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Content and connectivity: A magical combination

We're witnessing history's largest technological migration – the digital migration of humankind to a completely mobile Internet architecture. Mobile Internet has transformed life and work, realizing huge efficiency gains and presenting mobile operators with huge opportunities. But, questions remain.

How can operators develop new wireless data services and grow their mobile broadband business? How should mobile networks evolve? How can we protect existing investment?

Huawei has worked with mobile operators across the globe to formulate the following priorities:

Deliver ubiquitous connectivity to realize a cycle of value creation based on enhancing bandwidth and boosting connectivity and service capabilities. With HD video, virtual, reality, augmented reality, and driverless vehicles all on the rise, we need to provide innovative services that maximize user freedom.

Expand service boundaries by combining business models to cover various scenarios involving people and things. We can then build a fully connected world and extend operators' service boundaries into new blue oceans. We must redefine wireless business models so they provide platforms and network capabilities, not just connectivity. And we must re-engineer wireless business markets so they connect households and vertical industries, not just individuals.

Evolve wireless network architecture to face an undefined future with definite rules. After all, we may not be able to predict traffic growth or service demand. Mobile operators need to rebuild their networks' commercial capabilities by enhancing basic capabilities and evolving network technologies sequentially, including the co-existence of multiple generations: 3G, 4G, 4.5G, and 5G.

What have we done to achieve all this? We've innovated service-focused solutions such as video optimization. We've moved into wireless household connectivity, IoT, and radio trunking networks to expand services from B2C to B2B. And we've developed CloudRAN, a next-gen, evolvable, and flexible cloud network architecture.

We thus hope to provide users with the ultimate experience through content and pure freedom through full connectivity.

Deng Taihua, President of Huawei
Wireless Network Product Line

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PERSPECTIVES

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Yang Chaobin
Chief Marketing Officer, Huawei
Wireless Network Product Line

CloudRAN
Running with the clouds

Based on cloud architecture and SingleRAN, CloudRAN features a re-segmented wireless management framework, multiple connectivity capabilities, and elastic deployment architecture. The solution provides a powerful radio access network (RAN) development strategy to help operators achieve a better connected future.

The rise of mobile Internet has unleashed new types of services carried on public mobile networks that would have once been regarded as impossible. These include HD video, virtual reality (VR), augmented reality (AR), driverless vehicles, real-time industrial control, ubiquitous access to high-speed cloud content anytime, Internet of Things services, and public safety services – all are confirmed as key future wireless network applications. As network capabilities are opened and mobile edge computing (MEC) goes mainstream, the number of innovative mobile Internet business models will increase.

Over the next two to three years, mobile network operators' most pressing issues will be maximizing the value of mobile networks, constructing future-facing mobile access networks, and future service innovation. New wireless architecture will need to connect everything and adapt to an uncertain future.

Evolve to adapt

RAN architecture has evolved over two stages. In the era of traditional RANs – the first stage – operators built networks using different technologies based on independent designs, hardware components, and operating teams. They were expensive and flexibility was poor. Huawei's SingleRAN solution in 2007 marked the start of the second stage: SingleRAN enabled the integrated deployment of the following standards: GSM, WCDMA, CDMA2000, and LTE. This was completed on a single access platform that used the same hardware components, spectrum, transmission, network management, basebands, and master control. The SingleRAN solution significantly reduced RAN investment and maintenance costs, becoming the wireless industry's de facto standard architecture.

SingleRAN is one of Huawei Wireless' most impressive achievements in the past ten years. But, for the future, how will Huawei Wireless meet the challenges to come?

The next decade will see great changes in wireless communications. 4.5G, 5G and new forms of network construction and mobile applications will revolutionize mobile connectivity. But, evolution from 4G to 5G alone will not prompt transformation. Far from it.

Reconstructing basic interconnectivity capabilities as part of carriers' digital transformation will increase in prominence, because it will kick off a new stage of service interconnections and open reconstruction. In the future, new network architecture will be needed to meet a multitude of new requirements like network flexibility. These requirements will come from diverse services, new business models, and the need for faster connections and anytime, ubiquitous, and consistent experiences on complex multi-band, multi-standard heterogeneous networks.

With this uncertainty, Huawei Wireless has upped its game since SingleRAN with CloudRAN, its latest breakthrough in wireless communications networking.

Cloud tech on mobile architecture

Over the next two to three years, mobile network operators' most pressing issues will be maximizing the value of mobile networks, constructing future-facing mobile access networks, and future service innovation.

Six distinctive features of CloudRAN architecture

1 Cloud-based architecture

Adopting a cloud-based hardware and software system, CloudRAN includes a series of systematic cloudi capabilities like functions virtualization, resource cloudification, distributed architecture, layered capabilities , and flexible coordination.

2 Multi-standard connectivity

CloudRAN integrates all access technologies on to a single platform, including 4G, 4.5G, and future 5G technology, and various non-licensed spectrum access technologies such as Wi-Fi.

3 Elastic networks

CloudRAN's new network layering standard means the system is oriented to functions rather than network elements. This allows flexible, fast, and elastic functions deployment based on service development requirements.

CloudRAN is designed to help operators deal with the complexity of tomorrow's tech integration, service diversification, and business model fragmentation. Featuring redesigned wireless management architecture and capabilities like resource management, multi-tech connectivity, and elastic architecture, carriers can better cope with future uncertainties.

Cloud-based architecture

With cloud-based hardware and software systems, CloudRAN enables operators to build a service-driven and user-centric elastic network that supports 4G and 5G connectivity and embraces the diversity of future MBB and services for verticals.

