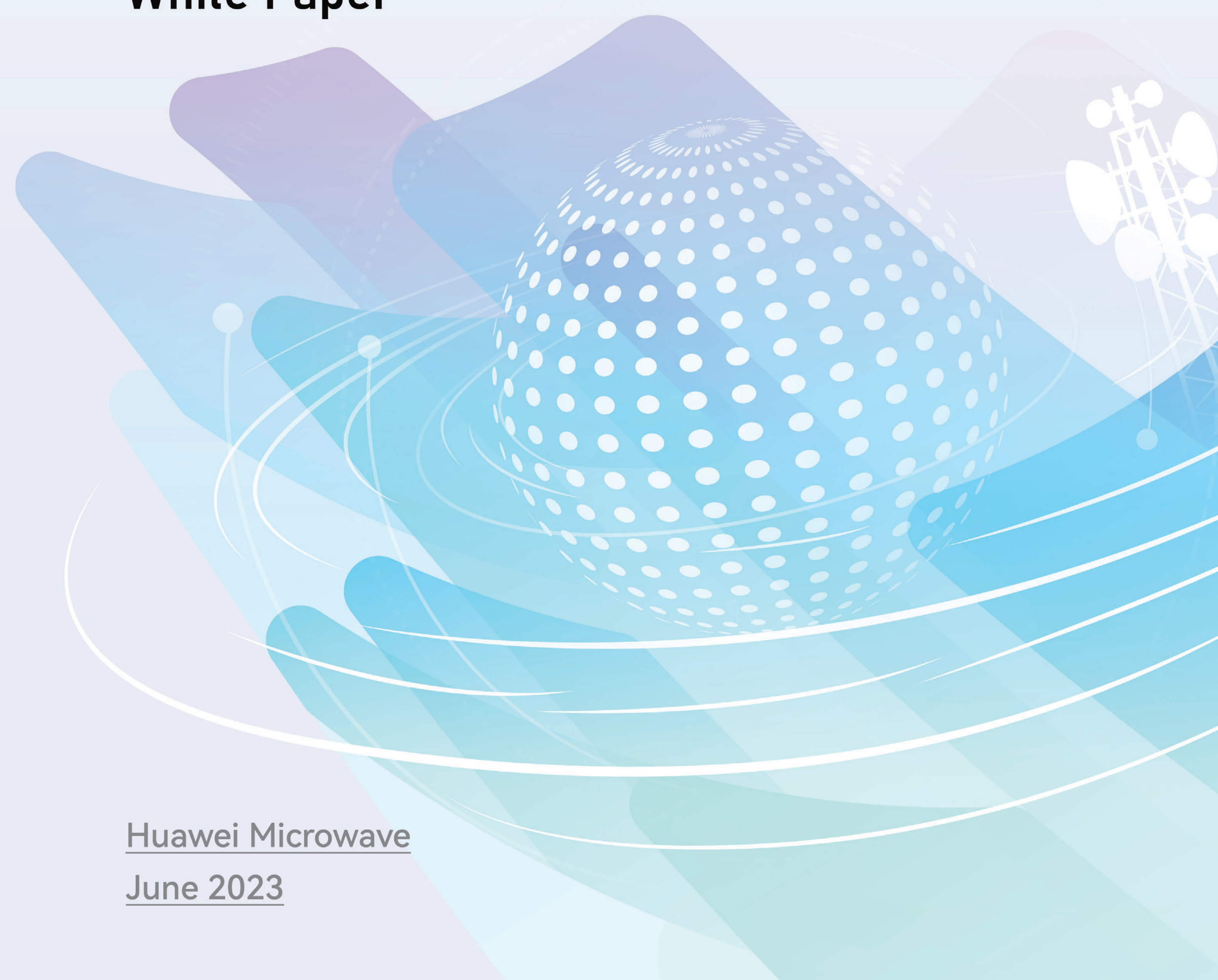
HUAWEI

2023

MICROWAVE INDUSTRY

White Paper



Huawei Microwave

June 2023

MICROWAVE INDUSTRY

At a Glance

Introduction

Microwave will still act as an important medium for mobile backhaul in the 5.5G era, projected to contribute to more than 60% of mobile backhaul solutions. The long-term evolution, strong demands, and diversified applications of mobile backhaul are the biggest drivers for the sustainability of the microwave industry as well as its technical research.

Progress has been made in the research of microwave link KPIs. This will allow microwave to be used more efficiently for mobile backhaul to meet the capacity and quality requirements and to support its long-term development.

Featuring large capacity and low spectrum costs, as well as empowered with other technologies for long-distance transmission, high-density deployment, and higher spectral efficiency, E-band is a prime section of microwave in the next 10 years to support the backhaul evolution in 5.5G and beyond.

Traditional microwave bands are the key to 5G deployment in suburban areas, highlighting the need for multi-carrier backhaul solutions based on multi-TX and ultra-wideband technologies to meet the capacity needs.

Long-haul microwave plays a pivotal role in fiber-lacking areas. To meet the demand for over 20 Gbit/s capacity in these places, multi-band and multi-carrier aggregation is required to work around the insufficiency of spectrum. It is also necessary to address the tower loads and tower rents that increase exponentially in conventional long-haul solutions.

Microwave fronthaul technology allows rural sites to share baseband resources of existing base stations to provide ubiquitous coverage at ultra-low costs and power consumption. This helps connect hundreds of millions of people in remote areas who have no access to mobile broadband.

Energy saving and automation facilitate the development of the microwave industry. As the deployment of microwave backhaul scales up, automation is ideal for efficient microwave O&M. Microwave networks use incumbent mobile towers to build backhaul networks, and long-distance transmission to reduce the number of devices on networks, thereby expanding the applications of microwave networks.

Chapter 1

New KPIs

The envisioned traffic levels associated to the spreading of 5G technologies and beyond have recently raised serious concerns on the economical sustainability – especially in terms of total cost of ownership (TCO) – of transport networks. In this context, cutting the system margins introduced by a potentially over-engineered design to improve the cost efficiency of wireless networks is necessary for telecom operators.

Investigating whether the current planning approach for microwave and mmWave backhaul links can lead to over-dimensioned deployments has recently become a matter of study by the ETSI Industry Specification Group (ISG) **[1]**, as such deployments may consequently result in extra costs for operators in terms of license fees, antenna size, products needed, and energy consumption. This chapter presents and discusses the main achievements of this investigation.

Current Planning Approach for Wireless Backhaul Links

Current planning approaches for dimensioning wireless backhaul links are typically based on the required target availability for one or more capacity values, with rain fading and other adverse propagation conditions considered, as detailed in the reference ITU-R Recommendation **[2]**. For example, a widely adopted planning rule is based on the following two key performance indicators (KPIs):

- Committed information rate (CIR) with a 99.99x% link availability target
- Peak information rate (PIR) based on the RAT used with a less conservative availability target (such as 99.9% or even 99%).

