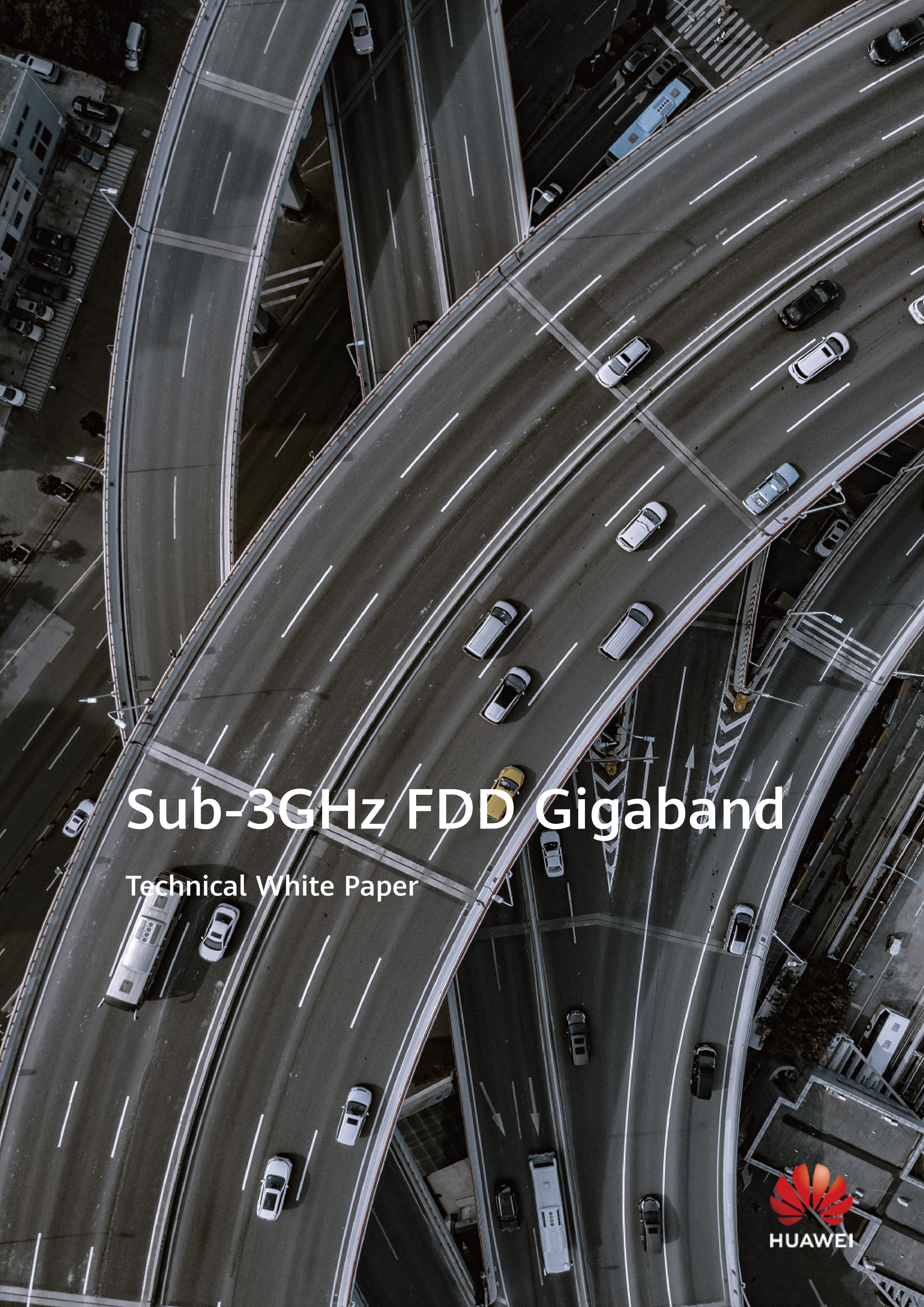

Sub-3GHz FDD Gigaband

Technical White Paper

HUAWEI

Introduction

1 Background

The mobile Internet has become an integral part of our everyday life, like water and electricity, and demand continues to grow year on year. To accommodate demand for mobile connections experience upgrading operators have added more spectrum, sites, antennas etc. to increase network capability for traffic growth, but this has led to a complicated network architecture and increased operating cost. Operators now find themselves with a dilemma — how to expand services while pursuing low cost deployment and operations reduces TCO. Sustainability also needs to consider energy saving, extended and selective use of material. Inevitably, network sustainability requires low cost deployment and operation as the network provides higher capacity by advanced technologies to boost spectrum capabilities. This requires base stations (BTS) to be redesigned in line with the trends for green and simplified evolution. sub-3 GHz Gigaband is a necessary direction for green mobile networks and simplified 5G sites evolution.

Gigaband employs ultra-wideband and multi-antenna MIMO technologies to facilitate the evolution of all sub-3 GHz spectrum to 5G. This enables multiple bands to be implemented in a single equipment. From the perspective of equipment and service deployment, it is necessary to re-design both hardware and software to enable all bands smooth migration to 5G and evolution to 5G-Advanced.

Gigaband commercialized by operator's networks. In addition, mobile equipment suppliers, telecom industry analysts, and policy makers see ultra-wideband and multi-antenna technologies as major trends towards simplified, green sub-3GHz 5G.

2 Objectives

Gigaband technologies support the strategy of simplified and green evolution of all bands to 5G networks, particularly sub-3 GHz multi-band deployments, providing a tenfold investment efficiency over 4G.