Cloud architecture is the basis of future networking. Huawei's All Cloud strategy sets out a blueprint for full E2E network cloudification. Huawei's CloudRAN fully integrates cloud concepts into the RAN, the most difficult part to cloudify, putting the last piece of the puzzle in place for full cloudification – an unprecedented innovation in wireless infrastructure.

CloudRAN transforms the RAN and delivers cloud capabilities like functions virtualization, resource cloudification, architecture distribution, capabilities layerization, and flexible coordination. The solution enables hardware resource pooling to maximize resource sharing. With fully distributed software architecture resembling those of Internet companies, CloudRAN gives elastic capabilities such as flexible fault handling and resource scheduling, and fully automates service deployment, resource scheduling, and troubleshooting.

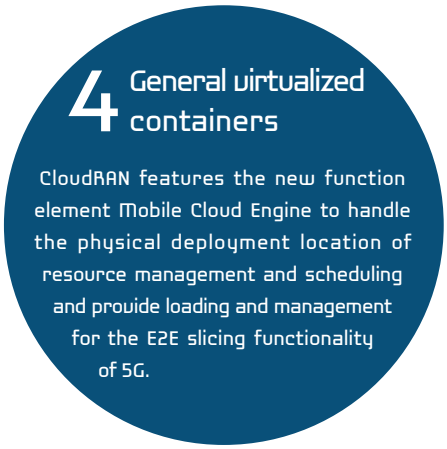
Multi-standard connectivity

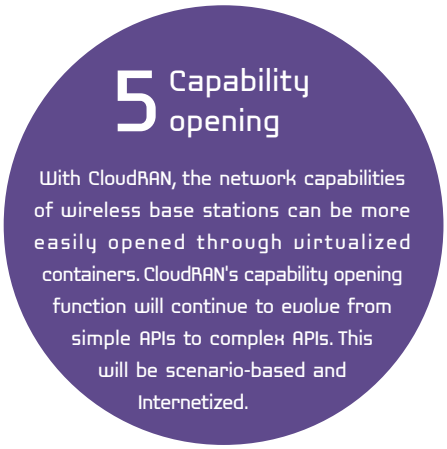
CloudRAN architecture adopts multi-connectivity technology to overcome the complexity of a multi-standard, multi-band, and multi-layer integration environment. It can also be applied to terminals for the optimum user experience.

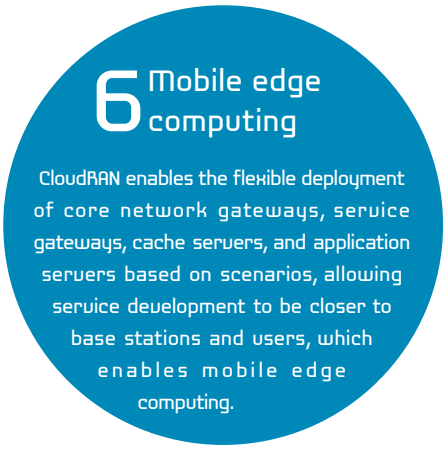
The industry agrees that 5G and LTE multiple connectivity are the future. Mainstream mobile terminals are capable of multi-standards access, but only in a single connectivity state. But, spurred by the industry, multiple-connectivity will happen. CloudRAN consolidates all access technologies on a single platform; the completed standards include TDD and FDD LTE dual connectivity and LTE Wi-Fi aggregation.

The new architecture will be able to connect to multiple types of access technologies, including traditional 4G, 4.5G, and future 5G technology, and various non-licensed spectrum access technologies such as Wi-Fi.

CloudRAN architecture overcomes anchor point selection with multiple-connectivity technology. The anchor point enables service distribution, carries out unified management, and







allocates high-level data, which is restored on the terminal via different air interface technology pipes. This enables operators to maximize the use of technology, spectrum, and hardware resources to increase overall resource efficiency.

Elastic networks

Like the early distributed base station design, CloudRAN balances distribution and centralization through a new, layered framework. All network functions can be configured and managed on-demand to deal with business model fragmentation and service growth in verticals.

CloudRAN's new network-layering standard means the system is function-oriented rather than based on network elements. Resource management adds more detailed functions to the traditional vertically managed wireless architecture systems. These capabilities can be configured on-demand and network functions atomization for optimal collaboration efficiency and fast and elastic function deployment to reflect service growth requirements.

Base station atomization considers the benefits as well as the technical costs. Dividing the horizontal layer of base stations into real-time and non-real-time sections will enable the system to better adapt to diverse network environments and implement multiple connectivity, multi-carrier, and multi-streaming technologies. In principle, real-time components are closer to base stations, enabling super-low latency and accelerating post-processing on complex data calculations at the front end.

Centralizing non-real-time components can support multi-dimensional wireless standard management and service distribution unification. With elastic architecture, real-time and non-real-time scheduling on different layers enables transition from network-

Like the early distributed base station design, CloudRAN balances distribution and centralization through a new, layered framework.

CloudRAN architecture can be used in different wireless network environments and scenarios to deal with different uncertainties.

centric to service-centric deployment.

General virtualized container design

CloudRAN will open management capabilities to better serve verticals. Huawei has included its Mobile Cloud Engine into the new architecture to configure where resource management and scheduling are physically located and to provide loading and management on E2E slicing for 5G by opening capabilities and resource management.

Mobile Cloud Engine is an optimized virtual machine for wireless capabilities that can run on dedicated platforms and general commercial-off-the-shelf (COTS) platforms with Cloud OS under a COTS cloud infrastructure. It offers carrier-class disaster recovery and on-demand deployment, flexible capacity expansion, independent feature upgrades, and other functions of native cloud architecture.