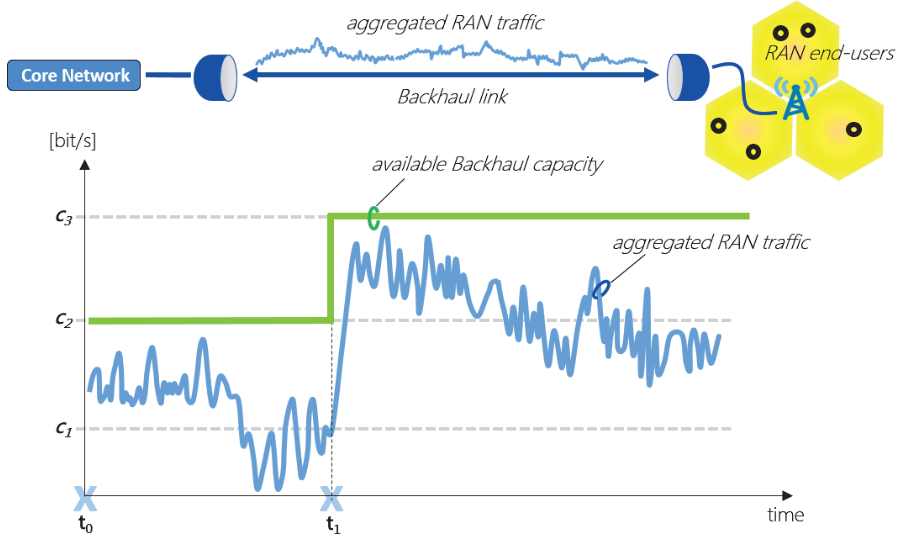
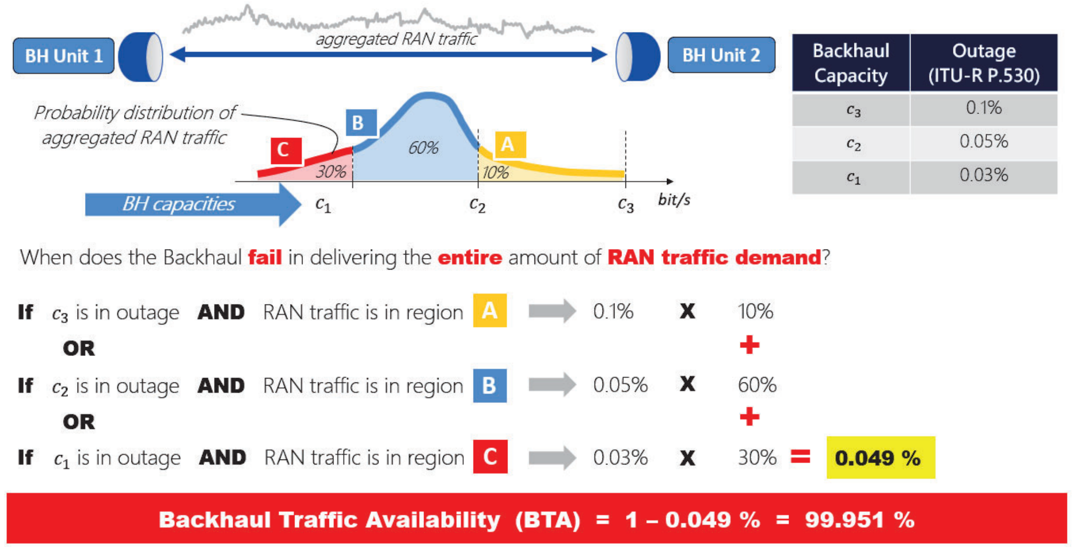


Figure 1-1 Available backhaul capacity compared to the actual aggregated RAN traffic requirements

This methodology is effective in dictating reference performance for backhaul environments. However, it fails to assess the impact of different backhaul outages in relation to the amount of radio access network (RAN) aggregated traffic to be carried. To give emphasis to this concept, as shown in , even if capacity c3 is not available on the backhaul link during [t0, t1], the registered quality of experience (QoE) for RAN end-users would not be impacted, as the actual RAN aggregated traffic demand can be fully delivered in this timespan with an available backhaul capacity c2. Furthermore, the unavailability of a backhaul link capacity in a certain period does not necessarily perceivably impact end-user QoE, as this performance metric is influenced by many factors and it is highly dependent on the specific service (such as video streaming, web browsing, or voice over IP) and the reaction capabilities (such as in terms of congestion management) allowed by the end-to-end network protocols.

New Traffic-Driven KPI Planning for Wireless Backhaul Links

ETIS ISG took up the challenge of relating backhaul link capacity outages to dynamic RAN aggregated traffic, and proposed the backhaul traffic availability (BTA) as a new KPI. The BTA is defined as the probability that a backhaul link is capable of meeting entire aggregated RAN traffic demand without affecting end-users QoE. From a mathematical point of view, it depends on the sum of the backhaul capacity outages weighted by occurrence probabilities of the RAN traffic, as schematically described in . Alternatively, the BTA can be viewed as the probability of a backhaul link not congesting the aggregated RAN traffic.



Backhaul Capacity	Outage (ITU-R P.530)
c_3	0.1%
c_2	0.05%
c_1	0.03%

Figure 1-2 Defining BTA through an example focused on a wireless backhaul link that can deliver discrete capacities c1, c2 and c3

Massive numerical simulations in various network conditions and with different profiles of aggregated RAN traffic showed that wireless backhaul links with BTA exceeding 99.8% do not lead to perceivable degradation in average end-to-end QoE, even in extremely demanding application scenarios. **Very interestingly, this BTA target level can be satisfied by most microwave and mmWave (including E-band) backhaul connections with hop lengths at least double these achievable with current approaches** (also see the example at the end of this chapter). **These important results** inherently shift focus from the performance of individual transport segments to the QoE of end-to-end connections. **They further confirm the conclusion that current wireless backhaul planning criteria lead to over-engineered link designs.**

New Traffic-Driven KPI Planning for Wireless Backhaul Links

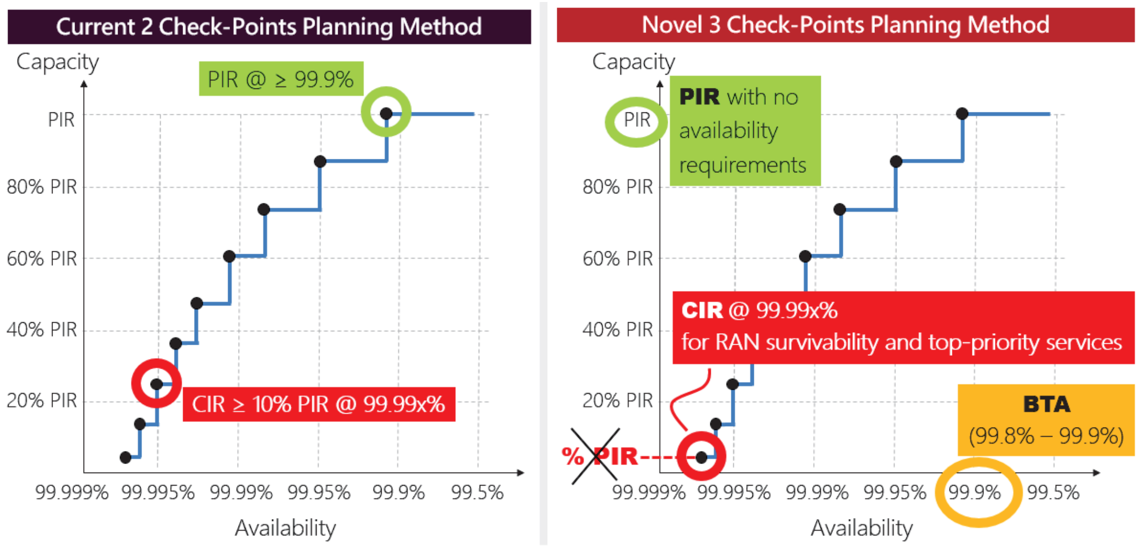
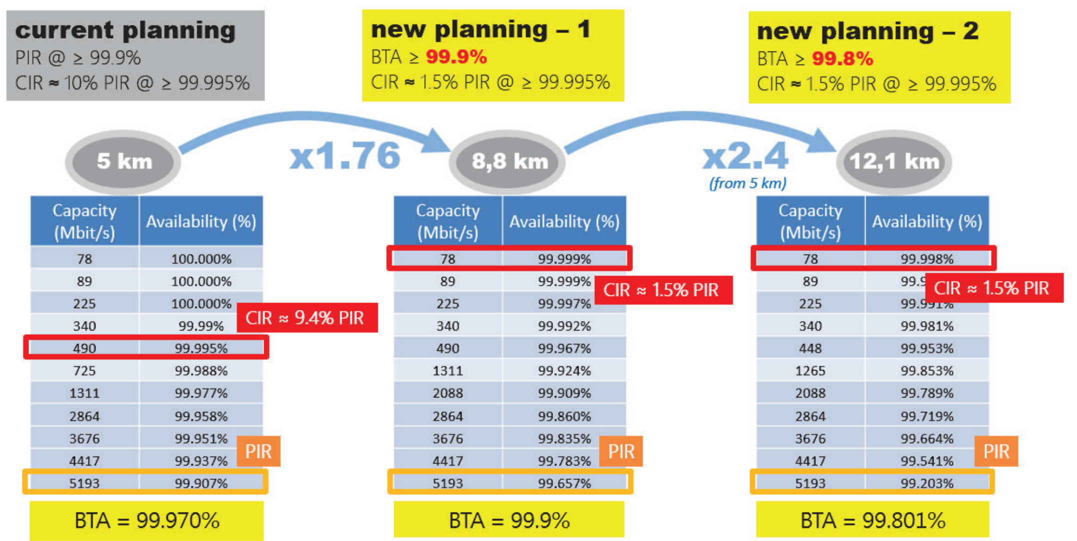


Figure 1-3 Two-checkpoint (PIR and CIR) planning and three-checkpoint (BTA, PIR, and CIR) planning

Figure 1-3 highlights how a two-checkpoint (PIR and CIR) planning differs from three-checkpoint (BTA, PIR and CIR) planning. For the latter to guarantee efficient wireless Backhaul network design, a conservative target BTA from 99.8% to 99.9% is required to avoid unnecessary resource waste by adapting the planning to the actual traffic demand. Since the BTA assures that the aggregated RAN traffic is not congested in most of the time without affecting end-user QoE, the new target PIR – still specified according to the RAT used – is no longer related to other availability requirements, meaning it can be dimensioned with a system-level criterion (between a 5 dB and 10 dB fade margin to ensure link stability).

