. The case does not work at penetration below 25%.
Price	We played around with pricing by raising it from $60 to $70 per month, reducing penetration to 35%. The result was not significant in the 5-year situation, but over 10 years, the result is ~25% increase in net revenues.
Market Situation	We believe that the case is viable if only one good FBB competitor. It's difficult to get the needed penetration with 2 or more BB competitors.

Scenario 2: Sub- 6 GHz

We reduced the equipment cost to per node by 25% and doubled the number of homes that could be reached, per node. We assume that because the service is Sub-6 GHz, that the incumbent DOCSIS provider is able to offer better speeds, but the MNO's service is better than the second FBB provider. Hence we cut the price to $50 per month. We assume 25% penetration of passed homes go to the MNO.

The significant reduction in the capex cost makes the business case easier for the FWA provider. Even at only 25% penetration, the service is much less underwater after 5 years, and nearly 3x more profitable by Year 10. At this lower cost, **the MNO must reach a minimum penetration rate of 20% to make the case work**.

The bottom line is that in a mmWave implementation in a downtown area with a competitive FBB provider, the MNO's FWA business case is heavily reliant on achieving at least 1/3 market share.

Scenario 3: Alternative Cost Options

We did some cost comparisons with other technologies and in some of the regions covered in this report. In the table below, here is where mmWave FWA compares most favorably.

Scenario	Explanation	Sample Areas
Fiber alternatives are >$1,000 per home passed	FWA is not competitive below ~$1,000 per home passed in an urban area	Many U.S. markets, and select cities in Europe with higher fiber costs
Only one competitive FBB provider	It is difficult for FWA to get to our threshold of >33% market share where 2+ good FBB providers present	U.S. cities with one competitive FBB provider.
ADSL/VDSL roadmap not compelling	The FWA business case looks better from a technology and QoS perspective	Many U.S. cities and denser suburban areas, with longer copper loop lengths

For sub- 6 GHz spectrum in urban areas, the key is for the MNO to have substantial mid-band spectrum. Two good examples are T-Mobile in the United States, which, if merges with Sprint, will have 120 MHz of spectrum in the 2.5 GHz band, and could offer a FWA service to compete with cable in some cities; and Three in the UK, which plans on an FWA service, leveraging its 144 MHz of spectrum in the 3.4-3.6 GHz band.

Business Case #2: Suburban Neighborhood (Europe)

Description of Situation. In this case, we model a suburb or small town in Europe of average density. The FWA solution is sub- 6 GHz. The area is not dense enough to support mmWave.

Prevailing Situation: The existing FBB situation is fair, with the main provider being xDSL offering a ~25 Mbps service. The MNO wants to offer a competitive FBB service. It would be for better broadband and some TV streaming use, but not a replacement for pay TV.

Markets That Reflect This Description Some suburbs outside main German cities fit this profile, where MNOs have abundant and somewhat underutilized spectrum. Three UK is another MNO that fits this profile and is looking at an FWA solution.

Build Requirement: The MNO is able to use some of its existing LTE spectrum in order to offer FWA, refarming some of the mobile capacity needs to lower bands. Also, an additional amount of spectrum is acquired in the 3.5 GHz band. Total allocated capacity for FWA is ~40 MHz.

Offering. The MNO models capacity at ~250 GB/month per household. The pricing is about $40 per month – reflecting overall lower prices in Europe for fixed broadband services. It's roughly similar to the xDSL provider.

Market Result: We assume a 40% penetration rate by Year 5, staying at that level. The result is a near breakeven at Year 5, and into positive territory in Year 6-7.

Summary. The business case hinges on the following key factors: ample mid-band spectrum, relatively low level of FBB competition, ability for FWA to offer a 25 Mbps or better service, and MNO achieving 40%+ penetration. In Europe, the most significant challenge will be the service price.

Key Levers

Lever	Affect
# of Homes Reached Per Node	Better propagation of mid-band results in substantially greater reach and lower cost per node than mmWave in urban areas
Capex Per Node	Lower than mmWave, but some 3.5 GHz band costs are slightly higher. Capex cost to reach 10k homes <50% of cost of urban mmWave case
CPE – Cost & Installation	Assume outdoor CPE & professional install. Cost of CPE slightly higher initially due to new 3.5 GHz band
Maintenance Opex	Can make a big difference. Our conservative estimate is 7%
Customer Penetration	Our 40% assumption driven by good opportunity for market entry, but mitigated somewhat by ~30% of homes in area that can't be reached by FWA. If 5G, can use Massive MIMO & beam forming to reach homes
Pricing	Our pricing is low due to lower FBB prices in Europe. Increasing price from $40 to $50 comes at risk of some penetration loss

Business Case #3: Dense Suburban Neighborhood: Fixed Broadband Operator

In this case, we take a different approach. This is a fairly dense residential neighborhood, served by two fixed broadband providers – one cable and one DSL. In this case, fiber reaches to "the curb", or a distribution point about 200 meters from the home. FWA is considered as an alternative to other 'last mile' solutions, such as G.fast.