Opening capabilities: A hotbed of service innovation

Communications networks must be able to open network capabilities. Thus, operators need to get involved in the Internet industry chain, and by monetizing network capabilities, transform towards bilateral business models. If RANs are closer to users, network information is more accurate. Opening RAN capabilities can bring more business value for operators. CloudRAN architecture opens wireless base station network capabilities through virtualized containers, including anonymized user locations, network optimization parameters, QoS, billing, users' context network information, and service APIs. These valuable data sources and interfaces can be used by OTT companies and verticals to innovate services.

CloudRAN's capability opening function will keep evolving from simple to complex APIs and into scenario-based and Internetized capabilities, helping operators to further expand individual and household markets, traditional enterprises, vertical industries, and Internet markets. Operators can then expand and succeed in the digital economy.

Enabling mobile edge computing

CloudRAN allows core network gateways, service gateways, cache servers, and application servers to be flexibly deployed based on scenario, allowing service development to be closer to base stations and users. This will also enable MEC, functions like reducing transmission distance and latency, and optimization processing.

Each function component can share computing and storage resources, lowering service development costs and greatly increasing MEC innovation. Running services as close to end users as possible slashes latency, enabling rapid feedback on network status and lessening congestion on the rest of the network. Tighter integration with wireless components enables CloudRAN to acquire information on traffic, wireless, and terminal device location more easily, which in turn allows big data analysis and new business models.

Benefits for verticals

CloudRAN architecture can be used in different wireless network environments and scenarios to deal with different kinds of uncertainty

that will occur in future as wireless networks evolve. This will enable wireless networks to become the core infrastructure and key innovation driver of socioeconomic development.

Sharing network resources

Two issues are that different operators offer a wide variety of network transmission resources and fiber-to-the site rates differ from country to country. Achieving on-demand provisioning of network resources requires resource sharing, including baseband resources and computing and storage. CloudRAN architecture allows maximum adaptation to current network environments, enabling operator networks to flexibly provision baseband, storage, and computing resources and services with maximum efficiency. They can then provide different services and deliver the best experience for different users.

Higher spectral efficiency, higher income

CloudRAN architecture turn interferences into gains by centrally deploying non-real-time management units. This allows multi-dimensional collaboration between different standards, frequency bands, base stations, and layering technology through greater ranges of time, spectrum, space, and different processing functions. It also allows increased system capacity through multi-site and multi-user MIMO collaboration and significantly improves cell edge user rates, thus guaranteeing user experience. CloudRAN also supports the automatic selection of different collaboration levels according to deployment conditions to maximize the value of operator assets.

These functions greatly increase spectral usage efficiency.

Ultimate experiences with ultra-broadband

CloudRAN's multiple concurrent connections capability allows users to receive signals from multiple technologies and simultaneously connect to multiple base stations. In the future, when Wi-Fi operates on unlicensed bands and LTE on licensed bands, multi-connectivity technology will allow simultaneous connections to Wi-Fi and LTE, or enable users to simultaneously connect to LTE and 5G and macro and micro base stations. This multi-connectivity will improve user perception of speeds. CloudRAN will also support functions such as ultra-high bandwidth carrier aggregation, fast collaboration, and balanced scheduling. These functions will enable gigabit+ download speeds, meeting the requirements of applications like video and VR/AR.

Service diversification and service innovation capabilities

CloudRAN architecture allows the flexible deployment of MEC according to service type. For example, video services can be deployed closer to the end user to reduce the transmission resources needed by the system, shortening latency and ensuring an optimal user experience.

CloudRAN architecture also allows developers to fully leverage the value of network capabilities through opening network capabilities. Developing services that match user needs can increase commercial value and service innovation; for example, anonymized user location data can help retailers select sites and push advertising or yield IoT surveillance information on crops to predict crop yields.

CloudRAN architecture also enables the on-demand deployment of real-time/non-real-time resources based on particular service requirements and the distribution of base stations, server rooms, and fiber resources to guarantee service experience and minimize network deployment and OPEX.

Mobile IoT will increase the value brought by CloudRAN. According to industry visionary Kevin Kelly, "We're at the most important stage, the beginning. It's a process. Every new thing we create is in essence still at the beginning stage." With CloudRAN, operators will be ready for the arrival of the better connected mobile era.

Wang Yufeng
Director of MBB Solution Support Dept., Huawei

The ROADS to MBB 2020 with CloudRAN

Mobile operators must continue improving the value of their networks, evolve connectivity capabilities, and build a future-oriented mobile industry. To do so, they need to create new markets by opening platforms and network capabilities and target new segments and consumers, for example, households and verticals. CloudRAN is a key support technology for achieving this.

By Sun Kun, Ding Jiangbo, Yu Luo

The MBB 2020 vision

We're fast approaching a key stage of development for the mobile industry: MBB 2020. Rather than describing a type of network and particular point in time, MBB 2020 represents a commercial and solution-led vision of mobile network development over the next five to ten years.

Huawei proposed the ROADS concept for the MBB 2020 vision at the end of 2015, setting out a path of continual evolution for the commercial capabilities of mobile networks and the construction process for the network technologies that will support this. Huawei hopes to help operators improve the commercial value of their networks and evolve the connectivity capabilities of their networks to build a future-oriented mobile industry.

CloudRAN is a key support technology for achieving this vision. Huawei will use CloudRAN as the bridge linking 4G and 5G. How will this and MBB 2020 be achieved? We asked Wang Yufeng, Director of the MBB Solution Support Department, to share his views.

Exploring new markets is a must for mobile operators

COMMUNICATE: MBB 2020 is a commercial vision. What are the main differences between MBB 2020 and operators' aims?

Wang Yufeng: The next five years will see dramatic changes in basic connectivity capabilities, and mobile operators will need to expand the scope of their current services and introduce innovative business models to create new revenue streams. With the rapid development of wireless technology, wireless networks can now carry services that they previously couldn't. This forces us to redefine the business models and target markets of wireless networks. Business models now include Connectivity as a Service, Platform as a Service, and – to open network capabilities – Infrastructure as a Service. Wireless commercial markets have expanded from Business to Customer (connectivity services for individual users) to Business to Household (B2H) and Business to Business (B2B).