This white paper will help you understand:
1. The technical driving force behind Gigaband
2. The key technical implementation of Gigaband
3. Commercial reference cases of Gigaband
4. Future evolution trends of Gigaband

3 Technical Driving Force Behind Gigaband

3.1 It Is a Big Challenge to Upgrade sub-3 GHz to 5G with Tiny bandwidths in multiple discrete bands

By analyzing the spectrum allocation of the (ITU) international Telecommunication Union, we can find out that operators typically own about 5-7 bands of sub-3G Hz FDD spectrum, with over 100 MHz available spectral bandwidth (downlink + uplink), as shown in Figure 1. In some multi-band deployment cases, the tower has four FDD bands with 3 sectors, three TDD AAUs, and even legacy GSM and UMTS equipment. This complicates antenna installation, with a single operator likely to have more than 24 modules on a tower. This limits the tower space available to deploy 5G's new bands.

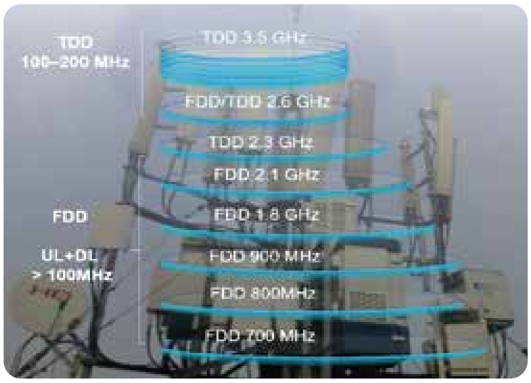

Figure 1 Multi-band deployment on a tower

3.2 Native 5G MIMO Evolution Based on nTnR Is Essential to Unleash the dividends of 5G technology

Evolving all bands to 5G is a mainstream trend. One major difference that 5G has over 4G is its extensive use of utilizes multiple antenna arrays and spatial diversity to increase multiple radio transmission channels. By increasing the number of channels, network capacity is boosted and faster data throughput. Scenario-specific spatial multiplexing in horizontal, vertical, and 3D directions can contribute to more than 10 times capacity increase due to a higher spectral efficiency, which will benefit network capacity significantly.

Summary: Operators need additional spectrum and multi-antenna deployments to ensure superb 5G experience with high bandwidth, vast connectivity, low latency, and elevated reliability.