Finally, wireless backhaul links should support a minimum capacity (or, CIR) exclusively targeted to guarantee both RAN's survivability and essential and top-priority services for as long as possible in a year (for example, 99.99x% available). For RAN's survivability, the amount of traffic needed can be easily calculated for different RATs, as it can be identified with necessary information flows to transfer control, management and synchronization planes to base stations. However, essential and top-priority services mostly depend on MNO proposition for customers and may comprise voice traffic (including emergency calls), guaranteed bit rate (GBR) applications (such as mission-critical voice/video, real-time streams and 5G new use cases), and service level agreement (SLA) traffic, making it more complex to determine the amount of traffic needed. In either case, the target CIRs used for wireless backhaul planning are highly dependent on RATs, and therefore cannot be blindly estimated as a fixed proportion of PIRs. For example, the **baseline CIR of a single 5G or 4G+5G site should be chosen as 1% to 2% of PIR,** which is significantly lower than the 10% to 20% percentage required in a current planning approach.



Capacity (Mbit/s)	Availability (%)
78	100.000%
89	100.000%
225	100.000%
340	99.99%
490	99.995%
725	99.988%
1311	99.977%
2864	99.958%
3676	99.951%
4417	99.937%
5193	99.907%

Capacity (Mbit/s)	Availability (%)
78	99.999%
89	99.999%
225	99.997%
340	99.992%
490	99.967%
1311	99.924%
2088	99.909%
2864	99.860%
3676	99.835%
4417	99.783%
5193	99.657%

Capacity (Mbit/s)	Availability (%)
78	99.998%
89	[illegible]
225	99.991%
340	99.981%
448	99.953%
1265	99.853%
2088	99.789%
2864	99.719%
3676	99.664%
4417	99.541%
5193	99.203%

Figure 1-4 Link lengths achieved with two-checkpoint and three-checkpoint planning, with E-band (1 GHz bandwidth, single polarization) and 18 GHz band (56 MHz, dual polarization) transmissions aggregated

Figure 1-4 highlights the benefits of new backhaul planning over current planning in achievable link lengths, with the aggregation of E-band and 18 GHz band transmissions. Previously, to ensure a PIR (5 Gbit/s in this case) is at least 99.9% available and a CIR of 490 Mbit/s (about 10% of PIR) is at least 99.995% available, a wireless backhaul link length cannot exceed 5 km in a climatic region with an annual rainfall rate of 42 mm/h. **Instead, with the new three-checkpoint planning,** if a target BTA is at least 99.8% and a target CIR is 1.5% of PIR and is 99.995% available, **the achievable hop length can at least double (up to 12.1 km in this case), with no perceivable impact to end-user QoE.**

Conclusions

The new three-checkpoint planning based on BTA (targeted at 99.8% to 99.9%), PIR (with 5–10 dB fade margin), and CIR (for both base station survivability and top-priority services) enables more efficient wireless backhaul planning than current approaches by increasing the achievable link lengths in most microwave and mmWave scenarios, while providing the same end-to-end QoE. This will help expand the application of wireless backhaul products (especially these operating in E-band) as alternatives to optical fiber in more transport networks and significantly reduce overall TCO.

References

[1] ETSI Group Report mWT 028 V1.1.1 (2023-04), "New KPI's for planning microwave and mmWave backhaul networks," April 2023.

[2] Recommendation ITU-R P.530-18 (September 2021): "Propagation data and prediction methods required for the design of terrestrial line-of-sight systems".

Chapter 2

E-band Backhaul Supporting Network Evolution into 5.5G and Beyond

E-band has seen wide use in the microwave industry. Currently, in countries where E-band usage is mature, such as Europe and the Middle East, the proportion of E-band deployment to microwave backhaul solutions is approximately 40%, and this proportion is still increasing. This is in line with our prediction last year that E-band deployments will account for 43% of all new microwave deployments worldwide in 2026 to become the prime spectrum for backhaul over the next decade.

What are the reasons why E-band has become the prime spectrum for wide deployment?

First, E-band has advantages in spectrum cost over Traditional microwave bands in most countries. In some countries or regions, the cost per MHz of E-band is only 10% or even lower of that of common bands. Reduced spectrum fees encourage operators to replace Traditional bands with E-band in urban areas in new backhaul networks.

In addition, high transmit power and high-gain antennas considerably improve the system gain of E-band and increase its transmission distance by 50%. Technological advances also promote this band to be widely used in vast rain zones P. In Asia-Pacific countries in rain zones P, E-band spectrum fees have been reduced. This has helped local operators quickly build 5G networks at a low cost based on E-band while also promoting local economic development.

Furthermore, the anti-shake technology can effectively address the tower type issues that hinder the universal deployment of E-band. It is widely known that due to E-band beams being narrow, pole deformation and shake caused by exposure to sun rays and wind respectively, adversely affect E-band deployment. In the future, the anti-shake capability will be upgraded from one dimension to two dimensions.

With the rapid growth of 5G, some of the leading operators in the industry require 10 Gbit/s capacity when building networks. Technological advances will allow E-band to achieve 25 Gbit/s or higher capacity, satisfying 5.5G and future backhaul capacity requirements.

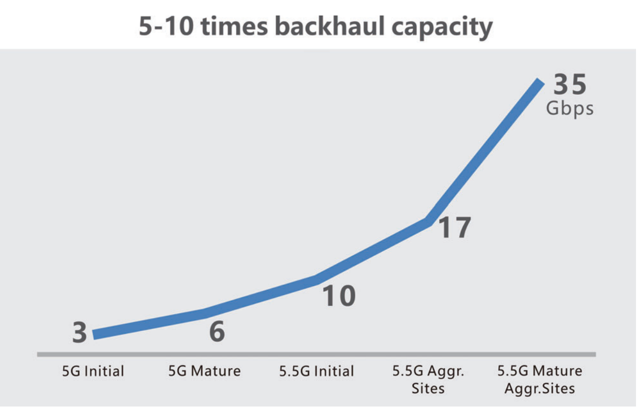


Figure 2-1 Backhaul capacity forecast

The extensive development of E-band also faces new challenges.

1. Conventional E-band devices not only have a limited number of interfaces, but also cannot support the various service types that come with the wider application of E-band, such as 2G, 3G, 4G, and 5G MBB services and enterprise services.

2. The scaling up of E-band solutions based on independent devices will cause more IP addresses to be consumed and require more refined network management. Despite the use of device virtualization in some cases, independent E-band physical devices still need to be bound to systems. After deploying E-band, operators in some areas even experience a four-fold increase in the number of independent devices to be managed on the network.

3. The Super Dual Band (SDB) solution perfectly combines the advantages of Traditional bands in transmission distance

and of E-band in capacity. The spectrum fee advantages of E-band will also quickly drive the large-scale development of the SDB solution, especially in rain zones P. Even though the combination of split and full outdoor (FO) E-band devices helps boost the flexibility of conventional SDB application deployment, the O&M still involves two different models and systems, which brings new challenges to the market.

The solution to these challenges is to unify product architecture for Traditional bands and E-band, so that they share a single platform, which significantly simplifies delivery and network O&M.

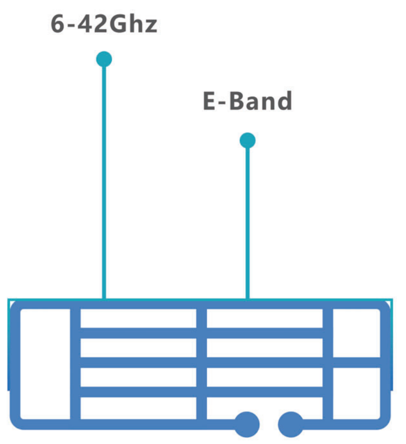


Figure 2-2 Unified architecture for all frequency bands

Chapter 3

Traditional Bands: Towards Multi-TX and Ultra-wideband

Traditional bands play a vital role in 5G backhaul. In Super Dual Band (SDB) or medium- and long-distance (exceeding the coverage area of SDB) backhaul scenarios, capacity requirements for traditional bands are 2–5 Gbit/s. With the continuous combination of the C-band and millimeter wave of the 5G RAN spectrum, capacity requirements for traditional bands are also on the rise.