Prevailing Situation: Two incumbent FBB providers, one cable and one DSL. The DSL provider needs to offer better service to keep up with cable. In countries with short loops, fiber generally gets to a 'distribution point' within a few hundred meters of the home. Two competing alternatives for that 'last few hundred meters' are G.fast and FWA. We consider mmWave-based FWA as an option, compared to providing fiber or G.fast directly to the home.

We assume this is a situation with sufficiently short copper loops that make the copper upgrade more feasible. We assume here that the DSL operator has access to infrastructure, and that it must acquire mmWave spectrum or have access to it.

Markets That Fit This Description. European cities where operators offer both fixed and mobile services would work well here, since the owned spectrum can be used for FWA. This case is most appropriate in cities/suburbs where there are relatively short copper lengths, where there are solutions to upgrade the DSL plant.

Build Requirement: The operator has fixed infrastructure in the form of utility poles, so it has line-of-sight to the household. We consider using mmWave-based FWA for the last 200 meters. This would require outdoor CPE at the home. We model a $50,000 cost per node. The operator is able to keep opex costs down due to owning its own infrastructure.

Offering. Quality of service matches/exceeds that of the other FBB provider (we model 150 Mbps). Pricing is competitive. The operator models capacity at ~500 GB/month per household, fitting the 'Netflix Household' profile.

Market Result: The two biggest dependencies are the # of households reached per node and the market penetration. As a $50k per node cost, anything fewer than 50 homes reached per node makes the solution more expensive than fiber. This scenario is also very sensitive to penetration --- there's a big difference between 40% and 50%.

Cost Comparison. In situations where FTTH gets close to $1,000 per home passed, G.fast and FWA are becoming good alternatives. In a number of scenarios where G.fast is being deployed, the average cost is in the $750 range. FWA is a viable alternative below that price, which means decent topography and being able to reach at least 50 homes per node.

Summary. The DSL provider must use FWA to offer a competitive service to G.fast. Being able to reach more than 50 homes per node is important, as is the need to maintain minimum 40% penetration of households passed. G.fast might offer a better alternative where it has to go 200 meters or less, especially if the incumbent operator has good prevailing infrastructure. It could well be that in some situations, an operator might use FWA to reach some clusters of homes, and G.fast for others, for example where fiber is greater than 200 meters from the household.

Key Dependencies

Lever	Affect
Availability of Spectrum	The DSL provider must have access to mmWave spectrum. Either it owns it, must acquire it, or can purchase it wholesale.
Topography	Since this is a dense suburban geography and not a downtown urban area, foliage and line-of-sight play a more critical role when mmWave spectrum is used.
Quality of CPE	Given mmWave sensitivities and the area topography, the quality of CPE is a major factor – it can have an effect on the % of homes reached from the distribution point
Opex Costs	DSL provider is able to leverage existing infrastructure to keep opex costs low, reducing backhaul
Cost of Fiber in the Country	This must be a country/market where the cost of providing FTTH is on the higher side. It should be >$750 per home passed for FWA to be competitive
Quality of Service	The operator must offer a service roughly equivalent to DOCSIS – 150 Mbps+ and 500 GB of capacity per HH, in order to fairly evenly split the market
Subscriber Penetration	The case hinges on the DSL provider achieving 40% penetration of the market or greater. Net 10-year revenues at 40% penetration are $0.5m and are $5.4m at 50% penetration.
Pricing	The business case does not work very well with broadband pricing much less than $60 per month.

Business Case #4: Ex-Urban/Rural

The business case for FWA becomes a little trickier when serving a rural area, which we define as less than 100 homes per mi^2 (or that present unique geographic/topographic challenges). It is more situational in nature.

There are two categories of FBB situation in rural areas:

- **Underserved**, meaning that there is a prevailing FBB solution, but it is inadequate in terms of % of homes reached, quality of service (speed/latency/reliability), and/or it is very expensive. Some of the lower-end DSL services and satellite are examples here.