B2H: An interesting fact is the B2H market, for example, family plans with shared data and bundled fixed broadband and mobile services, has the lowest churn rate. User loyalty increases greatly once services extend from an individual user to a household. Mobile operators can offer home

Rather than describing a type of network and particular point in time, MBB 2020 represents a commercial and solution-led vision of mobile network development over the next five to ten years.

broadband access for the B2H market using their wireless networks to increase revenues. These services also provide a solid foundation for providing smart home and home automation services.

B2B: The Internet of Things (IoT) is expected to grow into a trillion-dollar market. Operators need to build more IoT networks and leverage Low Power Wide Area (LPWA) technology to increase the share of cellular IoT (CIoT) from its current figure of 6 percent to 50 percent. Operators' wireless networks can also provide services for previously closed but lucrative markets such as public safety. Current wireless networks can meet the needs of specialist applications for high levels of security and quality, and provide wide coverage, low cost, and fast service rollout. B2B services represent a new blue ocean market for operators. Diving into this market will help them increase revenue.

COMMUNICATE: Do mobile operators have unique advantages in these new markets?

Wang Yufeng: Mobile operators have huge unique advantages in the new business scenarios of home broadband and CIoT.

Home broadband market: Mobile operators can use wireless home broadband access as a way to quickly boost their market share. When it comes to coverage, traditional fixed-line networks are hindered by trenching and deployment difficulties as well as high costs. Mobile broadband (MBB) networks, however, can cover dozens of square kilometres from a single well-located base station, with peak speeds of 1 Gbps and high-speed services that average 30 Mbps. According to ITU, the average global cost of FBB is 1.7 times higher than MBB, which makes it easier to create a wireless home broadband network. MBB enables coverage to be rapidly extended to rural and urban areas where FBB coverage is limited and shortens ROI from six years

to two.

CIoT market: Operators have natural advantages in system security, wide area coverage, QoS guarantees, and ecosystem maturity. A good IoT network should meet the following four requirements: 1) Network security; 2) Seamless network coverage; 3) Support for a mature ecosystem; and 4) Affordable terminals. CIoT technology meets these four requirements.

Wireless network technology has innate advantages in security and wide coverage, and it's easy to accelerate ecosystem maturity and make devices affordable. LPWA is expected to account for 70 percent of the CIoT market by 2020, with up to 2 billion connected devices. LPWA will be vital for enabling operators to increase the number of CIoT devices.

Reshaping commercial capabilities

COMMUNICATE: In the future, mobile operators will meet many new commercial opportunities. Will their networks provide sufficient support?

Wang Yufeng: To access these strategic opportunities, mobile operators need to rebuild the commercial capabilities across their entire networks. This will be divided into two steps. First, they need basic capabilities to generate new value and cope with the coming network traffic explosion by eliminating capacity bottlenecks, utilizing spectrum, well-planned base station solutions, innovating, and indoor digitalization – factors unrelated to technology. Second, operators will need to deal with the problem of the generational evolution of network technologies, including strategic positioning and the coexistence of multiple generations of technologies like 3G, 4G, 4.5G, and 5G.

Increasing air interface capacity

The three types of infrastructure involved in increasing air interface capacity are base stations, spectrum, and indoor digitalization. The formula for air interface capacity is as follows: Network capacity = no. of sites × spatial gain (no. of cells and MIMO etc.) × amount of spectrum. The following methods can thus be used to increase network capacity:

Building more base stations: Crowd sourcing when acquiring new types of sites, such as street light sites and wall sites, to accelerate the deployment of micro base sites and enable precision investment.

LPWA is expected to account for 70 percent of the CIoT market by 2020, with up to 2 billion connected devices. LPWA will be vital for enabling operators to increase the number of CIoT devices.

5G is the future of wireless networking and a mid- to long-term evolution target.

Innovating solutions: New splitting solutions that create parallel data streams over the air interface, enhancing investment efficiency.

Obtaining more spectrum: By 2020, MBB networks will require 1340 to 1960 MHz of total spectrum. This means that most countries will need to add 600 to 800 MHz of spectrum. If this is insufficient, unlicensed spectrum for on-demand use will be required.

The evolution and coexistence of multiple generations of technology: Looking to the future and the advancement of IoT technology, all verticals will become digitalized, intelligent, and more efficient. However, different verticals require different things from mobile networks. For operators, the best approach is to fully use their existing network resources.

Operators must continue to evolve networks from 4G to 4.5G: The 4.5G evolution of networks – that is, incorporating 5G technology into 4G networks – will help operators increase the value of their 4G networks and maximize the value of network resources.

5G is the future of wireless networking and is a mid- to long-term evolution target: 5G will bring higher speeds (> 10 Gbps), shorter latency (< 1ms), and enable many verticals by acting as a cross-industry point of integration.

The use of GSM/UMTS may persist over the long term because of commercial considerations: Whether or not a technology remains in use depends on its commercial viability. GSM, which is a long-term basic voice and universal access network, will continue to be used as a thin network for supporting roaming and low-end users. UMTS will become a basic data access network, and due to its maturity and low-cost industry chain support, will continue to deliver commercial returns over the long term.

CloudRAN is the bridge

COMMUNICATE: Can you give more detail about the solution and how it will work?

Wang Yufeng: Huawei's answer to the complex business objectives of the future is CloudRAN, a solution that considers the unique traits of wireless networking. CloudRAN enables completely different network capabilities than the simple base station as access capability center model of the past.