In order for traditional bands to achieve large-capacity transmission, aggregation of multiple dispersed channels is required. Traditional bands feature discrete and narrowband spectrums, with common bandwidths of 28 MHz, 40 MHz, and 56 MHz. The 80 MHz and 112 MHz spectrums are difficult to obtain and it is especially difficult to obtain high bandwidth for frequency bands below 15 GHz. For a traditional band to achieve a capacity of 2 Gbit/s, if the spectrum is 56 MHz, a 4+0 site needs to be deployed, with four channels aggregated, two frequencies, and two polarizations; if the spectrum is 28 MHz, an 8+0 site needs to be deployed, with eight channels aggregated, four frequencies, and two polarizations.

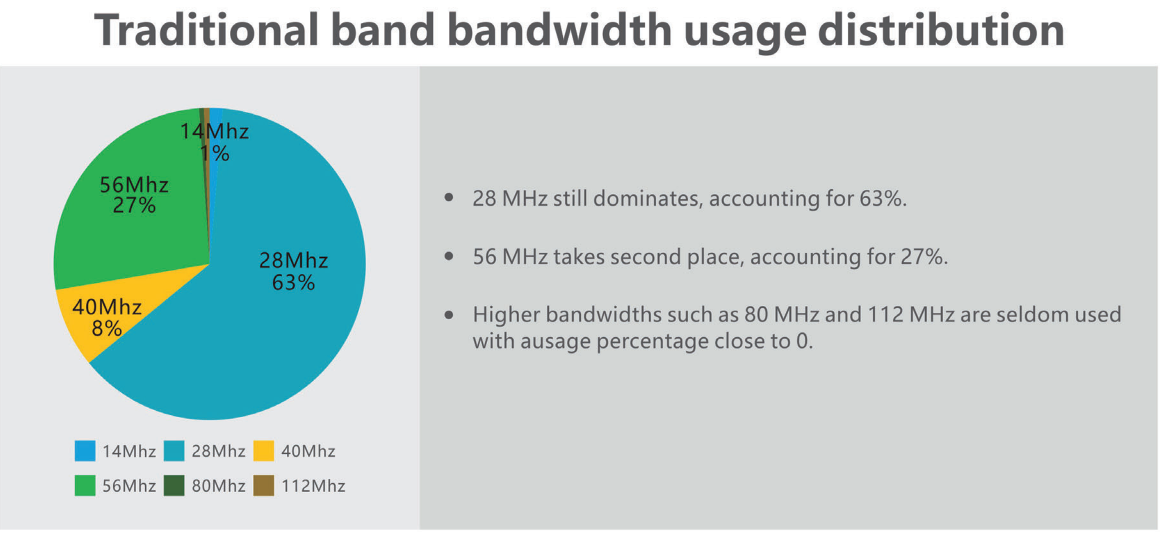


Figure 3-1 Traditional band bandwidth usage distribution

In traditional solutions, if multiple channels are aggregated based on the 1T1R single-carrier outdoor unit (ODU), problems arise such as excessive hardware, large insertion loss, and complex solutions. For example, four stacked ODUs are needed to deploy a 4+0 site and if the spectrum is 28 MHz, eight ODUs need to be stacked. Multiple ODUs need to be stacked through couplers, resulting in large insertion loss, and a larger antenna diameter is needed to compensate for the insertion loss. As a result, the hardware cost and tower load increase sharply, as shown in the following figure.

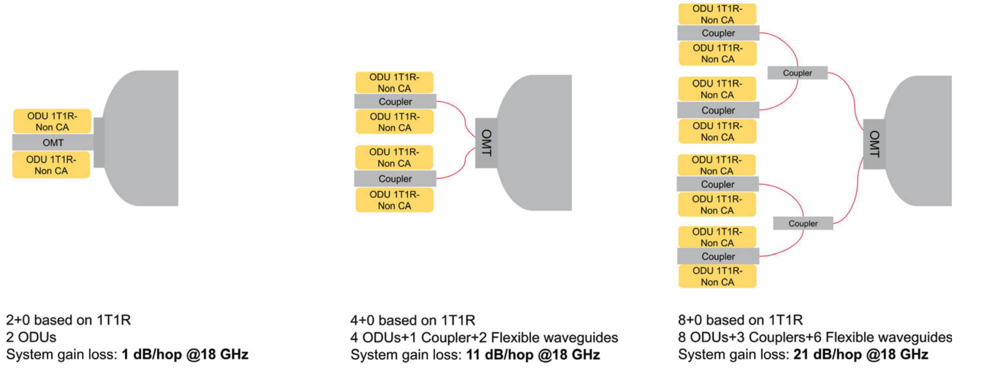


Figure 3-2 4+0 and 8+0 configuration example of 1T1R single-carrier ODU

If multiple channels are aggregated based on 1T1R-CA ODU, two modules are required in the 2+0 XPIC scenario because carrier aggregation (CA) cannot take effect. In the 4+0/8+0 or higher scenarios, problems such as excessive modules and complex solutions persist.

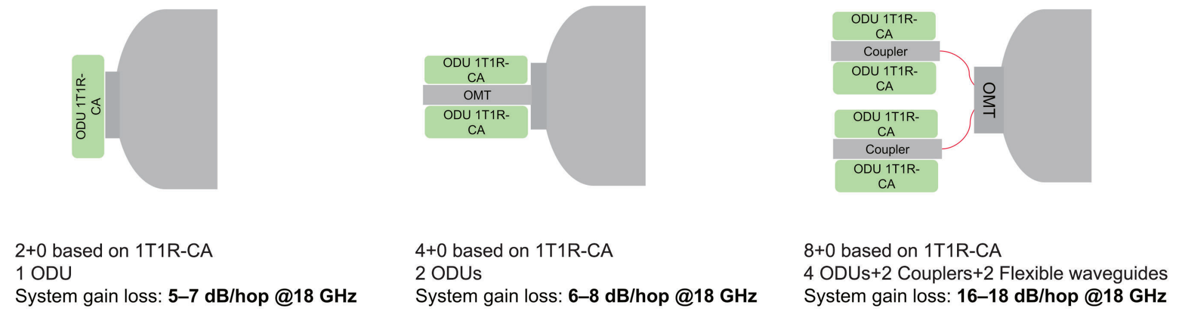


Figure 3-3 4+0 and 8+0 configuration example of 1T1R-CA ODU

2T2R-CA enables a single ODU to support four channels. In 4+0 scenarios, the ODU alone can support four channels, greatly reducing the number of modules installed on the tower. This greatly improves solution integration, reduces the insertion loss caused by flexible waveguides and couplers, simplifies the multi-channel configuration, and achieves low insertion loss convergence and smooth evolution. Huawei was the first in the industry to launch 2T2R-CA, which has since achieved widespread industry recognition.