4 Program of Gigaband

Huawei has been investing in Gigaband power amplification for decades, becoming the first vendor to bring wide-Band technology to base stations. In 2009, it commercially deployed 1.9GHz+2.1GHz TD-SCDMA wide-band power amplifiers in China for the first time in the industry. It launched FDD Wide-Band 2T4R RRUs in 2014 — the industry's first to support two bands (1.8 GHz + 2.1 GHz , 800 MHz + 900 MHz), Dual-mid-band 4T4R RRUs in 2017 (1.8 + 2.1 GHz), and Gigaband Triple-Low band RRUs in 2020.

In 2022, Gigaband reached a fresh milestone with a full-series of Gigaband innovations that consists of triple-band 4T4R and dual-band 8T8R RRU modules, with industry-leading performance. These iterative innovations invariably focus on building green sites and boosting spectral efficiency. Thanks to Gigaband and multi-antenna technology， the network's ROI in 5G is 10 times higher than in 4G.

4.1 Gigaband: Ultra-wideband

Radio units, both RRU (remote radio unit) and AAU (active antenna unit), are the main equipment of a base station in that they have a huge influence on network performance including coverage, user experience, and energy consumption. After several phases of development, radio units have evolved from single-carrier full band to multi-band and now to the ultra-wide giga hertz bandwidth solution named Gigaband.

A radio unit has multiple channels, with each comprising digital processing units, ADC/DAC units, tiny-amplitude signal amplifiers, power amplifiers, LNAs, and duplexer as shown in Figure 2. However,

Ultra-wideband radio units simultaneously handle signals of multiple bands and carriers. Based on this uniqueness, base station hardware can be simplified and extremely integrated to help cut power consumption.

The overall performance of radio units is measured based on a number of indicators, including receiver sensitivity, spectrum capabilities, energy efficiency, anti-interference capability, and

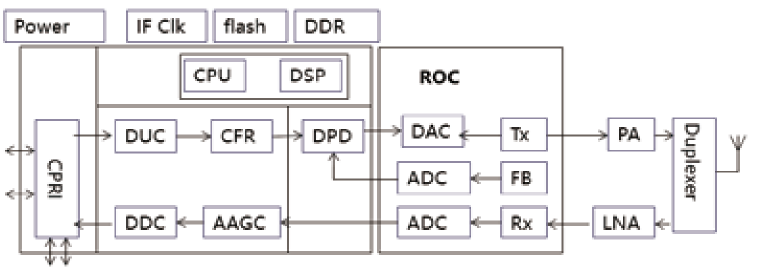

Figure 2 Mobile signal process flow

EVM (Error Vector Magnitude). it involves digital signal processing algorithms, AD (Analog-to-Digital) / DA (Digital- to-Analog) conversion, PA (Power Amplifier), and tiny-amplitude signal TX/RX links, all of which are the core technologies of base stations. The performance will ultimately affect the coverage, experience, performance, and resource allocation of mobile networks.

To develop superior performance FDD multi-band solutions, Huawei has redesigned radio units leveraging recent breakthroughs in key technologies, including DPD algorithms, ultra-wideband power amplifier (PA) architecture and materials, miniaturized multi-band filters, and passive cooling by bionic heat sink. As such, one set of analog circuits can adapt to two to three bands, significantly increasing the level of integration within base stations.

Benefits

With ultra-wideband radio frequency circuits, a single RRU module supports gigahertz of bandwidth in one PA module, making it possible to realize full power sharing Figure 3.

30% Power consumption saving, Compared with traditional RRU.

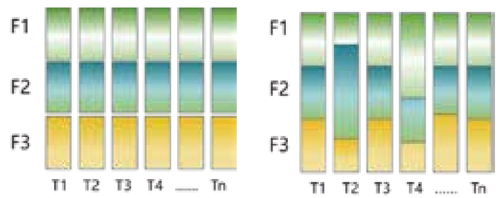

Figure 3 Ultra-wideband band power sharing

20% of power saving comes from our tidal effects power management algorithms, which make it possible to dynamically pool the power on one resource adjusting between coverage and capacity requirements based on demand and promoting green sustainable mobile networks.

