4G/5G FWA Broadband White Paper

HUAWEI

TABLE OF CONTENTS

Executive Summary 1

1. Background of Home Broadband 2

1.1. Home Broadband Industry Status 2
1.2. Broadband for All and the Challenges 6

2. Wireless Fiber Broadband Helps Broadband for All 10

2.1. What is Wireless Fiber? 10
2.2. Wireless Fiber Advantages over Fiber 11

3. Wireless Fiber Key Solutions to Improve Capability 15

3.1. Key Challenges for Wireless Broadband 15
3.2. Service Provision and Management Assistant System 15
3.3. End-to-End QoS Management Mechanism 16
3.4. Coverage and Experience Improvement Solution 17
3.5. Capacity Improvement 19

4. Wireless Fiber Network Plan and Evolution 21

4.1. Wireless Fiber Broadband is More Affordable 21
4.2. Cost-Per-Line Methodology and Impact 21
4.3. Service and Experience Target Definition 22
4.4. Target Network Design and Evolution 23
4.5. Capacity Expansion Methodology and Path 25

5. Regulator Recommendations for Boosting Wireless Broadband 27

5.1. Role of 4G/5G FWA in National Broadband Plans (NBPs) 27
5.2. Checklist for Utilizing FWA Broadband to Bridge Digital Divides 27

6. Success Stories 29

6.1. Case 1: Japan 29
6.2. Case 2: Philippines 29
6.3. Case 3: Sri Lanka 31
6.4. Case 4: Trinidad and Tobago 32

References 32

EXECUTIVE SUMMARY

Wireless Fiber provides fiber like speed by 4G/5G Fixed Wireless Access (FWA) technology.

Wireless Fiber offers a good choice to governments and operators to promote national broadband and provide an alternative option for Fixed Broadband (FBB) to offer home broadband services due to its leading technologies and mature ecosystem.

The white paper highlights the following facts and forecasts according to reliable sources:

Wireless Fiber is an alternative of fiber and can help "Broadband for All" and bridge the "Digital Divide".

Wireless Fiber reuses legacy mobile network infrastructure, does not need access permission and civil construction, and can easily provide inclusive fixed broadband with a low TCO. Wireless Fiber have following advantages:

1. Full connection
2. Fiber like experience
3. Fast deployment and fast ROI
4. Flexible price and speed on demand
5. 5G-oriented evolution

Wireless Fiber has been serving 100 million households, of which more than one billion households were not connected. Connection speeds need to be boosted for over 450 million households. Wireless Fiber has played a key role in the progress.

It has been put into commercial adoption globally. Typical cases include Japan, Sri Lanka, Philippines, and Trinidad and Tobago.

1. BACKGROUND OF HOME BROADBAND

1.1. Home Broadband Industry Status

1.1.1. Digital Divide in Home Broadband

The "digital divide" is a term that refers to the gaps in access to information and communication technology (ICT). In the home broadband (HBB), there is an obvious digital divide created by the gap between the rich and poor. Considering the impact of gender, age, occupation, and other factors on internet penetration, promoting HBB for women, the elderly, children, and people not working has profound social significance in narrowing the digital divide worldwide.

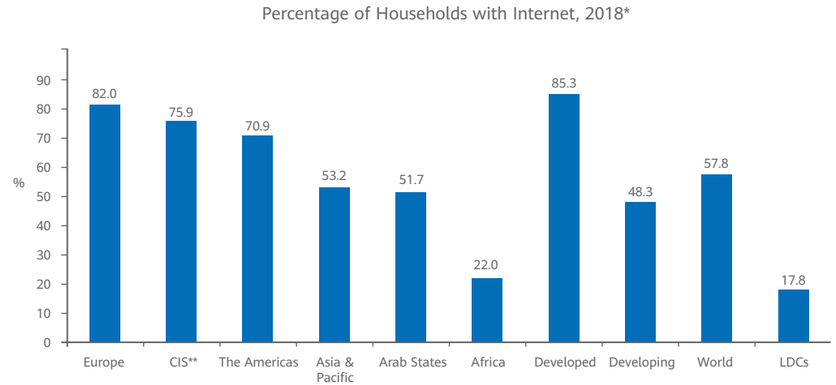


Figure 1: Percentage of Households with Internet Access

Unfortunately, due to the constraints of country/region, policy, educational level, occupation, age, gender, and income, people have access to vastly different amounts of information transmission resources. This fundamentally affects the common development and progress of mankind.

As shown in Figure 1, in developed countries, the proportion of households with Internet access at home is 1.7 times as high as that in developing countries.

Only 17.8% of households in LDCs have Internet access at home. In these countries, many Internet users are accessing the Internet from work, schools and universities, or from other shared public connections outside the home.

The digital divides are apparent in access to and use of broadband communications. Developed countries have significantly higher subscription and penetration rates for broadband and Internet than in LDCs. People in Europe, rich countries in North America, and parts of the Asia and Pacific region are also more

likely to be connected to the Internet than those in other regions, particularly Africa. Evidences show that the gap between LDCs and other developing countries is continuing, raising concerns on negatively impacting efforts to achieve the Sustainable Development Goals.

50% of the world's population is expected to have Internet access by the end of 2019. This means the other half – an estimated 3.8 billion people – are still not connected. In response, the United Nations' Broadband Commission for Sustainable Development has set seven ambitious yet achievable 2025 targets in support of "Connecting the Other Half" of the world's population.

Broadband Commission for Sustainable Development 2025 Targets include:

By 2025, all countries should have a funded national broadband plan or strategy, or include broadband in their universal access and services definition.

By 2025, entry-level broadband services should be made affordable in developing countries at less than 2% of monthly gross national income per capita.

By 2025, broadband/Internet user penetration should reach 75% worldwide, 65% in developing countries, and 35% in least developed countries.

By 2025, 60% of youth and adults should have achieved at least a minimum level of proficiency in sustainable digital skills.

By 2025, 40% of the world's population should be using digital financial services.

By 2025, unconnectedness of Micro-, Small- and Medium-sized enterprises should be reduced by 50%, by sector.

By 2025, gender equality should be achieved across all targets.

1.1.2. Home Broadband Speed Challenges

The concept of digital divide is not limited to people's lack of internet access. Households with broadband access also face challenges in the new digital divide. With social development and technological progress, more and more content is delivered through broadband. As a result, the capabilities and speed of broadband services become critical. The following figures illustrate vast differences in broadband access between countries. The speed gap also exists among areas of a country due to inequalities between countries and regions.

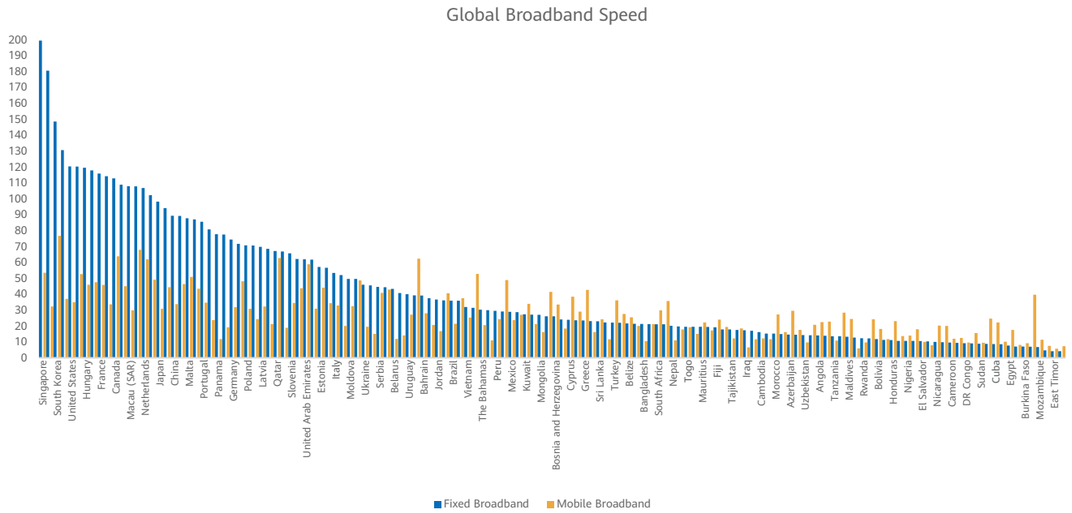


Figure 2: Global Broadband Speed (Mbps)

This report shows that the fixed broadband speed in major developing countries is lower than 20Mbps, and even some countries are below 10Mbps. Another finding is that mobile broadband speed in these countries are higher than fixed broadband, mainly due to the popularity of LTE networks.

1.1.3. Fixed Broadband Technological Overview

The most common fixed broadband connections are as follows:

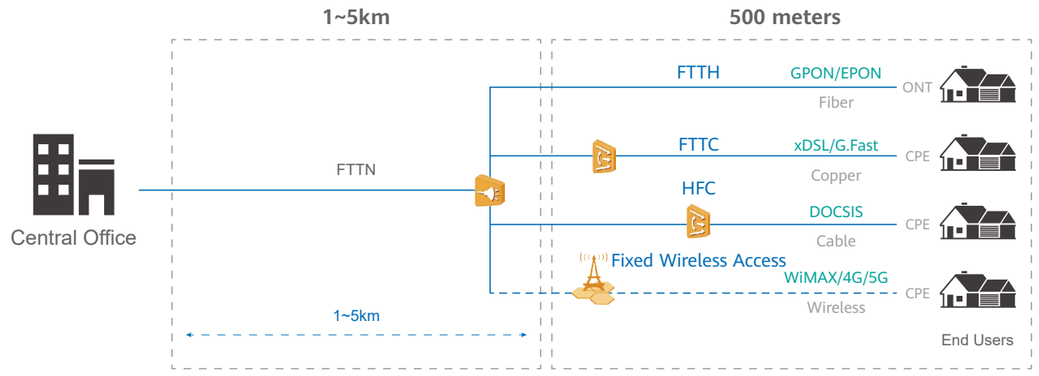


Figure 3: Fixed Broadband Technologies

- Digital Subscriber Line (DSL)
- Cable modem
- Fiber optic
- Fixed wireless

Digital Subscriber Line (DSL) is a wired transmission that uses traditional copper lines already installed to homes and businesses. DSL-based broadband provides transmission speeds ranging from several hundred Kbps to millions of bits per second (Mbps). Availability and speed of DSL services depend on the distance from a home or business to the closest central office or telephone exchange of broadband-equipped telephone company.