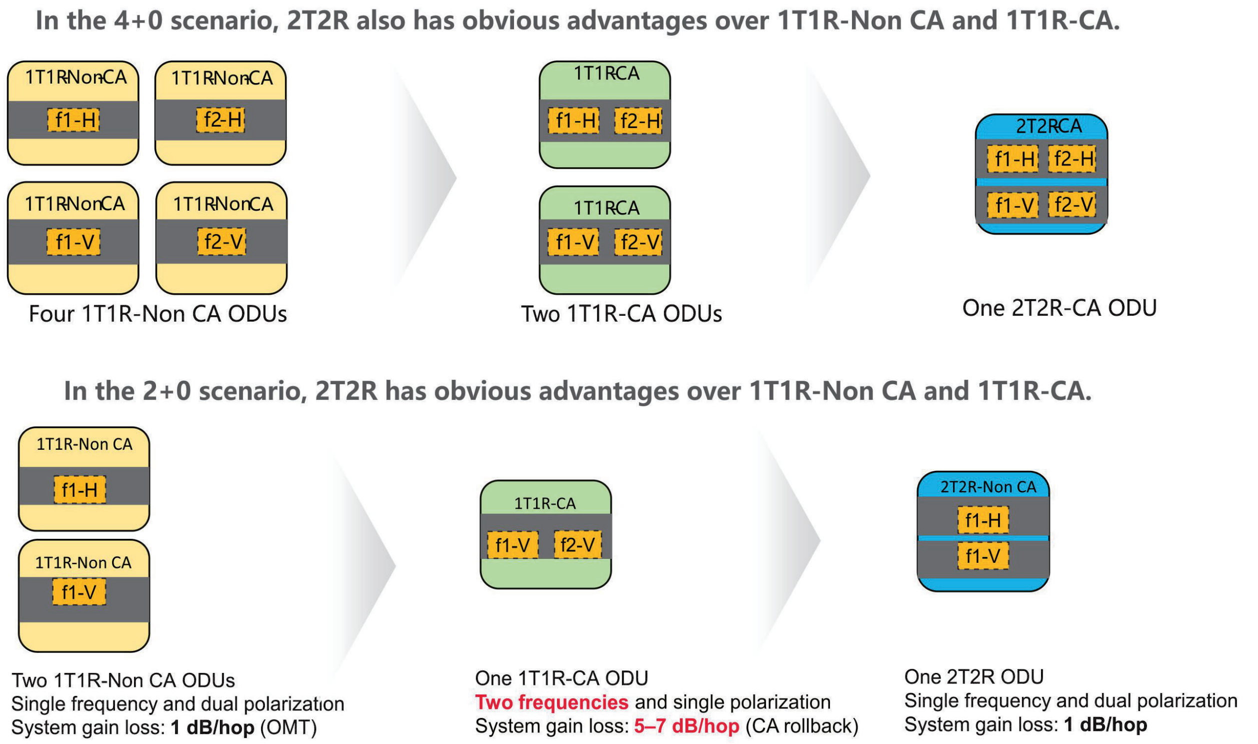


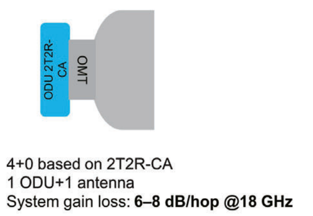
Figure 3-4 Configuration example of 2T2R-CA ODU

2T2R-CA module configuration:

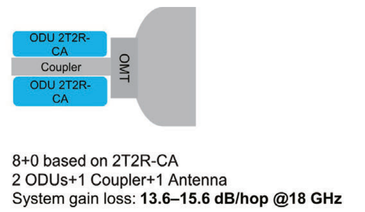
Small number of modules: The number of hardware devices is reduced by 33% (from 3 to 2) in 2+0 scenarios, by 75% (from 8 to 2) in 4+0 scenarios, and by 78% (from 18 to 4) in 8+0 scenarios.

Small insertion loss: The insertion loss can be reduced by 3–5 dB in 4+0 scenarios and by 5.4–7.4 dB in 8+0 scenarios. The antenna diameter can be reduced by one or two levels.

Solution	Hardware Quantity	System Gain Loss	Frequency Number
1T1R-Non CA	2 ODUs 1 Antenna	1 dB/hop	1
1T1R-CA	1 ODU 1 Antenna	6–8 dB/hop	2
2T2R-CA	1 ODU 1 Antenna	1 dB/hop	1



Solution	Hardware Quantity	System Gain Loss	Frequency Number
1T1R-Non CA	4 ODUs 1 Coupler 2 Flexible waveguides 1 Antenna	11 dB/hop	2
1T1R-CA	2 ODUs 1 Antenna	6–8 dB/hop	2
2T2R-CA	1 ODU 1 Antenna	6–8 dB/hop	2



Solution	Hardware Quantity	System Gain Loss	Frequency Number
1T1R-Non CA	8 ODUs 3 Couplers 6 Flexible waveguides 1 Antenna	21 dB/hop	4
1T1R-CA	4 ODUs 2 Couplers 2 Flexible waveguides 1 Antenna	13.6–15.6 dB/hop	4
2T2R-CA	2 ODUs 1 Coupler 1 Antenna	13.6–15.6 dB/hop	4

Figure 3-5 Configuration and System Gain Comparison

Two key points in the 2T2R-CA ODU solution:

One key point is wideband CA. In this solution, CA IBW is expanded to cover more frequencies, facilitating CA deployment.

There are eight frequencies, including 28 (C_8^2) pairwise combinations. If CA IBW can cover only four frequencies, only six (C_4^2) pairwise combinations can be obtained. The coverage proportion is only 21% (6/28), not 50%. As such, wideband CA through expanding CA IBW is needed to cover more frequencies, thereby facilitating CA deployment, as shown in the following figure:

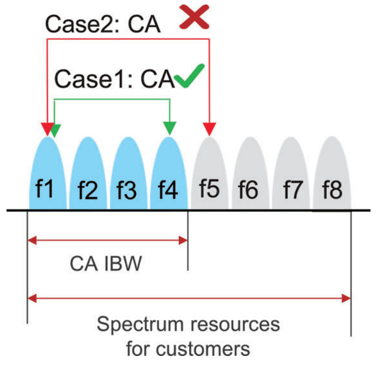


Figure 3-6 CA IBW

In the 4+0 scenario with CA enabled (as shown in Case 1), the hardware is reduced by 50% and the insertion loss by 0.6–1.4 dB compared to the scenario with CA disabled (as shown in Case 2). The higher the CA coverage proportion, the easier the CA deployment, and the higher the probability of CA gains.

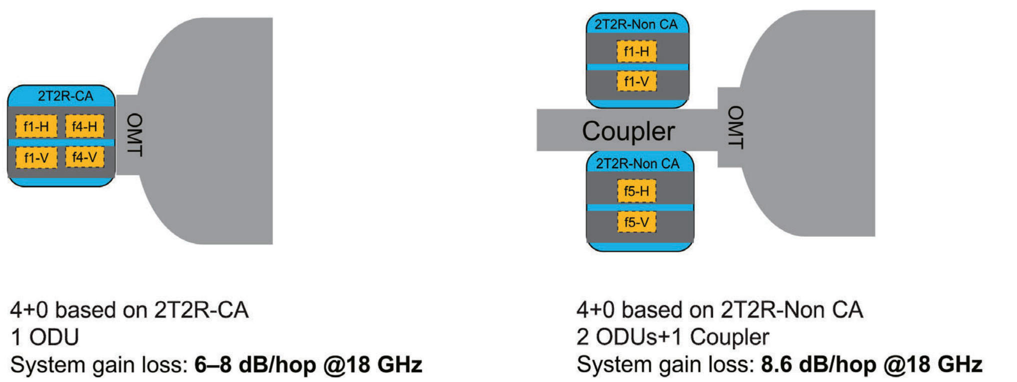


Figure 3-7 Configuration and system gain comparison of wideband CA ODU

The other key point is low CA transmit power loss value. Enabled CA leads to CA transmit power loss, whose effect on system gain is equivalent to that of combiner insertion loss. Technical measures are used to decrease the transmit power loss value, thereby reducing the antenna diameter and the total cost of operation (TCO).

CA has a smaller impact on system gain than couplers. Therefore, optimization of CA system gain will further enhance the advantages of CA over combiners.

CA loss causes:

1. Power amplifies (PA) have a fixed total transmit power. When CA is enabled, two carriers share the transmit power. The transmit power of each carrier in CA is reduced by half (theoretically 3 dB) compared with that when CA is disabled.
2. As shown in the following figure, when two 28 MHz carriers are used, they must separately comply with the 28 MHz template which has stricter requirements than the 56 MHz template. To meet the requirements of the 28 MHz template, the transmit power of a single carrier must be decreased to reduce intermodulation interference.

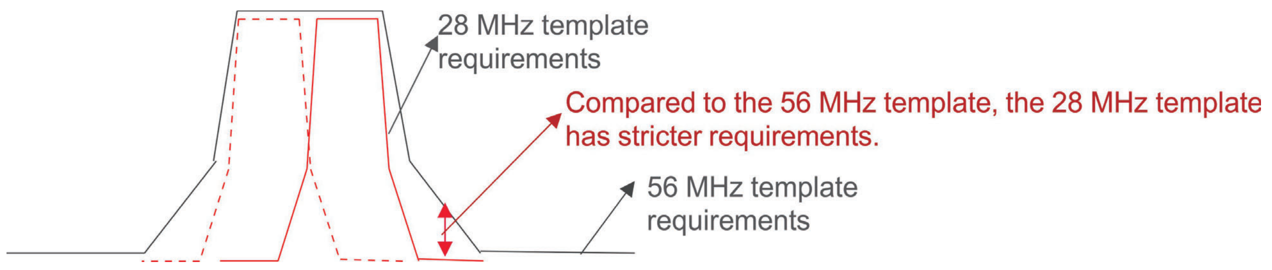


Figure 3-8 Examples of 28 MHz and 56 MHz spectrum templates

Advantages of reducing CA loss:

Using the 18 GHz scenario as an example, an increase in ODU transmit power by an average of 2.78 dB leads to the antenna diameter decreasing by one level. The CA loss value in the industry is 6–7 dB. CA loss leads to a one-level increase in the diameter of the antennas at two connected microwave sites, greatly increasing the TCO and making the deployment more difficult. Therefore, it is very important to reduce CA loss.