- **Unserved.** In these situations, there is no current FBB solution, except for perhaps satellite. A number of other concepts are in the works, such as Google Loon, OneWeb, and so on, but none has been launched yet.

Historically, using FWA to serve rural areas has relied on unlicensed solutions, delivered by Wireless Internet Service Providers (WISPs). We believe that the rural market is an opportunity for cellular, but very much on a case-by-case situation. Our model shows that a cellular-based FWA solution would be most effective if there is a 'cluster' of homes or buildings in a rural area of sufficient number where it makes sense to build a tower or add FWA infrastructure to existing infrastructure. This is particularly the case where an operator does not have spectrum below 1 GHz. If there is not sufficient density, then the comparative cost of cellular FWA might prove challenging to the business case.

In terms of solutions, mmWave generally does not apply in rural contexts. The new mid-band spectrum envisioned for LTE/5G, such as the 3.5 GHz band does not have sufficient propagation characteristics to reach homes in areas with density well under 100 homes per square mile. An MNO would need to have some holdings in the sub- 1 GHz bands to reach some of the homes. If there's a cluster of homes in a neighborhood or village of some sort, then mid-band assets could be deployed. Here, as 5G NR is deployed, Massive MIMO, MU-MIMO, and beam forming might be used to reach a higher % of homes.

The main 'competitor' to cellular in these situations is an unlicensed solution, which has mainly been the province of the WISPs. The general business case for WISPs is to erect a tower in a high location, which delivers adequate LOS to a sufficient cluster of homes. The average WISP has 1,000-2,000 customers. The solution is generally a 'good enough' service where there is no other broadband service available in the area. Many WISPs receive some federal subsidies to help make the economics work. The challenge for cellular MNOs here, even if they have access to tower facilities with sufficient backhaul, is the higher cost of the licensed solution. Our research indicates that an unlicensed solution costs half or less than cellular.

However, there are some changes happening in this part of the market. First, some of the WISPs are starting to migrate to LTE in some regions, which is a function of a broader and less expensive array of cellular network equipment and CPE becoming available, and in some cases offering faster speeds and greater capacity. Additionally, there has been some M&A in the WISP market, with a handful of WISPs now large enough to have the 'buying power' to consider a licensed FWA solution.

The availability of federal subsidies such as the Connect America Funds (CAF) can also be a game changer in some areas. AT&T has taken advantage of these funds (see above), as has C-Spire.

Rural Business Case in Our Market Framework

For the purposes of our model, we provide a sample business case that might look like a low population density ex-urban or rural (but not super-rural) area in the United States or western Europe.

The main difference here impacting cost is the low density, meaning that only 50 homes per node are reached. But, since this uses 4G LTE, the cost per node is half that of mmWave. This translates into cost per home passed of $1,000. The higher cost to reach homes is mitigated in the model by take-up of 60% among homes passed, at a relatively high price point, so it is not a competitive market. On a standalone business, the MNO just starts making a profit in Year 10.

Key Levers in Rural Business Case

The case here is a bit more straightforward, since the competitive environment is less intense. It is much more focused on the cost side: capex cost per node, and opex cost per node. These impact the case most significantly, since we assume that if the service quality is good, penetration among passed homes will be high and there is less price elasticity. If cost per node goes up dramatically, or if fewer than 40 homes are reached per node, the business case goes underwater quite quickly.

Here, the main issue will be comparing with unlicensed FWA solutions, which are significantly less expensive in rural areas. The roadmap of any incumbent FBB provider also has a big bearing on the case. We assume here that the MNO solution is better than the incumbent FBB provider (if and where in the market there is one), in most cases. Though we do note that quality of service varies more from one home to another than it does in our urban and suburban cases.

VII. Comparing Fixed Wireless Access to Fixed Network Options

It is a challenge to provide an apples-to-apples comparison of the cost of providing FWA compared to fixed network alternatives. We find that this varies significantly from one region/country/city to another. It is only possible to do a direct comparison when selecting a very specific location, and then taking into account the market situation there at this particular time (or projected). For example, when looking at FWA in an urban situation in Europe, here are the sorts of differences that affect the comparison to FTTH:

- **Major variation in cost per country**. The average cost of FTTH per home averages €600-700 ($700-820), but ranges from €200 ($234) in Spain to €2,500 ($2,937) in Sweden.
- **Variations in spectrum**. In Europe, in general FWA does not tend to compare favorably except for in certain specific situations. One of the more promising opportunities is in the UK, where Three UK has 144 MHz of spectrum in the 3.4-3.6 MHz bands. This allows the company to 'peel off' a significant chunk of spectrum for a dedicated FWA solution — something that its competitors, who only have 40 MHz of mid-band spectrum — can't do. Other opportunities will arise as swaths of mid-band spectrum become available.
- **Government subsidies**. Germany presents a special situation. First, prevailing broadband speeds are among the lowest in Europe. Second, the federal government and municipalities are providing subsidies to improve broadband in less densely populated suburban and rural areas, which is reducing FTTH costs to €300 ($352) per home passed. At the same time, MNOs there have an abundance of under-utilized spectrum

Each country (especially in Europe) is quite different in terms of which technology is emphasized for FBB.

Even when comparing DSL costs, it is not apple-to-apples. In the United States, longer loop lengths have made the DSL evolution path not very compelling beyond 25 Mbps. In some European countries, the VDSL loop lengths are a lot shorter, providing a good opportunity to upgrade networks, especially using G.fast to homes less than 200 meters away.

We find, in particular, that the opportunities for FWA in western Europe tend to be more niche oriented --- such as in a particular city, or with a particular operator. Europe's higher densities and other characteristics would generally support the FWA case on a standalone basis. But in many countries and cities in Europe, there tend to be better alternatives from an economic standpoint given the combination of better existing FTTH and FTTN infrastructure, higher level of FBB competition, and lower FBB prices, and other market-specific situations.

VIII. Conclusions

Fixed wireless access has been a niche market for many years -- mainly a broadband 'service of last resort' in areas not reached by conventional broadband. But with new spectrum in the mmWave and mid-bands, the approach of 5G, and advances in network equipment and CPE, FWA is poised to be a viable option for broadband service in certain market situations.

Our findings in this report point to particular contexts where FWA makes both economic and business sense. **We believe mobile network operators in developed country markets do have an opportunity participate in the broadband market – but the situation must be ripe.** The most attractive opportunities are in areas with no more than one 'good' incumbent broadband provider, and/or situations where for some reason make fiber or copper based solutions comparatively expensive with no near-term roadmap to that situation changing.

In this analysis, we find that the FWA business case is best supported in the following conditions:

- **Urban**. We believe that mmWave will usher in new opportunities for FWA, since it enables the MNO to offer a solution competitive with good broadband service. The MNO has a better chance at succeeding in cities with only one strong incumbent FBB provider. Additionally, scenarios where building FTTH would cost more than $750 per household lend themselves to an FWA solution.

  Cities with shorter copper loop lengths, such as many in Europe, could also support a fixed broadband provider upgrading its plant (for example using G.fast) and then FWA for the last ~200 meters.

  The case for sub-6 GHz works best in cities where an MNO has substantial spectrum, likely at least 40 MHz they can dedicate to FWA.

- **Suburban**. Suburban situations tend to be the most context specific. In denser suburban environments, there might be a case for mmWave, especially where 50 or more households can be reached via a single node. In cities, topographical challenges are more posed by buildings and interference. In suburbs, it's LOS (height of infrastructure) and foliage.

  Most suburban locations will rely on a sub-6 GHz solution, and we believe the coming wave of 3.5 GHz spectrum in many U.S. and European markets will be a boon to the FWA case.

Our analysis also supports the case for fixed broadband players to upgrade their plant to the distribution point and then reach a home using FWA, in certain context – short loop lengths, and ample spectrum/capacity. We assume they are able to offer QoS to match an incumbent cable or other FBB player and relatively split the market.

- **Rural**. In rural markets, FWA is rapidly becoming a more prevalent solution, since there's no magic bullet for lowering the cost to build out a fixed infrastructure. Improved FWA technology/solutions, more spectrum becoming available, and government subsidies in some of these locations all play a role.

  Rural markets for the foreseeable future will rely primarily on sub- 6 GHz LTE solutions, with the possibility of mmWave 5G where there is a cluster of homes such as in a village. Here, the main governor is whether a sufficient number of homes can be reached from a node, to justify the cost per node. Also, lower cost unlicensed FWA solutions are part of the economic equation.

All eyes will be on some early licensed FWA implementations in developed country markets, such as AT&T and Verizon in the United States, and some select deployments in Europe. We believe that as operators acquire additional sub- 6 GHz spectrum, and as mmWave and 5G services are rolled out, that fixed wireless access will represent an additional market opportunity for select mobile operators in particular market contexts.