The DSL enhances technology like ADSL. VDSL and G.fast can offer from 40-100Mbps and up to Gigabits rates, respectively. But in real networks, most xDSL broadband speeds are below 10Mbps as the speed is dependent on the FTTN network and the distance from home to the exchange. The copper line quality and the lack of record of copper also result in high maintenance costs.

Cable modem: Cable television companies provide broadband using the same coaxial cables that deliver pictures and sound to TV sets. A cable modem is an external device that normally has two connections: one to the cable wall outlet, and the other to a computer.

Cable operators use the DOCSIS standard to provide Internet access over their Hybrid fiber-coaxial (HFC) infrastructure. With DOCSIS3.0/3.1, a maximum of 1.2Gbps/10Gbps can be reached, respectively.

Fiber to the home (FTTH), also called "fiber to the premises" (FTTP), is the installation and use of optical fiber from a central point directly to individual buildings such as residences, apartment buildings and businesses to provide unprecedented high-speed Internet access. FTTH dramatically increases the connection speeds available to computer users.

While FTTH promises connection speeds of up to 100Mbps -- 20 to 100 times as fast as a typical cable modem or DSL connections.

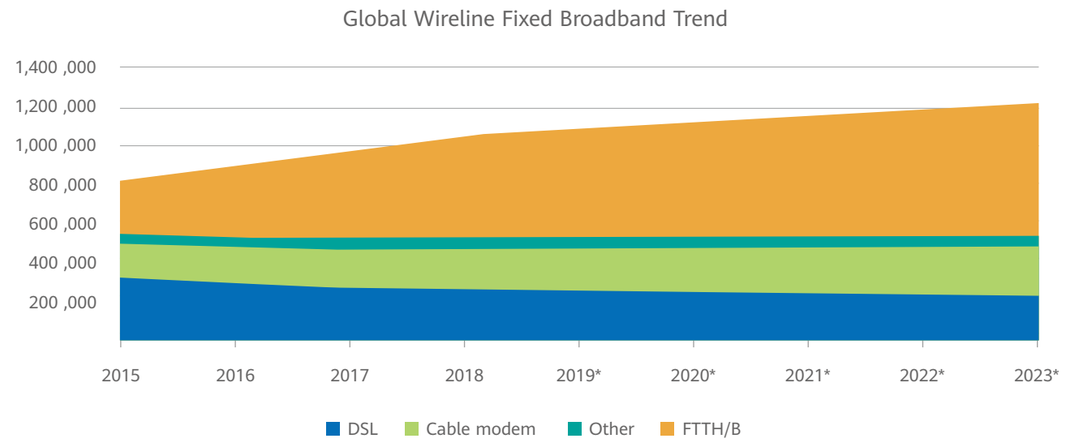


Figure 4: Global Wireline Fixed Broadband Trend (*Source Ovum)

According to Ovum's forecast, fixed wireline broadband technology will serve 1.2 billion by 2023. DSL will decline and FTTH/FTTB will increase significantly. But this still falls short of the United Nations' expectations.

Fixed Wireless Access will be a new option for fixed broadband (FWA). It is a process of accessing a communicating network or Internet on fixed wireless networks. It is a type of wireless broadband data communication, which is performed between two fixed locations - connected through fixed wireless access devices and equipment.

WIMAX is a major FWA technology developed a long time ago. Many operators have now already upgraded WIMAX to 4G LTE. With the evolution of 4G and the arrival of 5G, 4G/5G FWA provides users speed up to ~100Mbps and even G bps and become an alternative to FTTH.

1.2. Broadband for All and the Challenges

1.2.1. Why Broadband for All

According to the World Bank, a 10% increase in broadband penetration boosts average GDP by 1.3% and job creation by up to 3%. However, 6 billion people lack access to high speed Internet and 3.8 billion have no Internet access at all.

Broadband for All will ensure that everyone has access to high-speed broadband everywhere. Broadband for All bridges the digital divide and connects everyone to the Digital Economy everywhere.

There are several challenges to realize Broadband for All in home broadband.

1.2.2. Rural Home Broadband

There are a unique set of challenges associated with delivering high-speed broadband to rural areas that service providers do not encounter in more urban locations, including geographical variables and high costs.

Unlike "urban jungles", rural areas have a varying degree of terrains. Depending on geographical conditions of the region, providers can encounter anything from rock and sand to compacted dirt and mud — making planning and executing a fiber buildout difficult. Many times, technicians are unaware of what type of soil composition they will be digging into until the project has begun. Then, they may find that getting the adequate trenches dug to lay the fiber is nearly impossible.

At the same time, the population density of the rural market is very low, and the construction cost of the fixed network is high, which makes the operator's investment unable to be recovered, which is also a factor that restricts rural broadband. In fact, fixed broadband, especially fiber optics, is mainly concentrated in urban areas.

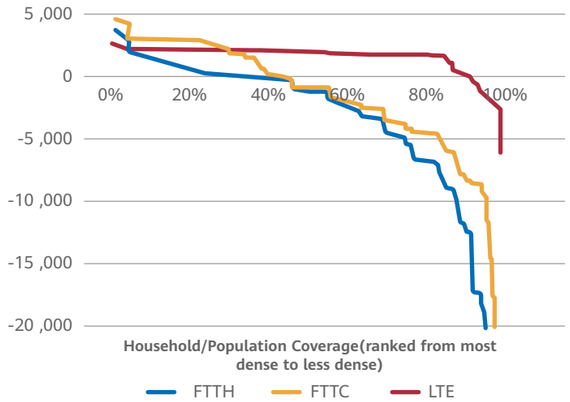


Figure 5: NPV vs Household/Population Coverage by Technology (*Source ITU)

As shown in this figure, the incremental costs for Fiber-To-The-Home (FTTH) and Fiber-To-The-Cabinet (FTTC) increase quickly when household/population coverage is below 40–50%, resulting in a negative Net Present Value (NPV). Long-Term Evolution (LTE) maintains a positive NPV even with household/population coverage of more than 90%.

1.2.3. Low Speed Copper Upgrade

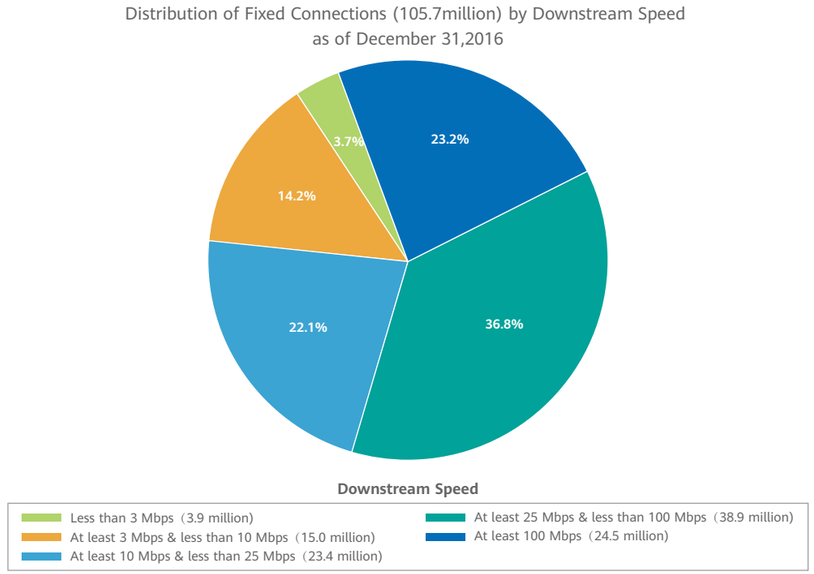


Figure 6: Distribution of Fixed Connections by Downstream Speed (*Source ITU)

There is a lack of broadband connections in rural areas. In cities, low-speed broadband speed upgrade is a challenge, too. According to ITU data, 40% of the world's fixed broadband is below 25Mbps. The main media is copper. Although optical fiber can replace copper to increase broadband speed, the replacement is very slow due to huge investment CAPEX and difficulties in obtaining the Right of Way (RoW). As shown in Figure 4, according to Ovum's forecast, 40% of broadband will still use DSL or cable by 2023.

1.2.4. Affordable Broadband Price

Affordable access to the Internet is one of Sustainable Development Goals. By 2025, entry-level broadband services should be made affordable in developing countries at less than 2% of monthly GNI per capital.

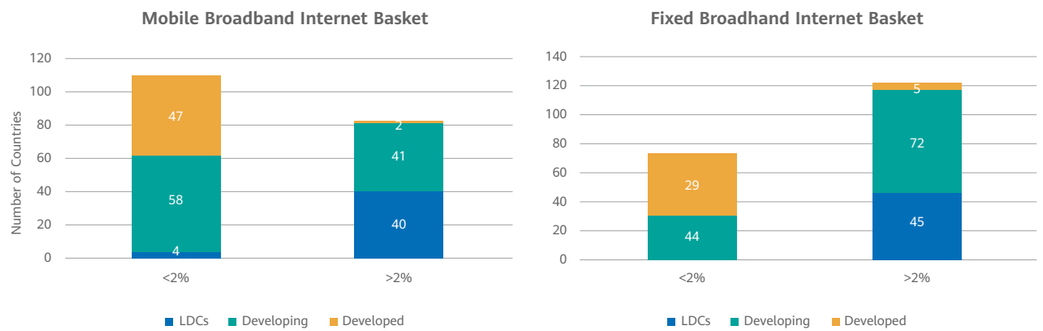


Figure 7: Affordability Broadband Prices Percentage as a GNI per Capital,2016 (*Source: ITU)

Mobile broadband is more affordable than fixed-broadband in most developing countries. For example, in LDCs, on average, an entry-level fixed-broadband subscription is 2.6 times more expensive than an entry-level mobile-broadband subscription.