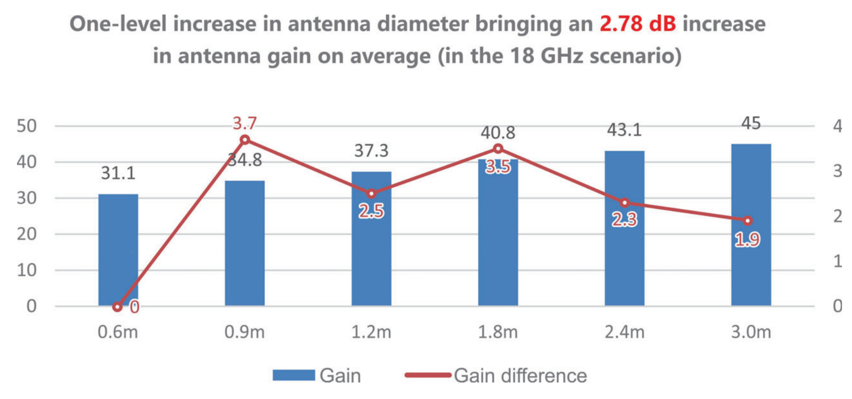


Figure 3-9 System gain of 18GHz antennas

Improvement direction:

1. Increasing the transmit power of a single carrier: Hardware enables the transmit power increase of a single carrier to reserve space for CA loss, thereby increasing the transmit power value of CA after the loss.
2. Reducing the CA loss range: Software algorithms are used to reduce intermodulation interference, thereby reducing power loss.

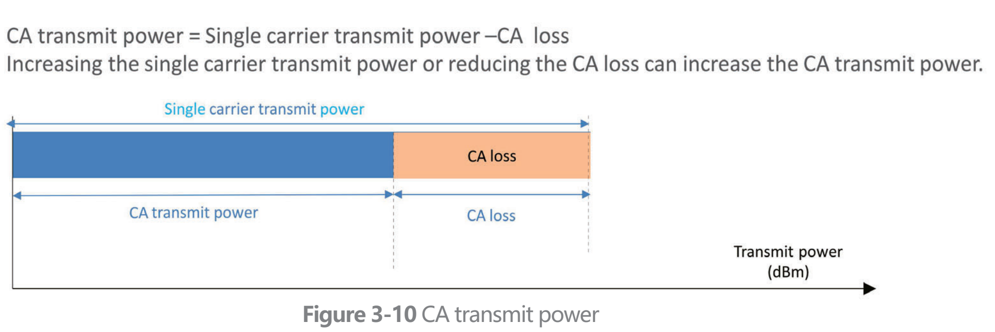


Figure 3-10 CA transmit power

Chapter 4

Long-haul Microwave: Ultra-Broadband, Simplified Deployment, and Capacity Expansion to over 20 Gbit/s

In areas where optical fibers are insufficient, the Long-haul microwave is used for long-distance and large-capacity transmission. As an important supplement to optical fibers, it has a long future and will evolve towards ultra-large capacity and simplified deployment.

Solutions for ultra-large capacity:

According to statistical trends, wireless service traffic doubles every two to three years. For the future 5G backhaul, the capacity of Long-haul microwave is expected to increase from 2–4 Gbit/s to over 20 Gbit/s. However, traditional Long-haul solutions are unable to accommodate this level of capacity expansion. There are two ways to obtain a larger capacity. The first is to improve spectrum utilization through the LOS MIMO technology which is immature in Long-haul scenarios. In addition, the increase in the number of MIMO antennas further increases the TCO, and for low-frequency long-distance transmission, there are more demanding requirements on the installation space of MIMO antennas. The other way to obtain a larger capacity is to use more spectrum, which can be achieved through band aggregation. Our research shows that the difference between the transmission distance of 11 GHz and that of 8 GHz in rain zone K is less than 10%. Therefore, using multiple frequency bands is the solution for obtaining larger capacity. Specifically, the four low frequency bands (6 GHz, 7 GHz, 8 GHz, and 11 GHz) can be bound to the same link to obtain ultra-high bandwidth, which can meet customers' requirements for Long-haul service development in the next 5 to 10 years.

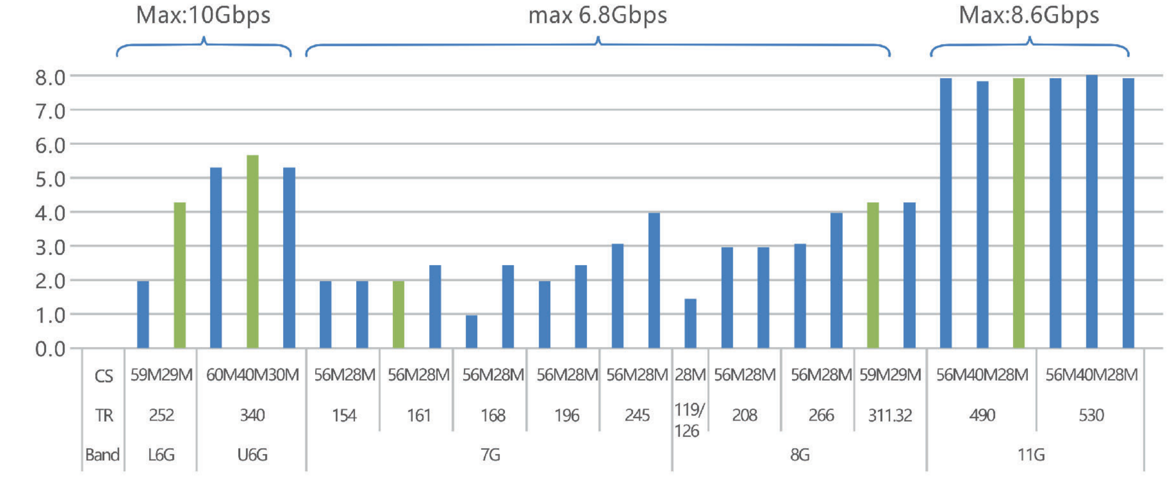


Figure 4-1 Capacity of 6/7/8/11GHz

Solutions for simplifying deployment:

Although the multi-band superposition solution can increase capacity, the traditional implementation mode requires that RF modules of each frequency band be superimposed, resulting in the stacking of RF modules. In addition, each frequency band requires corresponding antennas, resulting in accumulation of antennas. Together, they cause site deployment to be complex as well as greatly increasing tower rental costs.

To simplify deployment and reduce TCO, the Long-haul microwave solution improves integration and system gains, effectively reducing delivery complexity and antenna diameters.

Method 1 for improving integration: Single-band antennas are replaced by multi-band antennas by using wideband components, such as the feed boom and antenna, achieving full coverage of four frequency bands: 6 GHz, 7 GHz, 8 GHz, and 11 GHz.

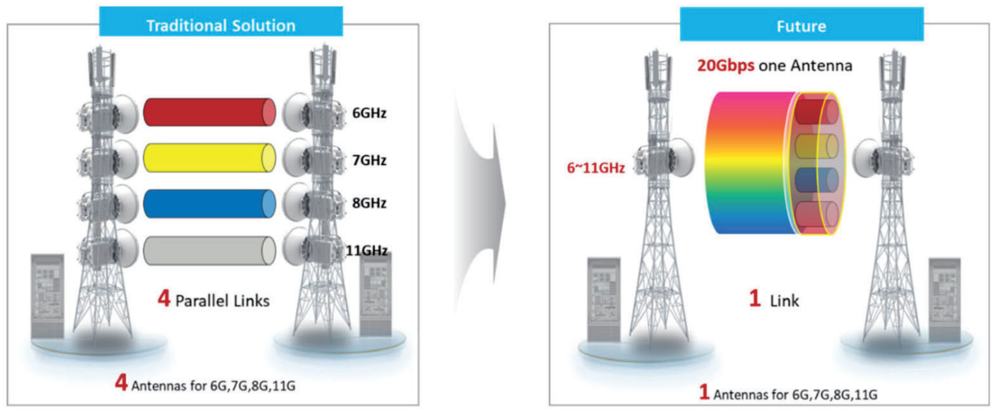


Figure 4-2 One antenna for 6/7/8/11GHz

Method 2 for improving integration: Single-carrier modules are replaced by multi-carrier modules, reducing the number of stacked RF modules. Traditional 1T RFUs are replaced by multi-carrier RFUs, and multi-carrier technologies for traditional bands are applied to Long-haul networks.