4.2 Gigaband: Multi-antenna

Technology Overview

Multi-antenna MIMO (Multiple Input, Multiple Output) utilizes multiple antenna arrays and spatial diversity to Duplicate copy air interface resource. By increasing the number of channels, within the FDD legacy spectrum, network capacity is boosted and user experience improved

Multi-antenna enabled MIMO is a fundamental 5G technology. Mobile networks have evolved to the 5G era where multi-antenna is the main methodologies for increasing spectral efficiency. With Massive MIMO, narrow beams can be leveraged to boost resource multiplexing.

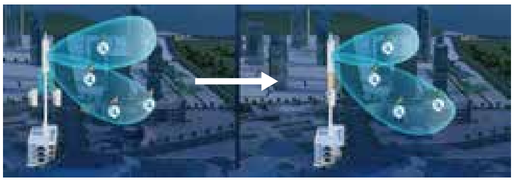

Figure 4 Crossing beam power sharing

Gigaband's multi-antenna capability is enabling multi-band spectrum convergence. With ultra-wide band technology significantly increasing the integration of radio frequency amplification circuits, these PA circuits are doubled in the same space, from 2T2R to 4T4R and even 8T8R, increasing radio channel resources. Increasing the antennas array also significantly reduces error in estimating the direction and phase of wireless transmissions. Moreover, algorithms are introduced to simplify multi-antenna beam forming, enabling precise multi-antenna adjustment down to physical channel RB level with higher beam-forming accuracy and efficiency.

Benefits

Multiplied capacity increase: Beam-forming is supported, with spectrum multiplexing over air interfaces used to improve spectral efficiency, that is to maximize system capacity by radio beam-forming transmission.

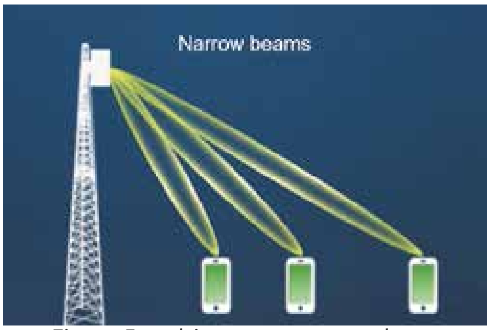

Figure 5 multi-antenna narrow beam

Improved user experience: Gigaband multi-antenna improves up link and down link coverage. With industry smartphones capability from 1T2R to 2T4R , multi-antenna receivers BTS, and signals sent from mobile devices via multi-path transmit diversity, BTS receive more signals from different directions and combine them to boost up link signal power via base station's multi-channel receivers, which will boost up link coverage by 3–6 dB Figure 6.

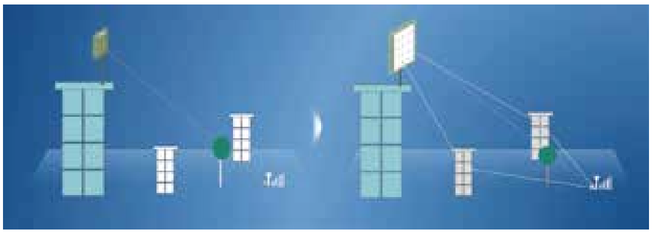

Figure 6 multi-antenna space division

Lower power consumption: Multi-antenna transmission allows for base stations to receive and combine more desired signals. This means that base stations and devices can set up and maintain their connections with minimal power use. Commercial tests have shown that, with a load level of 30%, 8T saves 30% of power consumption compared with 4T.

5 Huawei Gigaband Case study

Huawei Gigaband is mainly implemented in RRU modules. To migrate all bands to 5G in a green and simplified way, Gigaband products have been upgraded to triple-band 4T4R and dual-band 8T. They allow 4G and 5G to operate on the same hardware and platform and supports smooth evolution to 3GPP Release 18. Without depending on device capabilities, they can adapt to various high-gain features, such as TM4, TM9, and Type II codebook. With them, dynamic adjustment based on device penetration rates is supported to optimize radio resource utilization efficiency and ensure an optimal user experience is realized. To date, Gigaband products have been put into commercial use by more than 120 operators.