Fixed broadband requires much civil work and RoW costs, which usually account for 70–80% non-active equipment cost in FTTH, resulting in high costs per active user. Though regulators have made huge efforts, including infrastructure sharing, national broadband funding, RoW regulations, and many others, there are still many challenges to provide affordable fixed broadband services.

1.2.5. Broadband Competition

The lack of competition in fixed broadband leaves users fewer options to choose broadband services that meet their needs. For example, according to the FCC's Internet Access Services Report 2018, 13% of "developed blocks" cannot get broadband at all at the FCC's standard "broadband" definition of 25 Mbps in the downlink and 3 Mbps in the uplink. While 56% of blocks can get those speeds from at least two ISPs, 44 percent of blocks have access to 25 Mbps speeds from just one ISP.

The reasons of insufficient competition in fixed broadband are multifold. Exclusive RoW lead to insufficient competition, and ROI period is long and investment risks are high, resulting in a low willingness among network operators.

2. WIRELESS FIBER BROADBAND HELPS BROADBAND FOR ALL

2.1. What is Wireless Fiber?

Wireless Fiber is an alternative to fiber and can help realize "Broadband for All" and bridge the "Digital Divide".

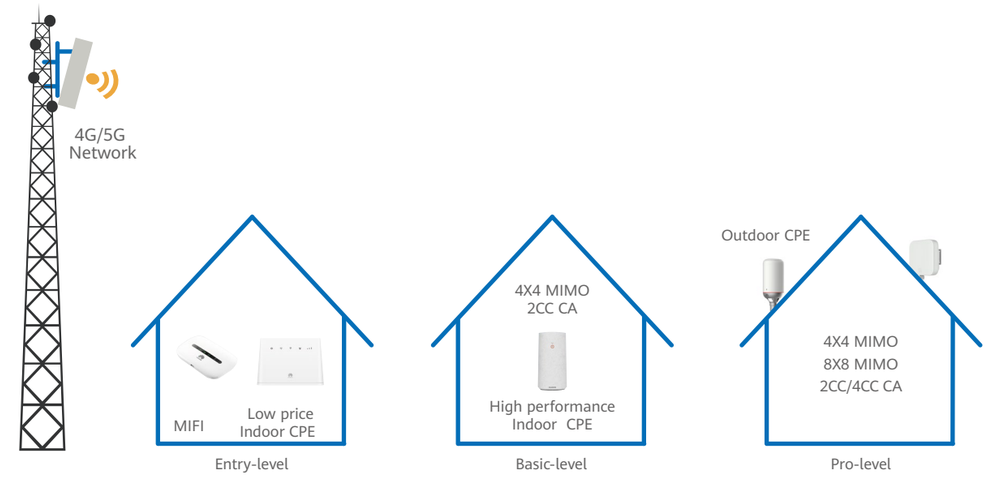


Figure 8: Wireless Fiber Definition

Wireless Fiber uses 4G/5G technology to enable fixed wireless broadband access. As shown in Figure 8, there are three levels of Wireless Fiber to address different classes of target household requirements.

- **Entry-level**: Cost-effective broadband data connections for low-income families. Data volumes are approximately 5–50 GB, meeting the requirements of most Internet browsing services in addition to some video on demand (VoD) services. Entry-level FWA cannot guarantee high speeds during peak hours, but the price per GB is much lower when compared with fixed or mobile broadband. Low-cost CPEs greatly reduce the barriers to Internet access, while satisfying the requirements of many of the low-income families as much as possible.
- **Basic-level**: Primarily used to migrate low-speed copper-based fixed broadband services. High-performance CPEs (with 4x4 MIMO and 2CC CA) can provide a peak rate of up to 600 Mbps at the near point, and an average rate of 10–20 Mbps (40 MHz spectrum) during busy hours. Basic-level broadband can satisfy the main service requirements of home broadband (HBB), including standard definition (SD) and high definition (HD) video.

- **Professional-level**: High-performance outdoor CPEs (with 4x4 MIMO and 4CC CA or 8x8 MIMO and 2CC CA) can provide a peak rate of up to Gbps and an average rate of 50 to 100 Mbps during busy hours. Outdoor CPEs provide more stable wireless broadband connections than indoor devices, particularly at the cell edge. Professional-level broadband is designed to meet the requirements of large families, delivering Full HD (FHD)/4K TV, augmented reality (AR), and virtual reality (VR).

2.2. Wireless Fiber Advantages over Fiber

2.2.1. Full Connections

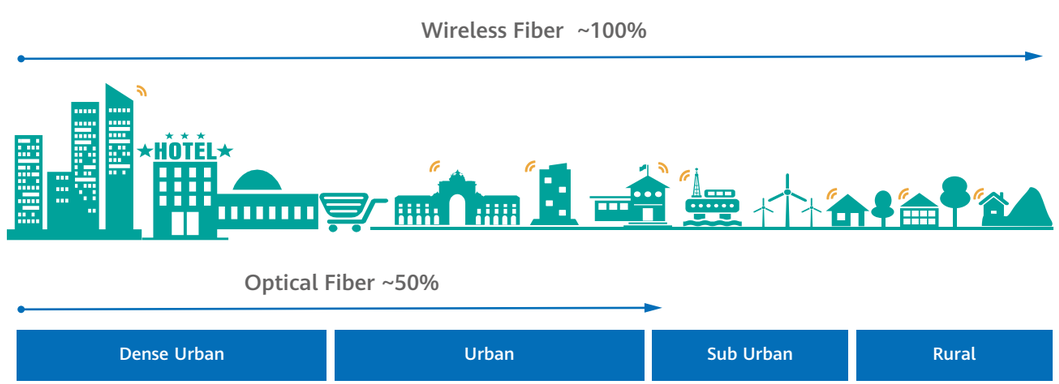


Figure 9: Wireless Fiber Ensures Ubiquitous Connections

Fixed broadband cover only half of the households required. Wireless Fiber increases the coverage to 90+%, including urban and rural places. With high-gain outdoor CPE, a coverage radius of 30 km or greater is supported, meeting the needs of both suburban and rural regions. Wireless Fiber allows for wireless coverage to support home broadband in most low-density areas where FTTH is not reachable, such as suburban and rural areas, due to investment considered economically unviable.

2.2.2. Fiber Like Experience

With the help of 4.5G and 5G technologies, Wireless Fiber offers up to Gbps broadband experience, helping operators provide fiber like broadband services.

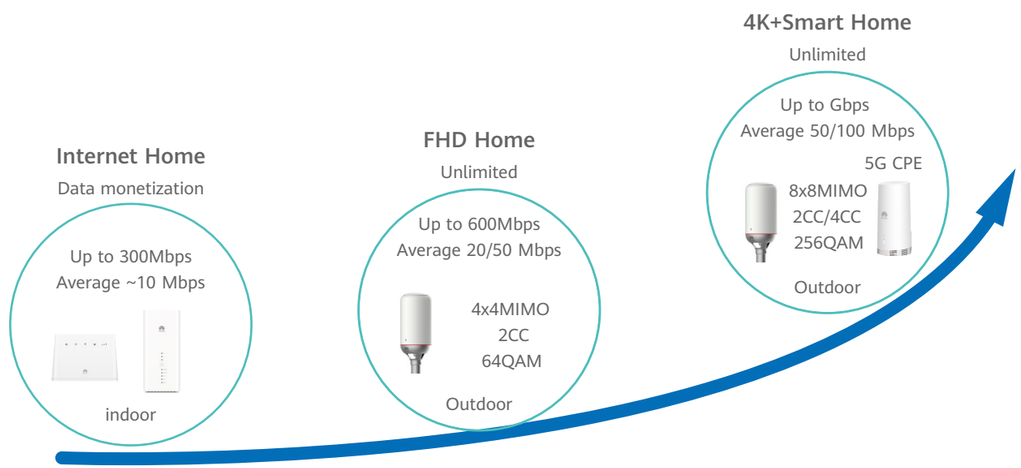


Figure 10: 4G and 5G FWA Experience Evolution

2.2.3. Fast Development

Fiber to the Home needs long time to obtain permission of RoW and considerable civil work, which further prolongs the deployment process.

Figure 11: Civil Work for Fiber Deployment

It usually takes about several weeks from service requests to service activation. In the worst case, no fiber connections will be available even after a few months. This will be completely changed with Wireless Fiber. Wireless Fiber does not need to obtain RoW permission and is easy to install, reducing the Service activation time to only 1 or 2 days.