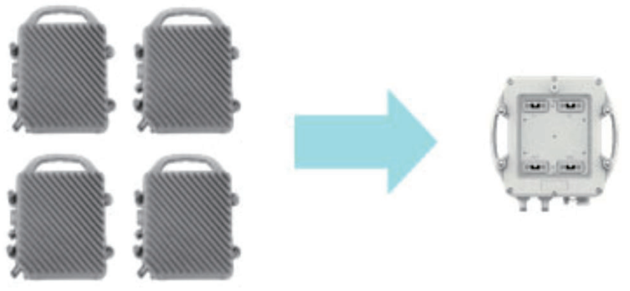


Figure 4-3 4 in 1 RFU

Improving the system gain and reducing the antenna diameter brings obvious benefits and is also a field of continuous research for the microwave industry. The diameter of the Long-haul microwave antenna is generally greater than 1.2 m. Each time the system gain increases by 2 dB to 3 dB, the diameter, area, and weight of antennas can be reduced, which in turn reduce tower rental costs.

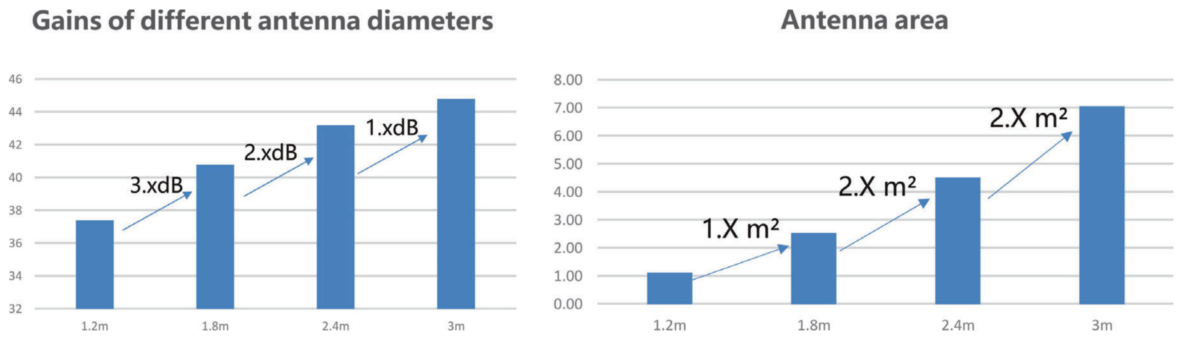


Figure 4-4 Gains and areas of different size antennas

Chapter 5

Rural Network Scenarios: Microwave Fronthaul Solution Helping Operators Quickly Build Networks and Achieve Universal Coverage

In 2022, there were still 350 million people around the world living in places without mobile network coverage. These places mainly consist of remote rural areas and mountainous areas in Africa, Southeast Asia, and Latin America. These areas are generally sparsely populated and inaccessible, with insufficient power and transmission resources. It is difficult to construct communication networks in such areas, and even if they are constructed, the expected revenue is low.

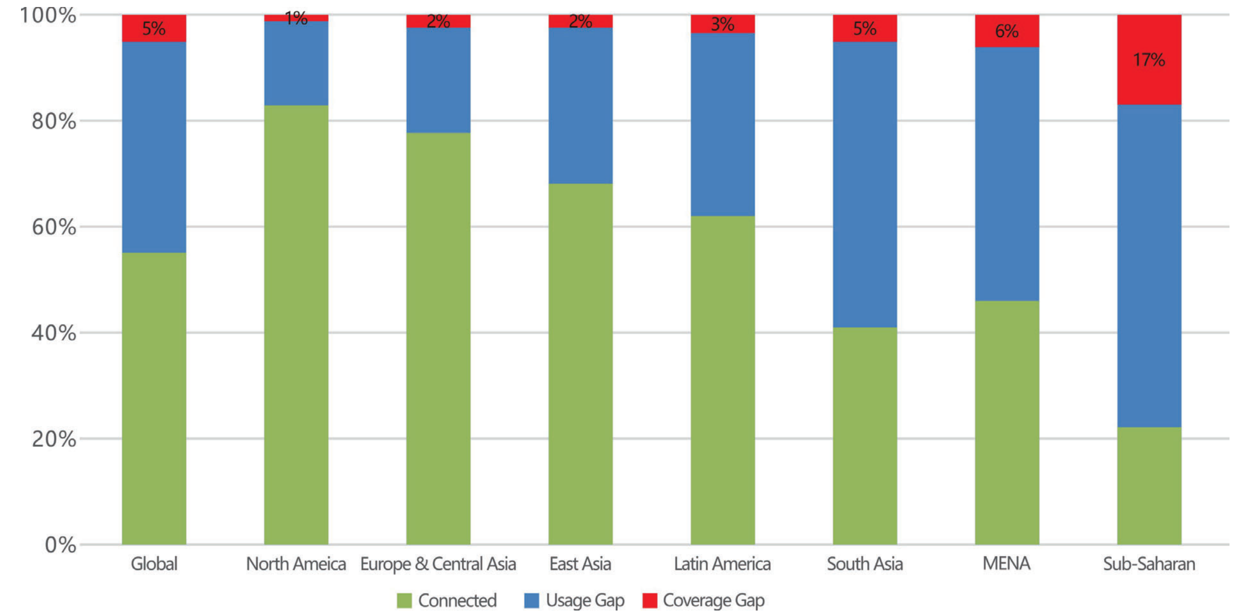


Figure 5-1 Global mobile network coverage

However, rural network coverage is attracting more and more attention, and many countries have included strong support for it in their policies. For example, some countries in Latin America have initiated large-scale site deployment based on government-driven coverage obligations and subsidies. In the next few years, rural network coverage will be an important part of wireless network development and popularization.

Rural networks are characterized by small capacity and wide coverage. The construction of traditional macro base stations requires large investments but the average revenue per user (ARPU) of rural networks is generally low – usually only about half of that in cities. Therefore, the return on investment (ROI) is also low. The key to building rural networks is reducing costs. Microwave fronthaul technology simplifies site deployment and facilitates rapid coverage of rural networks.

The key benefits of this solution are as follows:

1. Lower TCO: BBUs, cabinets, and equipment rooms are saved on leaf sites. In typical scenarios, the TCO can be reduced by 30%.
2. Fast deployment: Site devices are simplified and easy to be installed, shortening the TTM to one day.
3. Lower power consumption: No BBU is needed. Only one RRU and one microwave device are required. Compared with traditional sites, the power consumption is reduced by 20%.
4. Smooth evolution: When the service capacity increases to a certain extent and a site needs to evolve to a macro site, a BBU can be added to change the microwave fronthaul to the microwave backhaul for smooth capacity expansion.

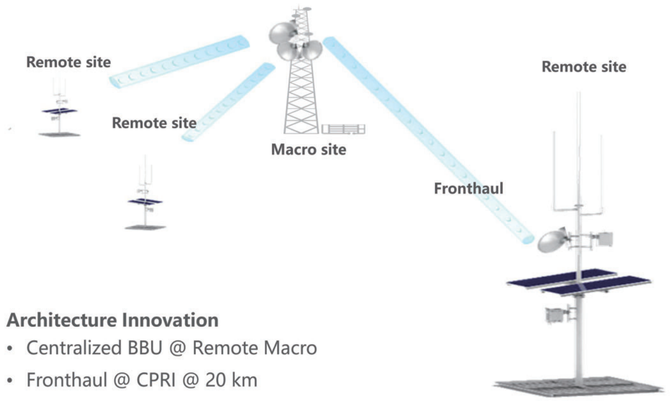


Figure 5-2 Microwave fronthaul architecture

The microwave fronthaul solution has the following two key points:

1. Common Public Radio Interface (CPRI) ports must be supported. Wireless fronthaul uses the CPRI transmission protocol and provides a large capacity. Huawei uses COE devices to convert CPRI frames into Ethernet frames and supports a maximum of 4:1 CPRI bandwidth compression. Currently, a maximum capacity of 2.5 Gbit/s and a maximum transmission distance of 20 km can be achieved. In the future, the maximum capacity can reach 10 Gbit/s or 25 Gbit/s. The following table lists the requirements for typical rural network scenarios.

Typical Configuration	Transmission Distance	Bandwidth	Typical Interface Type
2x5 MHz@1T+2x5 MHz@1T	20 km	500 Mbit/s	CPRI
2x10 MHz@2T+2x10 MHz@2T	10 km	1 Gbit/s	CPRI
3x10 MHz@4T	10 km	2 Gbit/s	CPRI

Table 5-1 Typical microwave fronthaul configurations

2. Microwave and wireless devices use the same NMS. In traditional microwave MBB backhaul applications, microwave devices and base station devices usually use independent NMSs. For fronthaul solutions, microwave carries wireless data between RRUs and BBUs and becomes a part of wireless sites. An independent NMS brings inconvenience to O&M and management of the overall solution, such as visualized O&M, configuration, and fault locating. In microwave fronthaul scenarios, it is necessary to incorporate microwave and access devices into a unified NMS to reduce O&M costs and greatly improve O&M efficiency.