Huawei's FDD Gigaband ultra-wideband multi-antenna products, which won the GSMA GLOMO award "Best Mobile Network Infrastructure" in 2022, represent a new direction of FDD evolution into simplified, green, and efficient 5G.

5.1 Gigaband of Low-Band 4T4R: Boosts Both Wide Indoor Coverage and Capacity

Low bands provide a larger potential for deep indoor coverage, as they suffer less from propagation and penetration loss than mid-bands. This leads to more users camping on low bands exhausting public resources and leading to poor user experience.

A Thailand operator built new networks on 700 MHz while modernizing 900 MHz in 2021 with 4T4R. After 700 MHz + 900MHz 4T4R was deployed the coverage improved by 3.5dB, bringing about a 41% Figure 7. improvement in user experience. Compared with the GL900 module, a single module now supports both 700 MHz and 900 MHz, and is six times more efficient, carrying three times more traffic and improving low-band experience by two.

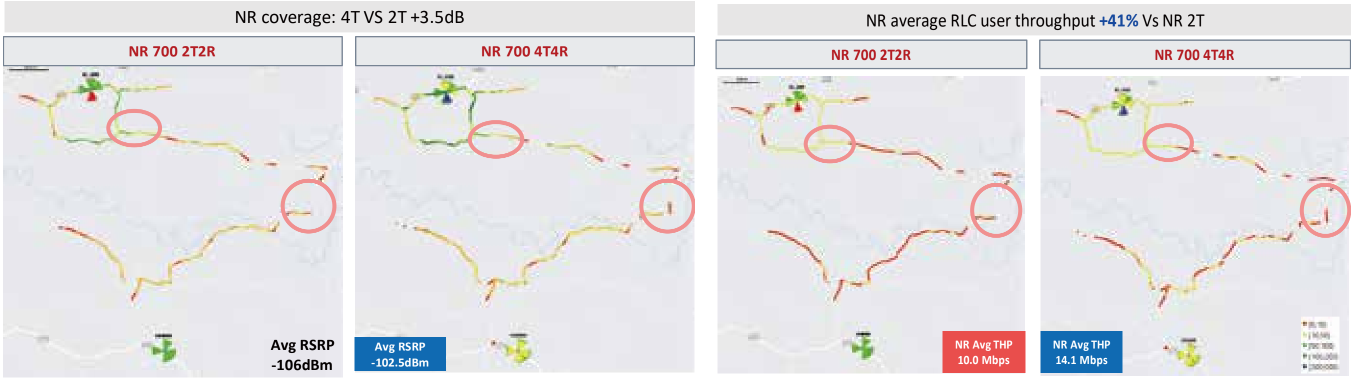

Figure 7 Low Band 2T2R VS 4T4R performance test

5.2 Gigaband of Mid-Band: Maximizes the Value of Golden Bands

Network advancement from 2G to 3G and 4G has proven that mid-bands are the most important spectrum for capacity and experience, and that they are also the bands receiving greatest investment. In Europe, operators have all prioritized mid-bands for new deployments and network modernization.

5.2.1 Tri-Band RRU: A New Band and Two Legacy Bands in One Box for Doubled Experience

After European countries licensed 1.4 GHz, operator A acquired this spectrum in 2021. At same time, its network was experiencing congestion every month in some hot spots. As such, operator A decided to migrate all mid-bands to 5G by dismantling legacy equipment and deploying Huawei's mid-tri-band RRU, with one box to replace the two band-specific modules. This led to a 20% power usage drop with only the legacy bands used and a 5% decline with all three bands being used. With capacity doubled, the energy-efficiency ratio increased by 1.5 times.