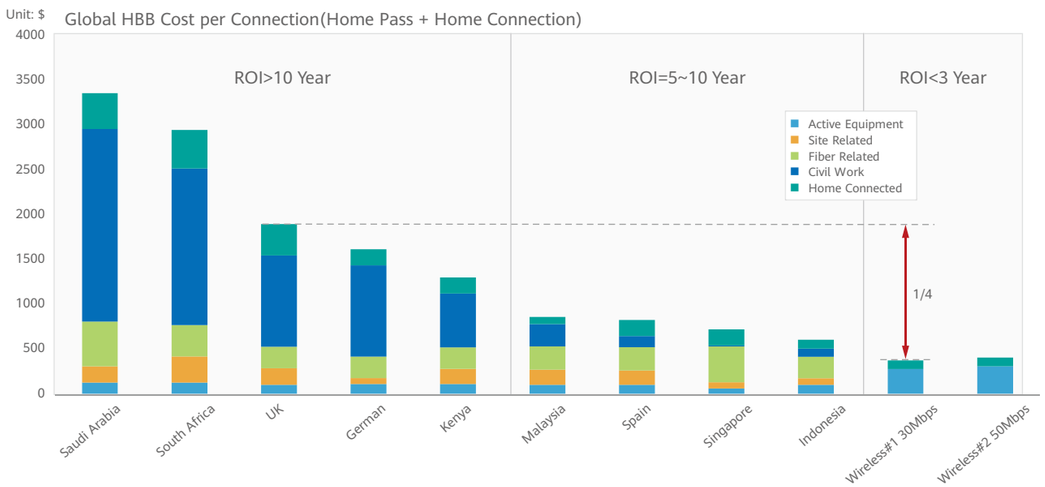


Figure 12: FTTH vs 4G FWA Cost per Connection (Source HUAWEI)

Wireless Fiber eliminates civil work costs, greatly reducing average per connection costs so that networks of the same TCO can serve more families than FTTH. This helps operators develop user bases much faster than FTTH.

2.2.4. Flexibility

There are several user segments. Some are price-sensitive and want data traffic at a lower cost. Other users are experience-sensitive and focus on high service quality. To seek wireless broadband development (since broadband users require high traffic), operators also concern how to maintain the service experience of mobile customers.

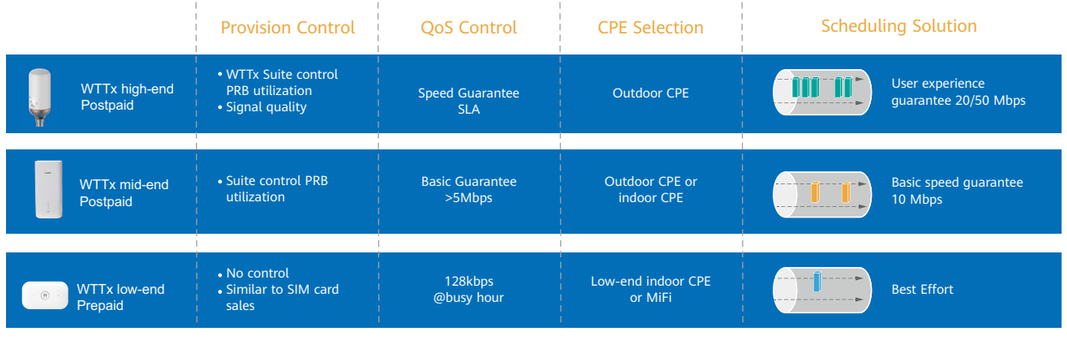


Figure 13: Flexible Speed-on-Demand to Address Different Market Segments

Wireless Fiber leverages 4G/5G wireless technologies, which promotes network sharing. This solution helps operators provide prepaid and postpaid packages for different consumer segments that have different service requirements. Prepaid packages unlock an enormous potential of broadband services in many developing countries. For example, in countries such as the Philippines, South Africa, and Sri Lanka, with prepaid packages, the growth of Fixed Wireless users outpaced that of fixed wireline broadband users.

2.2.5. Future 5G Evolution

In regard to network investment, operators pay continued attention to sustainable development of network architecture for the arrival of the imminent 5G era. Currently, wireless industry suppliers can basically provide 5G-ready hardware, which can help operators reduce investment risks and prepare for 5G.

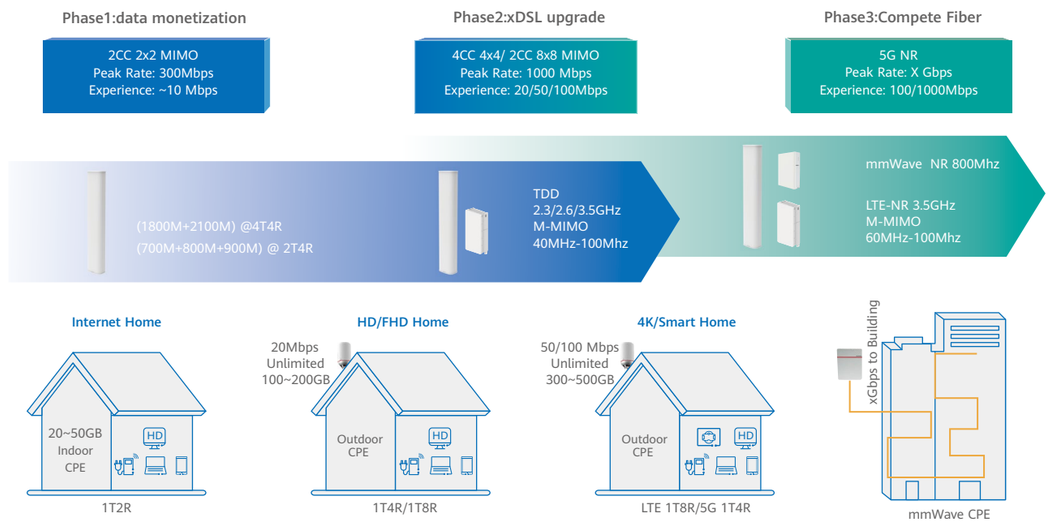


Figure 14: Pave the Path from 4G FWA to 5G FWA

3. WIRELESS FIBER KEY SOLUTIONS TO IMPROVE CAPABILITY

3.1. Key Challenges for Wireless Broadband

Wireless technologies faces many challenges to provide broadband access services.

1) Radio signal propagation is affected by the weather and geographical environments. How can the end user experience be ensured?

2) How can the experience of wireless broadband users be ensured when resources are insufficient in busy hours?

3) What technical solutions can continuously improve coverage experience and capacity?

3.2. Service Provision and Management Assistant System

To address the challenges of user experience management for wireless broadband services, a complete service provisioning and management system is required.

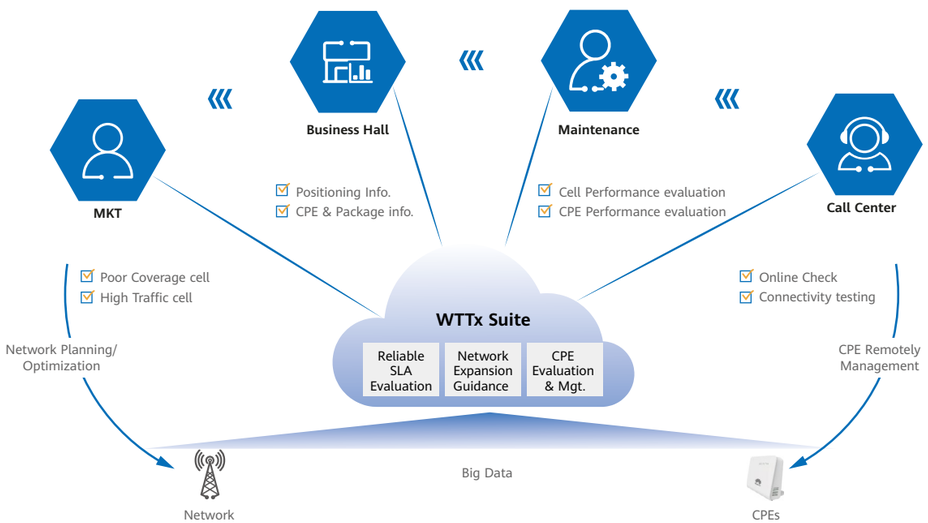


Figure 15: Service Provisioning and Management Assistant System (WTTx Suite)

WTTx Suite is a solution that assists telecom operators in providing FWA services and features, such as Provision Map, Post Evaluation, Abnormal CPE Analysis, and CPE Management. It helps customers quickly launch FWA services and detect network congestion and CPE experience problems in a timely manner and performs auxiliary analysis to promote development of FWA services.

1) Provision Map
Based on coverage, throughput, capacity, and CPE distribution policies (traffic- or throughput-specific packages, available CPE models, and available bands), it allows business hall staff to find the tariff package that can be used in an area and the CPEs recommended for the area.

2) Post Evaluation
It includes cell-level and CPE-level evaluation. Cell-level evaluation evaluates cell load, CPE throughput, and coverage distribution to identify top N cells. CPE-level evaluation evaluates the throughput and coverage of a single CPE.

3) Abnormal CPE Analysis
It includes CPE location change analysis, low-traffic CPE analysis, poor-experience CPE analysis, and churn subscriber analysis.

4) CPE Management
CPEs can be remotely managed through TR-069, including remote CPE configuration, status query, and CPE performance log collection.

3.3. End-to-End QoS Management Mechanism

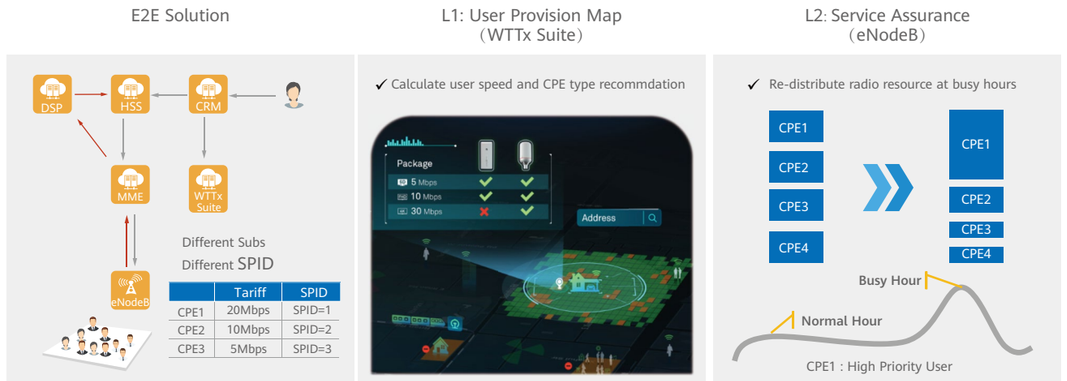


Figure 16: End-to-End QoS Management Mechanism

To ensure QoS of subscribers with different tariff packages, two layers of QoS mechanisms are required.