CloudRAN incorporates cloud technology into wireless access networks and supports access for different air interface technologies. By modernizing 4G network architecture in advance using CloudRAN, operators won't need to modify network architecture when 5G is introduced. Deploying CloudRAN architecture will enable operators to improve 4G performance. And because the architecture is 5G-based, operators only have to carry out simple air interface upgrades to support 5G when it's rolled out.

CloudRAN can improve the experience for end users. Current mobile phones can only receive one type of signal and connect to a single base station. In the future, they'll be able to receive multiple signals and connect to multiple base stations, which will increase mobile speeds by many times.

In the future, mobile networks will carry people-to-things communication as well as people-to-people communication. CloudRAN supports the flexible deployment of different services, meeting the QoS requirements of different types of service.

COMMUNICATE: What challenges will operators face when deploying CloudRAN? What does the commercial progress and timeline look like?

Wang Yufeng: CloudRAN architecture is flexible and it can meet different usage scenarios. It's no secret that operators' transmission networks have widely varying conditions and quality. Deploying CloudRAN on different transmission networks with differing conditions is a huge challenge. Huawei's CloudRAN is a complete solution, with a hierarchical design for network function elements. Real-time and non-real-time layers that can be deployed on different network nodes on an on-demand basis according to service requirements, and flexible architecture that adapts to different transmission network conditions, to maximize network efficiency and user experience.

CloudRAN deployment will be divided into two stages. In the current stage of 4G and 4.5G construction, deploying CloudRAN will allow operators to better support technologies such as LTE Dual Connectivity, LWA, and LAA. In the next stage, when 5G is introduced, CloudRAN network architecture will be ready to support new 5G air interfaces and standards without needing any changes.

Huawei has been talking with top-tier operators around the world for the past two years, and will begin testing CloudRAN with a number of them this year. In addition, initial commercial adoption is expected to commence at the end of 2017.

COMMUNICATE: Will standards need to be developed for CloudRAN? When will the standardization process be completed?

Wang Yufeng: Mobile communication systems are made up of two main things: interoperable interface technologies and implementation systems. Interoperable interfaces include GSM, UMTS, and LTE, which are defined by standards. These ensure seamless connection between terminals and networks, enabling end users to roam seamlessly anywhere in the world. SingleRAN (which was defined by Huawei) is a type of implementation system that operators can use to implement standardized technologies such as GSM, UMTS, or LTE. Operators favor SingleRAN over other methods because it guarantees the lowest TCO. Likewise, CloudRAN is a type of implementation architecture that can implement LTE and 5G. We believe that CloudRAN architecture is the best choice for operators to deliver better end-user experiences, minimize TCO for whole network deployment and O&M, and better tap into future new business opportunities other than people-to-people communication.

The future of MBB is impossible to predict. Looking back at history, transformation in infrastructure has driven huge socioeconomic and cultural advances. The ongoing and future evolution of communications technology will transform the basic capability infrastructure of society and usher in a Better Connected World.

On the path to 5G with 4.5G

In 2020, operators must support the coexistence of 4.5G and 5G new air interfaces if they want to deliver a superior mobile broadband experience. Evolving 4.5G in parallel to 5G new air interfaces will help operators develop new services, user behaviors, business models, and industry chains before 5G arrives, paving the way for next-gen 5G tech.

By Zhou Dongfei

Huawei announced the 4.5G concept in October 2014, with the 3GPP standards organization later officially dubbing it LTE-Advanced Pro. A year or so on, there's been major progress in 4.5G technology and deployment. Meanwhile, the ITU set out the marker, vision, and timeline for 5G in June 2015.

3GPP has started on the path to 5G standardization. With 5G widely predicted to be commercially deployed in 2020, why should operators invest in 4.5G now? What is the relationship between 4.5G and 5G?

The rise of mobile broadband

4G cannot meet new service and business demands

Huawei's mLAB forecasts that MBB users will double to 6.7 billion between 2015 and 2020, while average monthly data consumption per user will balloon tenfold to 5 GB. In the next two to three years, new services with higher demands on MBB network speed, capacity, and latency will start to emerge, including 2K and 4K video, virtual reality (VR), augmented reality (AR), and remote drones.

According to GSMA, the number of CIoT connections will surge to 1 billion by 2020, up from 243 million in 2014. As the report doesn't take into account the possibility of new services that could generate explosive data growth, the actual number of connections may be much greater than predicted.

The demands of the latest MBB services in terms of peak speeds, capacity, massive connections, and low latency already exceed the capabilities of today's 4G. Targeting new businesses individuals, homes, companies, and different verticals with MBB services requires 4G needs to be multi-purpose – something 4G networks were not designed to be.

Ultra-high capacity, massive

connections, and ultra-low latency

Next-gen mobile 4.5G and 5G technology will be defined using three measurement criteria: peak speed (plus capacity), number of connections, and latency.

Peak speed: 4G is defined as 150 Mbps, 4.5G as 1 Gbps and above, and 5G as 10 to 20 Gbps.

Connection numbers: A 4G network cell can carry several thousand, 4.5G uses CIoT to carry 100,000, and 5G will be required to carry 1 million connections per square kilometer.

E2E latency: Commercial 4G networks average 50 ms, 4.5G is required to deliver 10 ms, and 5G aims for 1 ms.

Protecting investment

When 4.5G was proposed, the aim was to achieve technical targets through 4G network evolution to protect operators' investments and maximize the value of network resources.

Key 4.5G technologies include Massive CA (carrier aggregation), High Order MIMO, and 256QAM high order modulation, which can increase peak speeds and capacity, and Narrow-Band IoT (NB-IoT) for massive connections. Each of these technologies can be built on current technology.