Figure 8 Tri-band RRU commercial test

5.2.2 Dual-Mid-Band 8T8R: Doubled Experience and Energy Efficiency

Dual-mid-band reconstruction is driven by capacity and deep indoor coverage in urban areas.

While 5G construction accelerates globally, 4G traffic still keep rising in most countries. Mid-bands already face congestion, causing user experience to deteriorate, while intensifying interference and shrinking coverage. Doubling channels to maximize spatial multiplexing gains with beam-forming is an effective way to boost capacity and user experience.

Based on Huawei's market insights, globally, the inter-site distance in mobile networks in major cities is 400–800-meter Figure 9, indicating that the cell edge rates at 1.8 GHz will not be enough to support Online conferences, classes, collaboration, and other services. It is also very difficult to acquire new sites. As such, multiple-antenna reception is an effective method to extend uplink coverage. With dual-band 8T8R and dual-band CA combined, the cell edge subscriber will reach 2.5 Mbps in LTE and 5 Mbps in 5G.

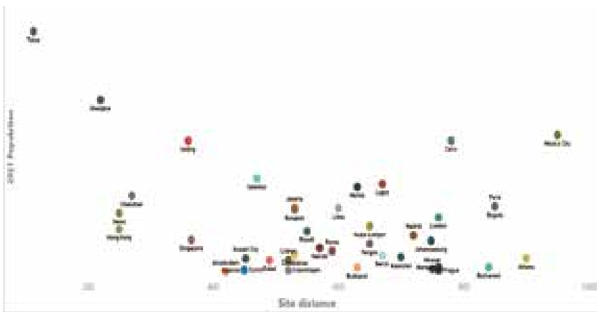

Figure 9 Top metropolis inter-site distance(ISD)

For Indonesian operator A, site spacing in dense urban areas is 600 m. Soaring 4G traffic has put it under growing pressure of network congestion. With no mid-band resources available to increase 4G capacity, it used Gigaband dual-band 8T8R to replace 4T6S deployment, and afterwards, capacity increased by 2.4 times and power consumption was cut by 26%.

Figure 10 8T8R performance Test

In China, 5G mid-band 8T8R has become a common method for improving coverage. After 2.1 GHz 4T4R was upgraded to 8T8R, an operator in Hubei saw its network coverage widen by 55%, with areas achieving uplink 3 Mbps increasing by 45%. After 2.1 GHz 8T8R 5G sites were deployed in a Shanghai residential area once plagued with weak coverage, the 5G grid coverage rate increased from 91% to 99%, extending 5G coverage to 20% more areas, accounting for a 30% boost in total 5G traffic in the area.

Compared with FDD 4T4R, FDD 8T8R uses multi-antenna arrays, advanced 8R IRC receivers, and high-precision channel estimation algorithms to widen the coverage by 20% to 40%. It also uses high-resolution spatial-domain pairing and unique high-precision convergence beam algorithms to boost cell capacity by 50% to 70%.

6 Future Evolution for Gigaband

As 3GPP specifications evolve to Release 17 and Release 18, all existing bands will move on to 5G. 1.5 GHz and 600 MHz band will also be licensed in many countries. New FDD flexible duplex will be expanded to more bands, including n13, n24, n85, n91, n92, n93 and n94.

FDD continuous high-bandwidth capabilities will be enhanced, with channels of up to 50 MHz supported on 2.1 GHz, 2.6 GHz, and n3 1.8 GHz. With Release 17 and Release 18, FDD multi-band concurrency and FDD+TDD multi-band aggregation will be supported, enabling multiple FDD discrete carriers to be combined to provide a similar experience to continuous wide-bandwidth carriers.

Ultra-wideband and multi-antenna solutions will remain a key focus of future 3GPP releases. Most operators will choose multi-band aggregation for network construction or use spectrum sharing or RAN sharing to implement single-band full-bandwidth construction. In either direction for network construction, Gigaband will continue to develop to support more bands and higher bandwidth in a more simplified and green way, while smoothly adapting to 3GPP Release 17 and Release 18.

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