1) User Provision Map

User Provision Map Assistant evaluates what tariff packages and CPEs can be offered to home users in a specified area. This mechanism greatly avoids the problem that the corresponding speed cannot be provided due to insufficient radio coverage or insufficient radio resources. This improves the initial service provisioning success rate and user satisfaction.

2) RAN Service Assurance

A series of QoS and resource management algorithms are required at the radio access network layer to ensure service quality of specific high-end users when network resources are insufficient during busy hours.

In addition, as the number of broadband users increases, the network must continuously monitor and predict the trend of user and traffic growth. If the user capacity exceeds the design requirement in the next quarter or half a year, the radio access network needs to be expanded to meet the user development requirements.

3.4. Coverage and Experience Improvement Solution

Compared with wired broadband, wireless broadband has a clear coverage cost advantage in suburban and rural scenarios. To widen coverage and better experience with controllable costs, enhanced technologies and solutions are required.

1) Outdoor CPE and antenna enhancement

In rural coverage scenarios, outdoor CPEs and antenna enhancement are mandatory because a large coverage radius is needed. As shown in the figure below, outdoor CPE coverage radius is five times larger than that of indoor CPEs. This helps operators with less base station investment to achieve wider coverage and meet the general coverage requirements of broadband services.

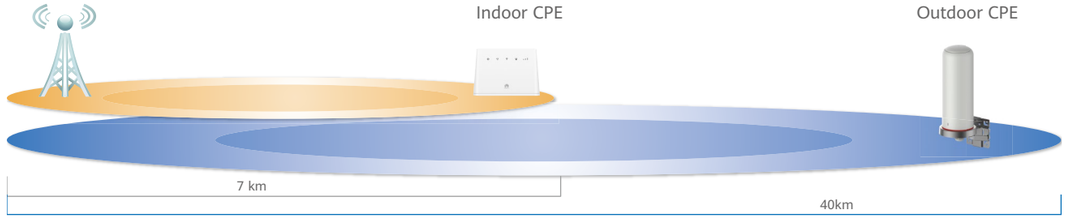


Figure 17: Rural Coverage Comparison (Indoor CPE and Outdoor CPE)

2) Higher Category CPE types

Peak User Rate with Category				
Category	Peak Rate	BW (MHz)	MCS	MIMO	CA
4	150 Mbps	64QAM	2x2	1 CC
6	300 Mbps	64QAM	2x2 or 4x4	2 CC
12	600 Mbps	64QAM or 256QAM	2x2 or 4x4	4 CC
16	1 Gbps	256QAM	2x2	5 CC
19	1.6 Gbps	256QAM or 64QAM	4x4 or 8x8	4 CC
20	2 Gbps	256QAM or 1024QAM	4x4 or 8x8	4 CC

The peak user experience is related to CPE categories. According to 3GPP, the peak rate of CAT4 terminals is 150Mbps, while that of the CAT20 terminal can be 2 Gbps.

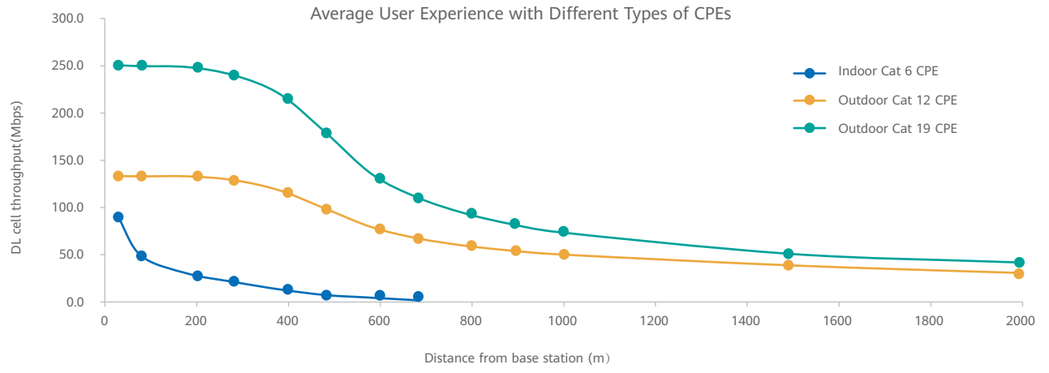


Figure 18: Average User Experience with Different CPEs

Higher category CPEs not only improves peak experience, but also improves user experience in edge areas via technologies such as carrier aggregation and multi-antenna reception.

The preceding figure shows the average user experience of indoor and outdoor CPEs in different categories. Outdoor CPEs with high categories are better than indoor CPEs in both peak and edge experience.

3.5. Capacity Improvement

Wireless technology enables home broadband services. A big challenge is how wireless base stations meet the capacity requirements in home scenarios so that wireless solutions can be preferred as they excel other optional technical solutions, such as FTTH in terms of costs.

The factors that restrict the capacity of wireless base stations are as follows:

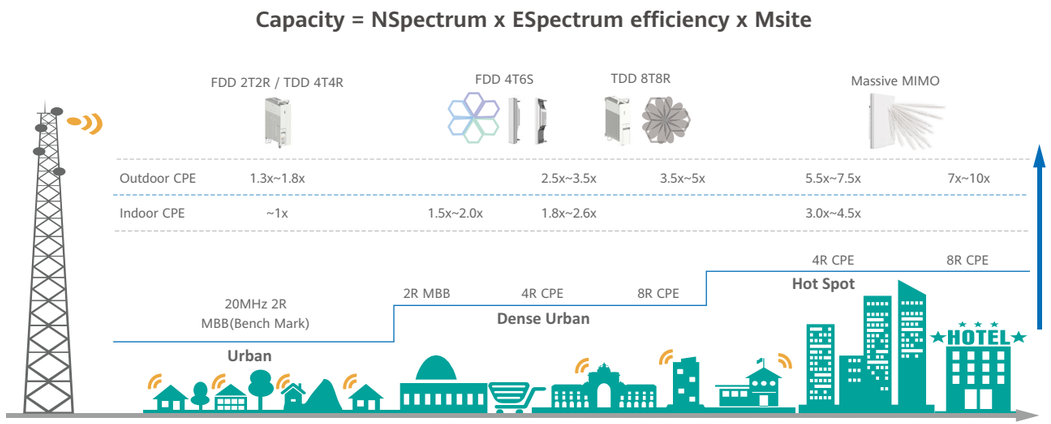


Figure 19: Capacity Gain with Different Solution

With LTE-A and 5G, spectral efficiency is greatly improved. The preceding figure shows the capacity gains of various multi-antenna technologies in indoor CPEs and outdoor CPEs. In FWA, if outdoor CPEs are used, capacity can be increased by 10 times compared with other mobile broadband technology, greatly reducing the per-GB cost.

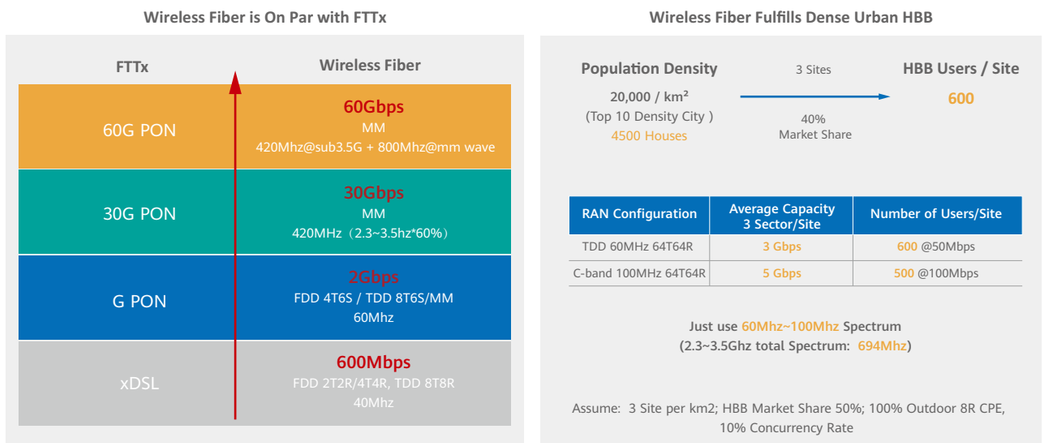


Figure 20: Wireless Fiber Fulfills HBB Requirements

Sufficient spectrum is essential for FWA. How much spectrum is needed to meet basic requirements of FWA? The population density of top 20 cities in the world is 20,000 per km2, and there are about 4500 households. Assume that the operator's market share is 40% and three base stations are used for coverage. Therefore, each base station has to cover 600 households.

According to the analysis above, 60 MHz to 100 MHz is needed to meet 50–100Mbps home broadband requirements. The total spectrum from 2.3 GHz to 3.5 GHz is about 694 MHz, which is enough for Wireless Fiber.

4. WIRELESS FIBER NETWORK PLAN AND EVOLUTION

4.1. Wireless Fiber Broadband is More Affordable

The data of usage (DOU) of FWA is usually 10-20 times more than MBB. Supposing a typical $10/5GB MBB package and $50/100GB FWA package, the per-GB price is $2 and $0.50, respectively, which is a four-time difference, indicating that FWA profitability is lower than MBB. But is it truly this case?