Chapter 6

Energy Saving and Automation: Green Microwave Solution Facilitating Industry Development

Over the past 30 years, global carbon emissions have increased by 30% and greenhouse gas emissions have been steadily rising. This has resulted in unprecedented global warming which poses a great threat to our society, economy, and environment for the foreseeable future.

To mitigate the negative impacts of climate change, international organizations have launched various climate change-related initiatives in numerous industries. To-date, more than 100 countries have proposed carbon neutrality targets. Green and low-carbon development has become a common goal for various industries and sectors of society.

With the acceleration of global digital transformation, the increasing demand for computing power, and the wider application of 5G, energy consumption and carbon emissions in the communications industry will soon experience rapid growth. Therefore, the communications industry is in urgent need of energy-saving and low-carbon technologies to promote high-quality green development.

For microwave networks, there are several directions for improving network energy efficiency:

The first is to exploit the green nature of microwave solutions. In the mobile backhaul, optical fiber deployment involves outside plant (OSP) engineering such as acquiring route permissions, digging trenches, and burying cables. The construction period is long and the cost is high. In addition, heavy machinery such as trenchers, bulldozers, and trucks are required, resulting in high carbon emissions. However, with microwave solutions, existing towers and site resources can be used, thereby avoiding the need to dig trenches and bury cables, which make microwave solutions more green and low-carbon.

Category	Microwave	Fiber
Engineering Cost	**Quick deployment,** short engineering period, and low cost	OSP engineering involved, which takes a long time and is costly
Execution Difficulty	**Strong cross-space capability, small land occupation, and easy deployment**	OSP engineering greatly affected by terrain
Maintainability	**Easy maintenance,** with no risk of cables being broken accidentally	Difficult to locate fault points in the event of cable damage
Disaster recovery capability	**Strong disaster resistance capability** and quick recovery after a disaster	Difficult to recover in the event of cable damage due to disasters such as earthquakes, landslides, and heavy snow

Table 6-1 Microwave deployment is greener and faster

The second is that greater simplicity means greater greenness. Network architecture affects the connection mode between devices and the number of devices. System architecture innovation reduces the number of hardware devices so that a simplified network can be built, which in return reduces energy consumption.

1. In urban areas, the E-band transmit power is increased to achieve a longer transmission distance. The original 2-hop E-band or 1-hop microwave dual-band links can be replaced, reducing power consumption by more than 30%.

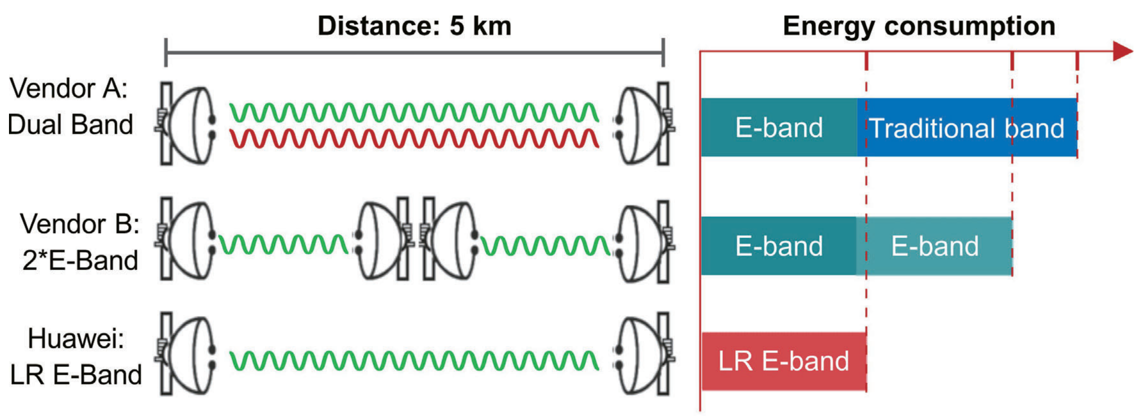


Figure 6-1 LR E-band solution save more power consumption

2. In suburban areas or long-distance transmission scenarios, four-channel CA ODUs and multi-band antennas are used to build a simplified solution, greatly reducing the number of hardware devices and thus reducing energy consumption by 30%.

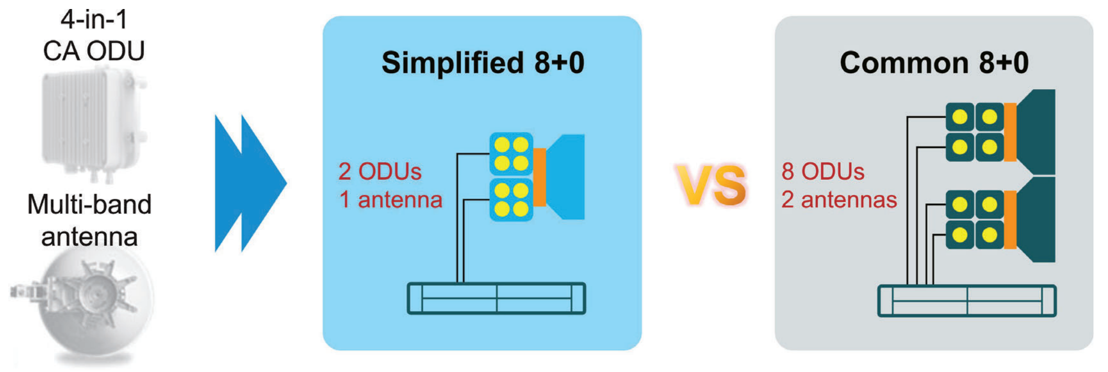


Figure 6-2 High-integrated solution save more device and power consumption

Thirdly, technical innovations enable the creation of green and energy-saving solutions. For instance, network devices can achieve static energy saving by disabling ports or components based on service configurations. Microwave automation achieves dynamic energy saving by automatically detecting traffic status and dynamically hibernating or shutting down redundant links based on network loads.

With the digital transformation of various industries and the intelligent connection of everything, the scale of microwave networks is expanding and the quality requirements are increasing. As such, traditional manual and machine-assisted O&M faces the following significant challenges:

Challenge 1: In the face of massive connections and diversified service types, the service provisioning period is long and dynamic bandwidth adjustment is difficult.

Challenge 2: The manual and machine-assisted passive O&M is inefficient and must be improved.

Challenge 3: Explosive traffic growth makes management and prediction difficult. How to identify traffic bottlenecks and expand capacity in a timely manner are challenges that need to be overcome.

For microwave networks, automation and intelligence are implemented in the following three aspects:

1. Network automation

– Automatic resource discovery reduces manual intervention and identifies resource bottlenecks in advance.

– Agile service provisioning: One-click E2E service provisioning simplifies service configuration parameters, and users only need to provide data such as source and sink ports, service types, and bandwidth. In this way, services can be automatically and quickly provisioned, greatly shortening the TTM.

– Agile network capacity expansion: Users can quickly create aggregation links by selecting primary and secondary links based on the microwave link in the network topology. In this way, the original link bandwidth can be expanded, simplifying procedures and improving efficiency.

2. Network insight: The health status of the entire network is visualized, providing the basis for network layout, optimization, and reconstruction. Meanwhile, network risks can be predicted and resolved in advance.

– The service/link performance dashboard provides service path restoration and link coloring to display the status of network-wide key indicators. This felicitates the detection of the network health status and quick identification of network bottlenecks.

– Base stations and microwave devices can be displayed in the same topology, and KPIs of wireless and microwave devices can be jointly analyzed. This solves difficulties in joint network evaluation and associated capacity expansion between wireless and microwave sites.

– Traffic trend analysis enables capacity expansion prediction and identification of links to be expanded in advance, reducing traffic loss caused by customer network congestion and improving service SLA.

3. Intelligent O&M: Intelligent O&M implements one ticket for one fault, transforming traditional alarm monitoring to fault-oriented O&M. Specific implementation is as follows:

– Noise reduction filtering is performed on massive alarm data on the live network. That is, invalid alarm data, such as repeated alarms, maintenance mode alarms, and intermittent alarms, is automatically identified and marked, greatly reducing the number of alarms.

– Alarms are intelligently aggregated based on correlation rules. For example, alarms are associated and aggregated based on the topology, context, and fault occurrence time associations of the alarmed objects to form associated fault events.

– Intelligent algorithms are used to identify root causes within and between fault events, identify fault scenarios, and analyze service impacts. In this way, suspected root alarms that cause fault events can be found and converted into trouble tickets.

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