Massive CA reuses existing carrier baseband boards, requiring only additional RF modules or baseband resources for new carriers. 256QAM high-order modulation can reuse the vast majority of existing RF modules. NB-IoT can also reuse the vast majority of legacy RF modules. 4.5G therefore only requires software upgrades and a small amount of new hardware to implement.

3GPP officially renames 4.5G

After Huawei proposed 4.5G, it approached the 3GPP to standardize the name. Following a process of discussion involving operators, equipment vendors, and chip makers, 3GPP confirmed LTE-Advanced Pro as the name for the LTE next-gen evolution solution on October 22, 2015. The approval of the marker and specifications indicated an industry consensus on 4.5G.

Major vendors have since released white papers describing the evolutionary path to next-gen LTE, and have started to incorporate 4.5G into their product plans. Qualcomm, for example, launched a 1 Gbps modem chipset at the Mobile World Congress (MWC) 2016, and demonstrated a 1 Gbps smart device prototype with Huawei.

4.5G goes global

4.5G network benchmarks: Gbps, Experience 4.0, and Connection+

Huawei has worked closely with the world's leading operators to discover their network pain points and service development trends for the coming two to three years and has developed three network construction benchmarks for 4.5G: Gbps, Experience 4.0, and Connection+.

Gbps: increases peak rates from 4G's 100 Mbps to 1 Gbps. Gbps is synonymous with

MBB pipeline capability and boosting peak rates, capacity, and cell edge rates.

Experience 4.0: requires MOS (voice service quality) and vMOS (video service quality) scores of 4.0 for high-definition voice and video.

Connection+: currently supports technologies such as NB-IoT, LiTRA (LTE integrated Trunked Radio) broadband trunking for public safety, and WTTx (wireless to the x) to power vertical markets.

The year of 4.5G: 2016 to see 60 networks rolled out globally

As of May 2016, 20 4.5G commercial and test networks had been deployed around the world, with 60 more expected before the end of the year.

1 Gbps-plus transmission rates on commercial networks have been demonstrated in Norway, Turkey, Germany, Kuwait, Saudi Arabia, UAE, China, Japan, Canada, Singapore, Thailand, and the Philippines. The UK and Korea have begun constructing national LiTRA-based public-safety networks, and pre-commercial deployment of NB-IoT is underway in Spain, South Korea, China, UAE, and Germany.

4.5G and 5G set for long-term coexistence

4.5G is the path to 5G

4.5G is an essential step to 5G. Although the ITU outlined the marker, vision, and timeline for 5G in June 2015, the telecom industry has yet to set out a process for moving from 4G to 5G. Why?

Widespread commercial deployment of 5G still a long way off: According to the ITU's timetable for 5G, technical performance requirements and evaluation methods will be defined over 2016 and 2017, technical proposals will be accepted and evaluation carried out between 2018 and 2019, and final specifications will be set in 2020, which means widespread 5G deployment will likely start after 2020.

5G is likely to adopt higher frequency spectrum: The advantage of using higher frequency spectrum is greater bandwidth. But, the cost of deep and wide-area network coverage is too high, so legacy low-frequency networks must coexist with 5G for the long-term to make up for a lack of coverage.

New 5G services can be cultivated on 4G networks: An example of this is NB-IoT's first commercial deployment in 2016. NB-IoT supports connectivity for 100,000 plus devices per cell. In addition, there is LTE-V Internet of Vehicles, which is the next major 4.5G target market. 3GPP will begin more standardization work on this in 2016 and 2017 to speed up development.

As of May 2016, 20 4.5G commercial and test networks had been deployed around the world, with 60 more expected before the end of the year.

4G needs to lay the groundwork for 5G's arrival: Adjusting wireless network architecture using CloudRAN will make it easier for operators to introduce new 5G air interfaces onto existing networks so as to avoid the need to carry out large-scale E2E network reconstruction.

4.5G evolving in parallel with 5G

From 2016, the 3GPP will start 5G standardization in step with

CloudRAN enables operators to carry out 5G-oriented network architecture cloud transformation on 4G and 4.5G networks.

ongoing LTE evolution. This will permit introduction of 5G technology on 4.5G networks. This 4G-ization of 5G, or introducing 5G technology on 4G networks, in fact began before the standardization process.

Massive MIMO: A key 5G technology. Commercial deployment of LTE TDD supporting 128T128R (128 transceiver channels) is already underway in China. FDD Massive MIMO that can support 16, 32, and 64 antennas is being continually refined in 3GPP's R13 and R14.

Shorter TTI (transmission time interval): A crucial technology for achieving the 1 ms latency target of 5G, and one that 3GPP has begun standardizing. 4.5G is expected to support OFDM (Orthogonal frequency-division multiplexing) symbol-level latency, which approaches 5G air interface latency requirements.

Network slicing: Another key 5G technology that has been introduced in 4.5G networks. Network slicing allows NB-IoT, LiTRA, and WTTx to be implemented on a single network. The next step will introduce CloudRAN architecture for more flexible and efficient RAN slicing, enabling multiple services on a single network.

Huawei spearheads 4.5G

At MWC 2016, Huawei announced GigaRadio based on 4.5G network construction standards. The solution supports gigabit peak speeds for individual users, gigabit throughput on a single module, single site x-gigabit capability, and a seamless indoor gigabit experience. GigaRadio is over a year ahead of the industry in terms of capabilities, and will help drive technological innovation, user experience, and commercial success for operators.

During the Huawei Global Analyst Summit 2016, Huawei announced the CloudRAN solution. Using a cloud-based hardware and software system, CloudRAN supports functions virtualization, resource cloudification, and systematic cloud capabilities that can be flexibly coordinated. CloudRAN enables fully flexible new network architecture from topology to resource distribution. The solution's multi-connectivity supports 4G, 4.5G, 5G, and Wi-Fi for multiple technology and multi-cell coordination, on-demand deployment of real-time and non-real-time functions, and network slicing.