The comparison is based on per GB cost, which is related to such factors as site costs, service models, and site capacity. In terms of site costs, FWA can reuse MBB infrastructure and save site costs. In service models, user behavior is different between FWA and MBB, FWA has longer busy hours than MBB and produces more data a day, which also helps make full use of idle resources. FWA site capacity is higher than MBB UE because of specialized features.

According to elaborate analysis, FWA per-GB cost is about 1/4 to 1/10 of MBB. FWA supports 4 to10 times greater DOU given the same ARPU, which can be illustrated as follows.

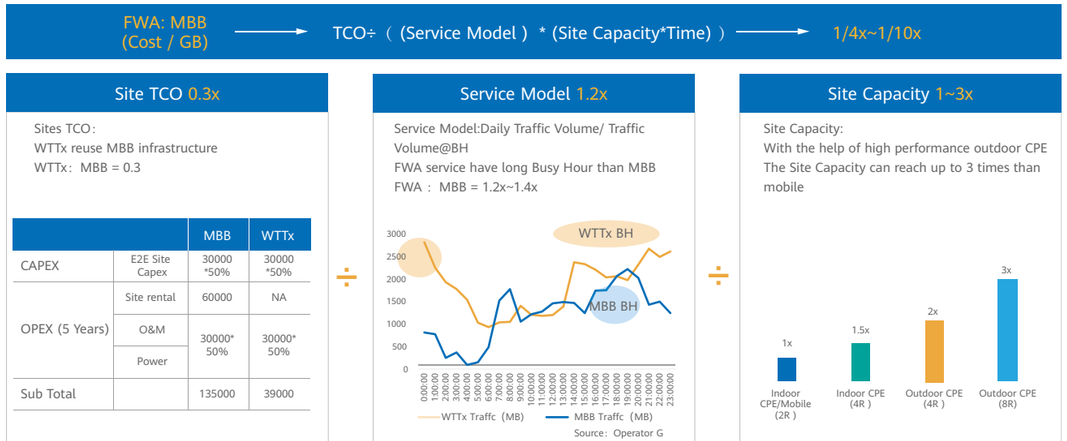


Figure 21: Per-GB Cost Comparison between MBB and FWA

4.2. Cost-Per-Line Methodology and Impact

For FWA, the main investment is concentrated on wireless networks. The wireless network capacities can be different with different CPEs, which means that the number of users supported is different, depending on CPEs used. The FWA cost-per-line (CPL) is combined wireless networks and CPEs.

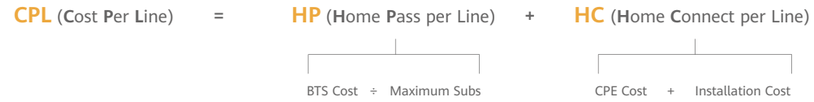


Figure 22: Cost Per Line Definition

CPL is an end-to-end concept. It should not only consider the terminal cost. High-end CPE brings capacity improvement, and a higher improvement leads to a smaller CPL. Compared with low-end CPEs, high-end CPEs have greater MIMO specifications to allow for higher capacity on entire wireless networks. Although CPEs means additional investment, the average CPL will be lower. For example, based on Massive MIMO with a 60MHz bandwidth, the spectral efficiency of high-end CPEs ($150) is higher than low-end CPEs ($60), resulting in a lower CPL($358 vs $491). The table below gives an example of CPL calculation for different CPEs.

Key Assumptions

TDD Specturm BW	60MHz
Guaranteed Speed	20Mbps
Active Ratio	50%
Duty Ratio	20%

*MM Site Capacity（20Mhz）

Indoor 2R CPE	103Mbps
Indoor 4R CPE	150Mbps
Outdoor 4R CPE	250Mbps

Calculations

CPE Type	Home Pass per Line			Home Connect per Line			CPL ($)
	BTS Cost($)	Maximum Subs	HP($)	CPE Cost($)	Installation Cost($)	HC($)	
Indoor 2R	200,000	464	431	60	0	60	491
Indoor 4R	200,000	675	296	90	0	90	386
Outdoor 4R	200,000	1125	178	150	30	180	358

Figure 23: End-to-End CPL with Different CPEs

High-performance outdoor CPEs are perfect for high quality FWA services and better support end-to-end cost effective deployments.

4.3. Service and Experience Target Definition

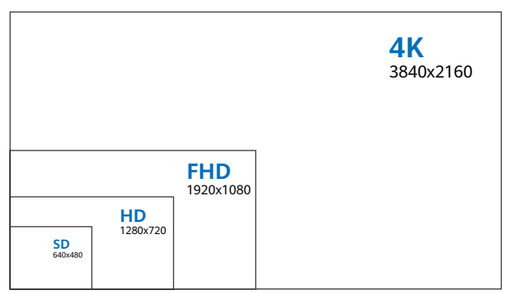


Figure 24: Common Video Resolutions

Typical fixed home broadband services include video, internet browsing, and IoT. Video services represent the biggest requirements for network bandwidth. Common video resolutions are SD (480p), HD (720p), FHD (1080p), and UHD (4K).

Based on current network testing and theoretical calculation, video service experience baseline is suggested as follows:

Resolution	Typical Bit Rate (YouTube)	Required Average Throughput Zero-frame-freezing Playback Percentage ≥ 90%	Required Perfect Throughput Zero- frame-freezing Playback Percentage ≥ 98%	Typical Value
4K	15 Mbps	24 Mbps	31 Mbps	25 Mbps
2K	6 Mbps	9 Mbps	12 Mbps	10 Mbps
1080p	3 Mbps	4.5 Mbps	6 Mbps	5 Mbps
720p	1.5 Mbps	2.3 Mbps	3 Mbps	2.5 Mbps
480p	700 kbps	1 Mbps	1.4 Mbps	1.2 Mbps

To ensure 4K video service experience at home, the average experience rate of FWA home broadband services must reach 25 Mbps. With radio resource sharing in mind, the cell edge experience rate must reach 100 Mbps in order to meet this requirement for cell edge users, if 25% PRB resources are allocated to a user during busy hours. Based on this, the following table lists the broadband experience rate and cell edge peak experience rate required for various home video services.

Resolution	Typical Bit Rate (YouTube)	Average Throughput	Cell Edge Throughput
4K	15 Mbps	25 Mbps	100 Mbps
2K	6 Mbps	10 Mbps	40 Mbps
1080p	3 Mbps	5 Mbps	20 Mbps
720p	1.5 Mbps	2.5 Mbps	10 Mbps
480p	700 kbps	1.2 Mbps	5 Mbps

Based on the required average throughput and cell edge throughput specific to video services, 4G FWA is recommended for SD/HD/FHD video services, which require an approximate 20 Mbps cell edge throughput. In addition, 5G FWA is recommended for FHD/4K video services, which require an approximate 50 Mbps to 100 Mbps cell edge throughput.

4.4. Target Network Design and Evolution

FWA target network design needs to consider the following issues:

1. Investment guidance: whether the business logic is established for FWA investment and ROI requirements is met.
2. Continuous provisioning: whether FWA affects MBB development, and FWA with fast traffic growth will take up network resources.
3. Sustainable development: whether services and networks develop continuously and can evolve to 5G.

FWA fully utilizes the advantages of wireless networks to adapt to business requirements (subscriber growth or speed requirement). FWA investment can be on-demand, unlike FTTH that needs a huge investment in the initial phase.

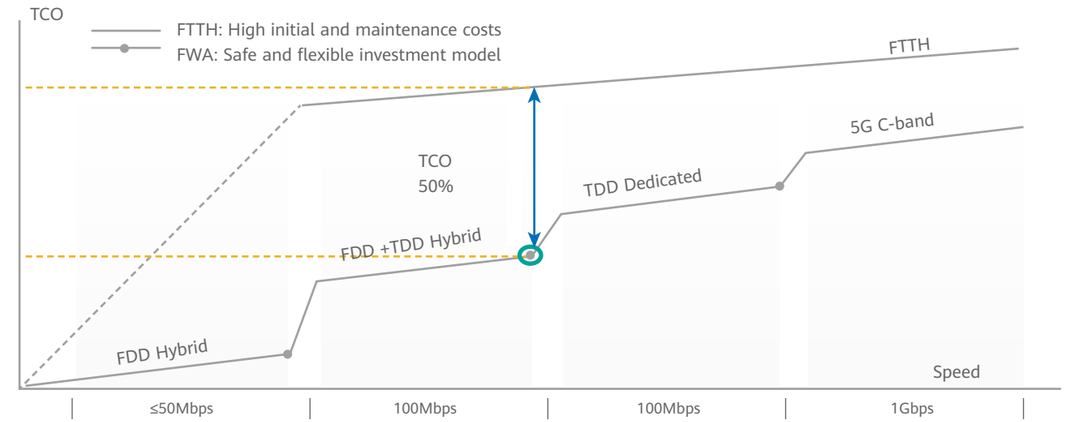
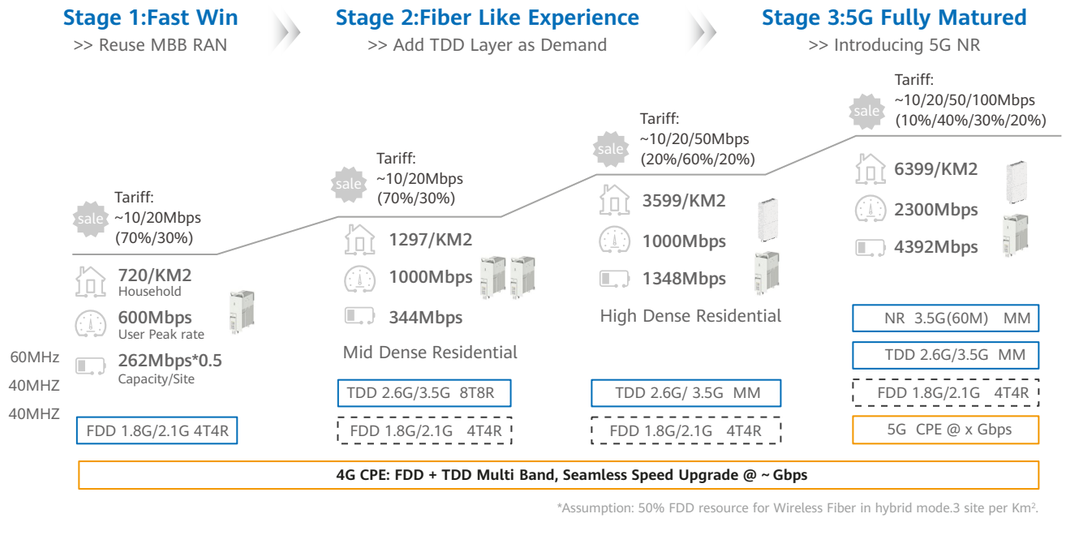