APPENDIX – BUSINESS CASE DETAILS

Business Case #1 Detail: Typical Downtown - mmWave

Demographics and Topography

Spectrum Band	200 MHz of spectrum in the 28 GHz (mmWave) band
Density	900 homes per square mile
Topography	Foliage not a serious issue
Infrastructure	MNO reutilizes most of its LTE plant and has to add some small cells for 5G

Market Situation

Mobile Market: 4 facilities-based wireless operators. Two of them also have FBB/landline assets, but not in this city.	**Broadband Market**: One broadband provider offering a solid 150 Mbps service, for $60/month. 60% market share. One legacy DSL operator offering a 25 Mbps service. 40% market share
Customer Situation: Customers have been looking for a more competitive broadband market. Investment roadmap for incumbent DSL provider is limited.	
FWA Strategy. The FWA provider offers a service equal to or better than the incumbent cable provider, at a similar price.	

Key Cost Assumptions

Cost Per Node	$80,000
# of Homes in Served Area	10,000. We assume reach 80%
# of Homes/Node	80
Total Nodes	125
Total Capex	$10 million
Maintenance Capex	$1.2m over 5 years
Capacity	Total capacity for FWA is minimum 1.5 GHz per site
Opex Per Node	$500 per month

Capex Cost Per Home

Category	Assumptions	Results
Capex Per Home *Passed*	125 Nodes x $80/node x 10,000	$1,000 per home ***passed***
CPE	$300 for outdoor CPE	$300 per home ***served***
Installation	$150 professional install	$150 per home ***served***
Cost Per Connected Home	Home Passed + CPE+ Install	**$1,400 per home *served***
Cost Per Home Served over 5 years	Total Capex + Homes Served Divided By Penetration, 5 years	**$3,215**

Revenue Model: Year 5

Market Penetration	40% in Year 5	4,000 customers
Monthly Price	$60	$720 annual revenues/cust.
Total Revenues ***(after Opex)***	# of customers x monthly price	5 years: $6.4m 10 Years: $17m
Net Revenues	Revenues after all capex, opex, and maintenance capex	5 years: -$6.7m 10 Years: $1.5m

Business Case #2 Detail: Suburban Neighborhood, Sub- 6 GHz

Demographics and Topography

Spectrum Band	20 MHz of existing LTE spectrum allocated to FWA, and 20 MHz of new spectrum in the 3.5 GHz band.
Density	300-400 homes per square mile
Topography	Some foliage issues. ~30% of homes in addressed area cannot be effectively served by FWA
Infrastructure	MNO must add some new equipment to existing LTE sites and add new equipment to 3.5 GHz sites

Market Situation

Mobile Market: Competitive LTE market	**Broadband Market**: xDSL provider offering a fair FBB service, ~25 Mbps. No fiber
Customer Situation: Customers have been looking for a more competitive broadband product	
FWA Strategy. The FWA provider offers a service better than the incumbent DSL provider, for a slightly higher price. But is not able to reach all homes in addressed area	

Key Cost Assumptions

Cost Per Node	$50,000
# of Homes in Served Area	10,000. We assume reach 60-70%
# of Homes/Node	120
Total Nodes	83
Total Capex	$4.2 million
Maintenance Capex	Works up to 5% of total capex by Year 5, and 7% of total capex, years 6-10
Capacity	Total capacity for FWA is 1.5 GHz per site
Opex Per Node	$750 per month per node

Capex Cost Per Home

Category	Assumptions	Results
Capex Per Home *Passed*	83 Nodes x $50k/node x 10,000	$417 per home ***passed***
CPE	$300 for outdoor CPE	$300 per home ***served***
Installation	$150 professional install	$150 per home ***served***
Cost Per Connected Home	Home Passed + CPE+ Install	**$867 per home *served***
Cost Per Home *Served*	Total Capex + Homes Served Divided By Penetration, 5 years.	**$1,623**

Revenue Model: Year 5

Market Penetration	40% in Year 5	4,000 customers
Monthly Price	$40	$480 annual revenues/cust.
Total Revenues ***(after Opex)***	# of customers x monthly price	5 years: $3.5m 10 Years: $9.4m
Net Revenues	Revenues after all capex, opex, and maintenance capex	5 years: -$3.2m 10 Years: $1.2m

Business Case #3 Detail: Dense Suburban Neighborhood, mmWave, DSL Provider Using G.Fast/FWA