CloudRAN enables operators to carry out 5G-oriented network architecture cloud transformation on 4G and 4.5G networks, which will allow them to directly deploy 5G air interfaces via CloudRAN architecture when the 5G era rolls around.

By 2020, it will be essential for operators to support 4.5G and 5G new air interface collaboration and coexistence if they want to deliver a superior MBB experience.

Sprinting the last mile with WTTx

WTTx is a new approach for solving the old last mile problem. Using WTTx avoids trenching and wiring, yielding quicker time to market, faster user growth rate, and shorter payback period.

By Wu Shengfei

According to the *State of Broadband 2015* report issued by the ITU and UNESCO, broadband connectivity is an important economic growth enabler that ordinary people should be able to afford.

ITU data shows that 4.2 billion people lack Internet access. For the 3 billion connected, basic broadband services no longer meet requirements, hence the slew of national broadband plans being implemented across the planet.

Whether the objective is connecting the unconnected or boosting speed, the last mile problem for broadband networks persists. With the rapid development of wireless tech and fiber optic taking over from copper, a new approach is necessary.

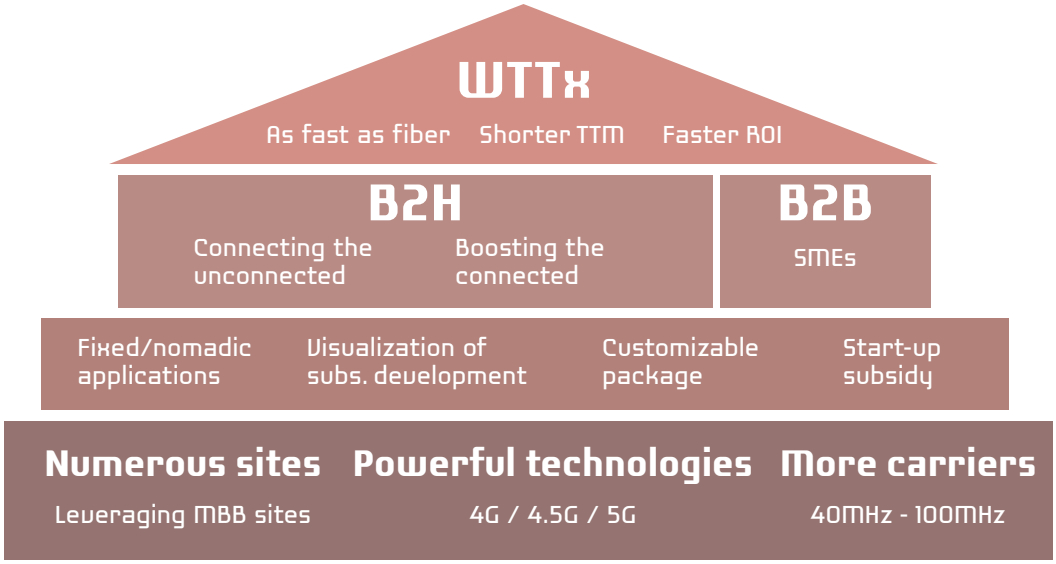
WTTx covers the gap

Ovum states that the number of global 4G users crossed the 1 billion mark in 2015, with strong double-digit growth to reach this number in just six years. But, will this trend continue over the next five?

If 4G is used to provide the last mile of broadband, a landmark turning point will have been reached. If 4G, 4.5G, and 5G apply to fixed broadband scenarios as WTTx, can they provide a wireless access solution to rival the FTTx experience?

WTTx: As fast as fiber

Benefiting from 4G and 4.5G, peak rates from WTTx keep jumping. New tech like 4x4 MIMO, 256QAM, FDD+TDD CA, Massive CA, and Massive MIMO require only 40 to 60 MHz of spectrum to enable gigabit cell peak rates, so better home broadband can arise from WTTx based on 4.5G.



WTTx Value House

The jump in single user peak rates – from 150 Mbps (UE CAT 4) to 600 Mbps (UE CAT 12) and then to 1 Gbps (UE CAT 16) – means WTTx surpasses copper and matches fiber optic in terms of experience. More importantly, improving cell capacity can solve direct restraints on capacity growth; for example, supporting up to 100 MHz spectrum can increase cell capacity. Using Massive MIMO to achieve spatial multiplexing for large numbers of users increases cell capacity fivefold, so operators can carry more WTTx users and boost single user rates.

WTTx: Same services

TV has moved on from a device that receives broadcasts to one that provides video on demand. How can Internet video be delivered to millions of households cost-effectively? WTTx, which can bear IPTV, can deliver TV shows, Internet video, and web browsing. Its multifunctional design is also affordable for most households.

Other than video, VoIP over WTTx is a mature service that can provide triple-play – data, video, and voice – over WTTx as easily as fixed-line broadband can.

Sharing resources

WTTx quickly provides high-quality services with fast ROI, while FTTx is known for its stability and reliability. Thus, the two are complementary. In areas that need broadband, a WTTx solution can explore the potential of the business-to-household (B2H) and B2B markets. Once a certain user base has been developed, fiber optic can be rolled out according to demand, enabling targeted FTTx construction.

WTTx and MBB are both based on 4G/4.5G technology. WTTx serves households, while MBB serves individuals. Both can, to a certain extent, share network resources. When fiber optic is extended to areas that have WTTx coverage, WTTx network resources can be released to meet the surging demand in MBB traffic.