Figure 25: FWA TCO Comparison with FTTX

Usually FWA evolution is divided into three phases. The first phase is "Fast Win", focusing on reusing MBB RANs, during which operators maximize existing network resources and quickly provide household network connections for connecting the unconnected. The second phase is "the fiber-like experience". As the number of services and users continues to increase, it is necessary to adopt dedicated networks to support FWA. In this stage, TDD dedicated networks are usually added on demand, and multi-antenna technology is used to support high-quality FWA experience. The third phase is "5G FWA". With mature 5G commercial use and continuous improvement of user experience, it is necessary to introduce 5G NR to develop FWA. 5G NR spectrum is introduced to develop FWA, providing users with up to Gbps FWA experience.



*Assumption: 50% FDD resource for Wireless Fiber in hybrid mode.3 site per Km².

Figure 26: FWA Target Network Evolution

4.5. Capacity Expansion Methodology and Path

FWA capacity planning is based on capacity assessment of existing networks and capacity requirements for business development. Based on spectrum resources, equipment status, and business development, a reasonable, phased deployment plan is developed to ensure stable growth of service and operating income.

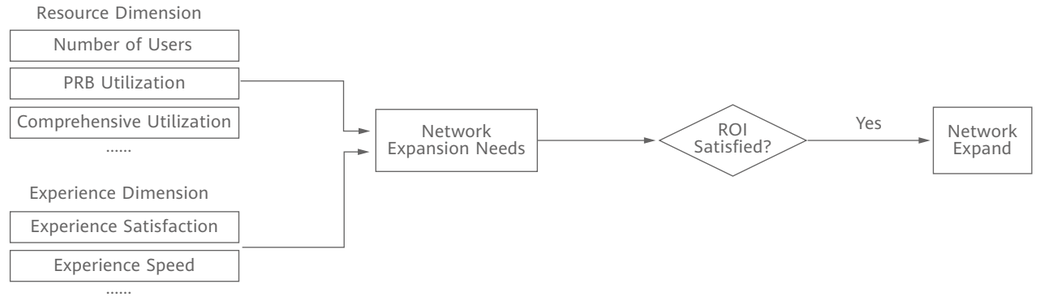
Capacity planning is an iterative process. Based on historical user scale and service trends, combined with operator development strategies, a reasonable capacity plan can be formulated. In conjunction with daily capacity monitoring methods, the capacity planning scheme is iteratively revised in a certain period to ensure that network capacity sustains normal business growth. After capacity expansion, suppressed needs of the existing network can be released, and network resources can be deployed in line with time tables to suit future-oriented development.

FWA provisioning evaluation is based on existing network data. It aims to support the development of FWA users in dedicated networks and hybrid networks. It helps customers evaluate network capacity and include the following functions:

1. FWA capacity evaluation: perform capacity evaluation based on user scale, traffic, user experience, and resource utilization.
2. FWA impact evaluation: analyze WBB impact on MBB experience in different scenarios of hybrid networks.
3. FWA service evaluation in terms of service supportability, cell-level user capacity, package proposal, and suitable CPEs in networks where FWA services have been deployed or not.

There are usually two principles for network expansion. The first is based on network load, whose decision standard is resources, including radio resources (PRB utilization, control channel utilization, number of users, and others) and processing capacity (such as CPU usage). For most operators, the common standards are PRB utilization and number of users. The second is based on user experience, which is essential for value-added service (such as FWA and video) development and operator competition. To meet the demands of different services, it is necessary to evaluate network experience to guide network expansion, such as user experience satisfaction and XMbps anytime and anywhere.

For FWA, most operators usually pay more attention to service ROI. Therefore, it is recommended that ROI be considered during an expansion evaluation. Based on expansion plans, the capacity and number of new FWA subscribers supported after expansion can be determined. Then, in line with ROI requirements (it is approximately two to three years for FWA), the number of new subscribers in the market can be calculated. If the number of new subscribers in the market cannot be met, no new FWA subscribers are provided in this area, and the expansion is not needed.



There are mainly three ways for network expansion. The first one is to deploy more spectrum. The second one is to add base stations. The third one is to use multi-antenna technology to improve spectral utilization and expand cell capacity in the case of limited spectrum and site resources. The following figure illustrates site capacity evolution roadmap.

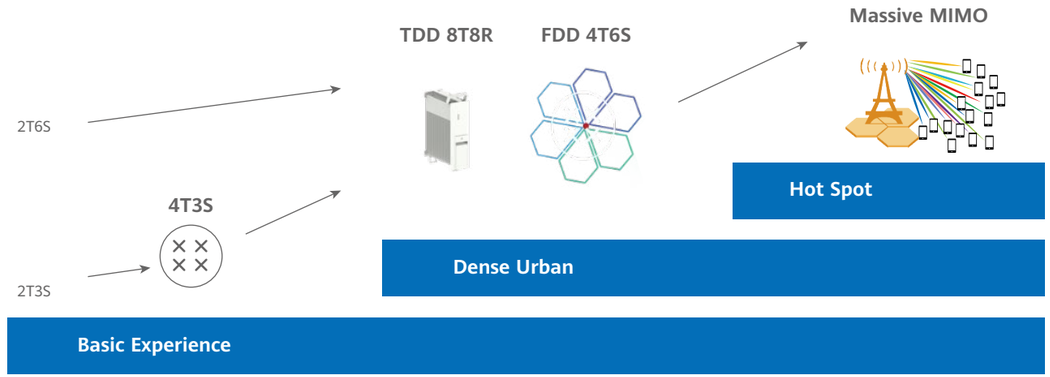


Figure 27: FWA Capacity Evolution Solution

5. REGULATOR RECOMMENDATIONS FOR BOOSTING WIRELESS BROADBAND

5.1. Role of 4G/5G FWA in National Broadband Plans (NBPs)

The major policy challenge is to harness market forces to promote convergence or equalization in living standards between villages, cities, and towns. Policy makers will be more efficient if they look at development strategies for broader economic areas that integrate cities with their surrounding rural areas. Stable and efficient policies and regulations are critical to ensure that operators have the best environments to extend broadband coverage to underserved areas.

There is an industry consensus that broadband penetration rate and data service access, what we now call Digital Inclusion, must be increased. While various approaches can tackle the challenges of connecting the unconnected, FWA may be the optimal and most cost effective.

Governments must strive to foster markets that are accessible to all and encourage the innovative use of technologies. To ensure market access for 4G/5G FWA operators, it is important to establish a legal and regulatory framework that break can legacy rules and puts no limits on the number of independent service providers that are permitted to provide 4G/5G FWA services to consumers. Competition among a large number of market players encourages investment in infrastructure, provisioning of new services, and service improvements in quality and availability of lower prices.

Furthermore, governments should include 4G/5G FWA into NBPs, and it is essential to introduce a strategy or specific goal on FWA solutions for hard-to-reach areas. NBPs need to recognize FWA as essential to provide broadband access to rural, remote or geographically challenged areas. Governments must leverage FWA in those areas where Fiber-to-the-Home technologies are not feasible.

5.2. Checklist for Utilizing FWA Broadband to Bridge Digital Divides

The following checklist comprises top 10 policy elements as a starting point for countries willing to utilize 4G/5G FWA broadband to help bridge digital divides:

1) Determine broadband as an urgent need in government policies and regulations to serve rural populations and acknowledge that there is a need to increase fixed broadband competition in cities so that citizens can freely choose two or more fixed broadband service providers to promote the quality of broadband services.
2) Identify rural, remote, and low-population density communities where broadband networks cannot be realized by Fiber-to-the-Home broadband.
3) Given the investment return in areas of different population density and meeting the differentiated requirements among different users and enterprises, formulate reasonable fixed broadband rate standards for different geographical areas, such as <10Mbps, 20Mbps, 50Mbps, 100Mbps, 1000Mbps.
4) Include 4G/5G FWA broadband as an available alternative of fiber and integral part of any NBP.
5) Formulate 4G/5G FWA broadband standards for base stations, CPEs, and speed test evaluation specifications to standardize FWA fixed broadband service stability.
6) Allocate contiguous wide-bandwidth spectrum (for example 60MHz-100MHz) for FWA. Decrease spectrum fees and combine with FWA coverage targets to stimulate social entities and operators to participate in national broadband programs.
7) Acquire unbiased, professional, technological, financial, and management expertise to develop optimal network design on a case-by-case basis, considering rural customer requirements.
8) Consider, define, and implement financing policies to support high speed broadband connectivity services in remote areas and low-speed broadband community, including broadband target, USFs, tax incentives, spectrum fee refund for broadband connection, and/or government funding for pilot projects.
9) Identify potential partnerships with international organizations, multilateral development banks, and FWA operators for specific projects.
10) Conduct capacity-building workshops with stakeholders on technical and policy issues.