Demographics and Topography

Spectrum Band	Must be minimum of 100 MHz of mmWave spectrum
Density	600-800 homes per square mile
Topography	Typical suburban foliage. ~20% of homes in addressed area cannot be effectively served by FWA
Infrastructure	DSL provider must have some of own infrastructure to provide LOS and reduce backhaul costs

Market Situation

Mobile Market: Three incumbent mobile operators – none with enough sub-mmWave spectrum to offer competitive broadband	**Broadband Market**: Cable provider offering good FBB service. DSL provider needs to keep pace
Customer Situation: Customers want at least a two-payer FBB market.	
FWA Strategy. DSL provider upgrades copper network with G.fast and FWA to offer a competitive FBB service.	

Key Cost Assumptions

Cost Per Node	$50,000
# of Homes in Served Area	10,000. We assume reach 60-70%
# of Homes/Node	60
Total Nodes	167
Total Capex	$8.3 million
Maintenance Capex	Works up to 5% of total capex by Year 5, and 7% of total capex, years 6-10
Capacity	Total capacity for FWA is 1.5 GHz per site
Opex Per Node	$500 per month per node (~30% less than other cases)

Capex Cost Per Home

Category	Assumptions	Results
Capex Per Home *Passed*	167 Nodes x $50k/node x 10,000	$833 per home ***passed***
CPE	$400 for outdoor CPE	4300 per home ***served***
Installation	$150 professional install	$150 per home ***served***
Cost Per Connected Home	Home Passed + CPE+ Install	**$867 per home *passed***
Cost Per Home *Served*	Total Capex + Homes Served Divided By Penetration, 5 years.	**$1,383 per home *passed***

Revenue Model: Year 5

Market Penetration	40% in Year 5	4,000 customers
Monthly Price	$60	$720 annual revenues/cust.
Total Revenues ***(after Opex)***	# of customers x monthly price	5 years: $5.6m 10 Years: $15.0m
Net Revenues	Revenues after all capex, opex, and maintenance capex	5 years: -$5.9m 10 Years: $0.5m

Business Case #4 Detail: Rural, Under-Served/Unserved area

Demographics and Topography

Spectrum Band	Mainly reliant on low-band spectrum
Density	Under 100 homes per square mile, but not 'super rural'
Topography	
Infrastructure	MNO must add some new equipment to existing LTE sites. Sites must have good LOS

Market Situation

Mobile Market: 2-3 MNOs, spectrum slightly underutilized	**Broadband Market**: One relatively poor DSL service
Customer Situation: Customers have been looking for better quality broadband service	
FWA Strategy. The FWA provider offers a service better than the incumbent DSL provider, for a slightly higher price. Must be 25-50 Mbps. But is not able to reach all homes in addressed area and QoS varies more significantly from one household to another	

Key Cost Assumptions

Cost Per Node	$40,000
# of Homes in Served Area	1,000 We assume reach 60%
# of Homes/Node	40
Total Nodes	25
Total Capex	$1.25 million
Maintenance Capex	Works up to 5% of total capex by Year 5, and 7% of total capex, years 6-10
Capacity	Total capacity for FWA is 1 GHz per site
Opex Per Node	$500 per month per node

Capex Cost Per Home

Category	Assumptions	Results
Capex Per Home *Passed*	25 Nodes x $40k/node x 1,000	$1,050 per home ***passed***
CPE	$300 for outdoor CPE	$300 per home ***served***
Installation	$150 professional install	$150 per home ***served***
Cost Per Connected Home	Home Passed + CPE+ Install	**$1,400 per home *served***
Cost Per Home *Served*	Total Capex + Homes Served Divided By Penetration, 5 years.	**$2,283**

Revenue Model: Year 5

Market Penetration	60% in Year 5	480 customers
Monthly Price	$60	$720 annual revenues/cust.
Total Revenues ***(after Opex)***	# of customers x monthly price	5 years: $676,000 10 Years: $1.8m
Net Revenues	Revenues after all capex, opex, and maintenance capex	5 years: -$420,000 10 Years: $430,000

Author's Note

This research was conducted exclusively by Mobile Ecosystem, on behalf of NetComm with the purpose of advancing thought leadership on the business case for fixed wireless access. In preparing this report, we held more than 30 discussions with ecosystem participants and relied on previous work Mobile Ecosystem has conducted on FWA. The research did not focus on capabilities of specific network equipment or CPE, and is not an endorsement of any particular supplier's products or solutions.