6. SUCCESS STORIES

6.1. Case 1: Japan

Operator S is a typical MBB operator, with its FTTH market share very low in Japan. In order to increase change broadband market share without resorting to fiber resources, operator S decided to develop FWA broadband service. By making full use of abundant TDD spectrum, operator S has proposed a strategic collaboration of FWA and MBB to quickly grow its broadband user base.

Operator S's FWA service is rolled out in many scenarios and has great market potential. In old and underdeveloped areas where there are no fiber resources, the people needs to have low-cost wireless broadband solutions to connect the Internet. Some users, especially students, frequently moved from one apartment to another, making them unable to wait for 15 days, which is usual cases in Japan, to apply for fixed line. Besides, Japan has 2.9 million households with low rate ADSL, presenting an urgent need of higher-capacity networks to enhance - broadband experience.

Operator S precisely identified these scenarios of its FWA service and introduced an attractive tariff strategy. As a result, the FWA service gained a rapid development. Operator S started its wireless broadband business since December 12th, 2014, which provides fiber-like experience. The wireless broadband subscriber base has grown by 5 times in 2 years. Just in 2018 Q3, 3 million wireless broadband subscribers were added.

To further improve user experience, operator S has deployed Massive MIMO in hotspots or in-depth coverage regions, which created a 5-times capacity growth on existing networks. Operator S utilized high performance CPEs, such as 4R/8R CPE, to improve spectral efficiency to enlarge cell capacity. In most areas, FWA can provide a speed of up to 261Mbps. In some areas, the highest speed even topped 350Mbps, with an average speed ranging 40 Mbps to 50 Mbps.

6.2. Case 2: Philippines

The Philippines is a Southeast Asia country that consists of more than 7000 islands and covers an area of 300,000 km2. Special geographic conditions and private land ownership present enormous challenges of deploying home broadband infrastructure.

Operator G believes that home broadband is an opportunity it cannot afford to miss. Up to 65% of the Philippines' population are 15 to 64 years old, and such groups are open-minded and yearn for Internet access, online gaming, and online social activities. Strongly influenced by the American cultures, they are big fans of music and basketball.

Based on the market characteristics and potential user needs, Operator G formulated the strategy of using FWA to quickly increase its home broadband user base. This commercial strategy, which includes customized services and packages for target customer segments, has proved to be hugely successful.

Since the commercial launch of 4G FWA services in July 2013, Operator G has quickly developed its home broadband user bases due to its excellent operation, especially in Luzon and Metro Manila, and attracted numerous users, successfully changing its unfavorable situation in the market. According to its 2018 financial report, Operator G has increased the total number of FWA users to more than 1,000,000 while fixed line broadband user scale was only 630,000. FWA contributes to over 80% of its home broadband user growth.

Social Value: Bridging Digital Divides

FWA helps Operator G provide over one million home broadband connections, accounting for 26% of Philippine home broadband connections and increasing Philippine home broadband penetration ratio from 12% to 17% since the launch. Operator G has also introduced entertainment content and applications that provide a rich and colorful digital life, including Spotify, HOOQ, free NBA LEAGUE PASS, TV entrance Chromecast, and many others. Meanwhile, the introduction of innovative prepaid broadband plans makes broadband services more affordable and accessible.

Business Value: Revenue Growth

After FWA introduction, broadband revenue ratio increased from 13% in 2017 to 15% in 2018. FWA contributes heavily to Operator G's home broadband user base growth since 2018. HPW users' ARPU has increased by 41% over last year. It has gained a solid foundation for a higher profit margin and shorter ROI of Operator G's Wireless Network Broadband initiative.

Future Value: Not only for 4G FWA, but also for 5G FWA

As a frontier in wireless broadband services, Operator G has worked with Huawei in building 5G wireless networks. Platform investments in FWA will also be helpful for 5G. Operator G is already planning to launch commercial 5G FWA postpaid services at 2019 Q2.

6.3. Case 3: Sri Lanka

Sri Lanka is an isolated island nation located in the Indian Ocean to the southwest of the Bay of Bengal, with a population of approximately 20.64 million. Operator D, the largest mobile operator in Sri Lanka, is committed to providing cutting-edge communication services to Sri Lankan enterprises and inhabitants and enriching lives through better communications. The penetration rate of home broadband in Sri Lanka is approximately 12% and home broadband is still unavailable for about 5 million households, indicating large market potential.

With five mobile operators in Sri Lanka, MBB competition is fierce and it is hard for operator D to get continuous revenue growth from mobile market. The cost of deploying fixed broadband is high and time to market is too long. To make full use of advantages in networks, spectrum resources, and sites, operator D began to deploy 4G FWA (WTTx) in 2013 to provide broadband services for households and SMEs. With FWA services, operator D increased home broadband penetration ratio from 9% to 26%, lifting 0.8 million households away from digital divides. During 2013-2018, 4G FWA contributed to 60% share of the net additions in home broadband.

There are three success DNAs operator D has created:

1) Precision Marketing Strategy and Plan: includes precise investment focus on target households and SME markets. Competitive & flexible packages are introduced for groups of different income levels, and such rich tariff packages enable operator D to successfully expand its subscriber bases and offer users with multiple package options. Huawei's WTTx suite map helped to achieve quick FWA user acquisition. Home broadband coverage can be applied on its official website, and plug & play CPEs can be obtained immediately after a purchase order is completed. Subscribers can enjoy 7 days of free trial home broadband services, with no commitment, and a full refund will be provided if FWA services are not totally satisfied. Home-visit speed testing, if required, is also available. All these methods help with a great subscriber base growth.
2) Differentiated Services: Operator D is an integrate operator and possess DTV services, adding extra strength to offer enriched channels and content resources. Bundling video and broadband services increases ARPU and reduces subscriber churn rate.
3) Best User Experience: Huawei provided a series of innovative WTTx (Huawei's version of FWA) solutions for operator D, including Carrier Aggregation, 8T8R, and Massive MIMO. Operator D and Huawei cooperatively launched the first 4.5G commercial network in South Asia and deployed 5G-ready WTTx solution that allows for coverage of more than 67% population.

6.4. Case 4: Trinidad and Tobago

In Trinidad and Tobago, fixed-line users have reached 250,000, with penetration rate exceeding 70% among the 350,000 households. There are three operators competing for much adopted fixed broadband. Operator T, as a traditional operator in Trinidad and Tobago, faced financial constraints (21.4% decline in copper revenue in one year) and quick loss of broadband subscribers (33% in 18 months) under intense competition because of bad user experience and high OPEX with copper.

Considering that Huawei's WTTx can replace copper with 17 month ROI and fiber costs 1700+USD per line with an ROI longer than 7 years, operator T formulated the "Zero Copper" strategy in 2018, aiming to reduce overstaffing, organizational complexity, and expenditure and replace high OPEX copper with WTTX.

WTTx is fast and low cost for migrating copper to WTTx thanks to having sufficient spectrum (TDD 50MHz) to meet wide coverage requirements of legacy copper users. WTTx is used to enable basic coverage and fiber is used to cover dense areas to make full use of existing resources. Therefore, WTTx + Fiber will fully replace copper to provide coverage to 95% of population and upgrade HBB Experience.

Operator T launched bundled packages to enhance user loyalty, including triple play business that includes internet, voice and OTT video services. Massive MIMO and outdoor CPEs are used on a large scale to guarantee OTT video experience, making this operator to improve monetization.

Operator T ensures services affordable to every citizen with the price 30% lower than the average on the market. WTTx enables B2H for operator T and provides opportunities to explore new business, such as wireless to the enterprise (WTTe), wireless to the building (WTTb) and wireless to the camera (WTTc).

REFERENCES

[1] The Economic Contribution of Broadband, Digitization and ICT Regulation, ITU

[2] The State of Broadband 2018, ITU

[3] Internet Access Services: Status as of December 31, 2016,FCC

[4] Policy Options for Promoting High-Speed Broadband, ITU

[5] Experience-driven Video Bearer Network White Paper, Huawei

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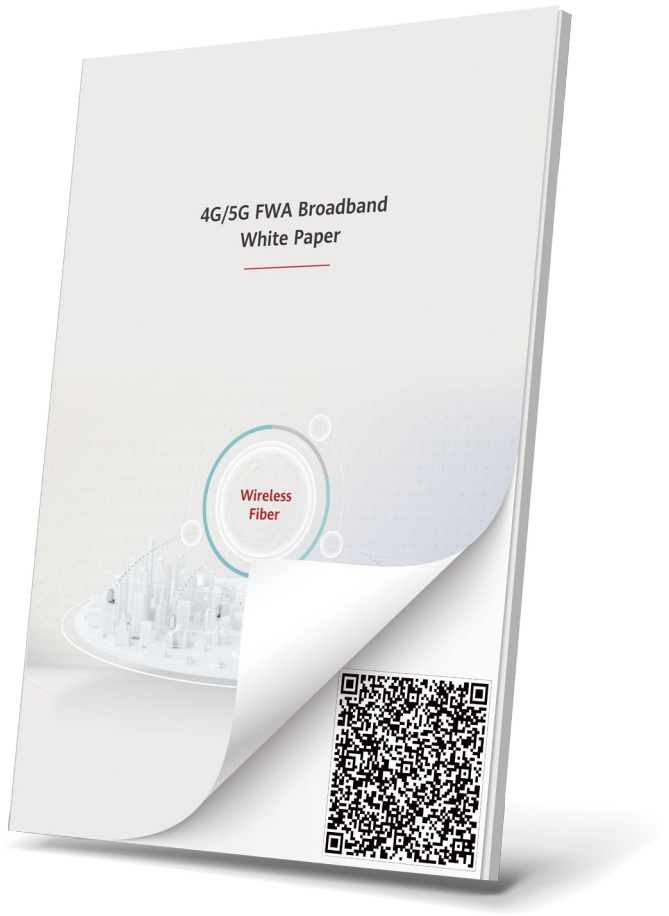

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