Two types of resources can be shared between WTTx and MBB: site resources and carrier resources. When MBB loads are light, individual MBB users and household WTTx users can share the same carrier without obvious conflict in resource demand. When loads are heavy, WTTx and MBB typically use different frequency bands or carriers to avoid demand conflicts. For example, WTTx uses 2.3 GHz, 2.6 GHz, and 3.5 GHz, which offer large bandwidth and are efficient and inexpensive. MBB uses frequency bands such as 1.8 GHz and 800 MHz, which often carry massive amounts of mobile users but have comparatively limited resources. Guaranteeing mobile user experience is necessary so that main income streams are not affected.

WTTx creates a new B2H blue ocean market

Mobile operators' focus on B2C, with SIM cards sitting at the core of their service models from 2G to today's 4G. Over the past 20 or so years, operators have introduced some B2B services, the majority of which are bundled sales of simple service combinations on a B2C basis. B2H is a good direction for operators seeking to move beyond B2C.

Little competition exists in the fixed-line broadband market for households, the APRU of which is between six and eight times higher than mobile APRU. It's thus a blue ocean of income for mobile operators, with WTTx as the best vessel for sailing into the future.

WTTx for the home

Typically low-churn, B2H services include family plans with shared data and bundled fixed-broadband and mobile services. Mobile operators can provide these types of services on wireless networks, paving the way for smart homes.

Household broadband penetration with fixed-broadband is typically less than 20 percent in many developing countries, and much lower in populous countries like Indonesia, where it's only 6.7 percent. Fixed line broadband is often unfeasible: in many countries, copper infrastructure is terrible, and building FTTx is costly and hindered by private property rights and other restrictions.

In more developed countries where market leaders own copper and fiber resources, competitors cannot provide household broadband or profit from doing so due to high rental costs. The big players can also offer bundled packages with mobile, fixed-line broadband, and IPTV. Providing home broadband services via WTTx, therefore, can act as a powerful tool for smaller operators to take on the top-tier operators in developed countries and expand broadband coverage in developing countries

Searching for spectrum

Spectrum is the key to wireless networks. A 3G carrier uses 5 MHz, a 4G carrier 20 MHz, while a 5G carrier will use 100 MHz. Technology has boosted spectrum efficiency, but the market is calling for greater bandwidth. Because it's for household and enterprise users, WTTx has a much larger demand for bandwidth than MBB, and so operators are looking in earnest for more spectrums to provide a better WTTx experience. For example, Saudi Arabia's largest operator STC has 50 MHz of spectrum in the 2.3 GHz band and 70 MHz of spectrum in the 3.5 GHz band. Sri Lanka's leading mobile operator, Dialog, has 75 MHz of spectrum in the 2.3 GHz band. In early 2016, Norway's number one and two – Telenor and TeliaSonera – acquired 90 MHz and 100 MHz of spectrum in the 3.7 GHz band, which they plan to use to expand B2H and B2B services.

WTTx: The way to success

WTTx offers a low barrier for entry, fast service provisioning, and rapid profits. Assuming a certain amount of spectrum and site resources are available, our deployment recommendations are as follows:

Get scenario based

Through combining wired and wireless, universal broadband is becoming more feasible, opening up a new blue ocean market for operators and, ultimately, connecting the unconnected.

In some developing countries, governments stipulate that newly released BWA spectrum can only provide fixed broadband services, meaning that CPE can be locked to a certain cell to prevent roaming and thus meet regulatory requirements.

In developed countries, governments generally have policies of spectrum neutrality. In addition to providing fixed broadband applications, operators also support nomadic applications, which suits out-of-town trips – a common behavior in many countries.

Visualize for precise service rollout

WTTx is a wireless network, so it's difficult to accurately predict which areas can grow users at what rate, which in turn impacts service rollout efficiency. Our mature coverage and capacity planning methods and experience can visualize user development, greatly increasing the success of WTTx.

Don't forget enterprises

Enterprise customers tend to generate high profits, often requiring VPN support alongside broadband to set up their own private networks over public networks.

Early subscriber subsidies

Like MBB, WTTx requires a certain scale of subscriber base to succeed, and early stage subsidies provide some necessary fuel.

WTTx drives universal broadband

WTTx has already been widely adopted around the world, and not just in large emerging markets. The simple implementation and economic viability of WTTx has greatly expanded the potential market size for operators and increased broadband penetration, bringing enormous socioeconomic benefits.

In China, for example, the Chinese government launched a National Broadband Strategy in 2013, and in 2014 the Ministry of Industry and Information Technology released a policy promoting rural broadband penetration. This generated a positive response in the nation's central and western provinces, with Jilin Mobile growing broadband penetration by 300,000 rural households in the span of just a year.

In Saudi Arabia, where broadband development has been relatively slow, just 2 million households out of 5 million have fixed broadband access. To increase broadband penetration, the government released a wireless broadband plan in 2012. The two leading operators, STC and Mobily, constructed WTTx on 2.3 GHz and 2.6 GHz bands and, in three years, added 3 million subscribers. Alongside wired networks, universal broadband access had almost been achieved.

With the advent of the digital era, universal broadband is viewed as a basic human right in many countries. ITU figures show that 148 nations already have national broadband plans in place to promote universal broadband penetration.

The success of WTTx around the world shows how this new approach is an effective way to solve the last mile problem. Through combining wired and wireless, universal broadband is becoming more feasible, opening up a new blue ocean market for operators and, ultimately, connecting the unconnected.

NB-IoT: A shot in the arm for cellular IoT

Offering deep coverage, low power consumption, low cost, and large numbers of devices, Narrowband Internet of Things (NB-IoT) meets the requirements for LPWA (Low Power Wide Area) applications. It can provide operators with a technological edge for a competitive shot in the arm in the cellular IoT (CIoT) market and for transformation.

By Yu Hui

As IoT devices become more commonplace, the penetration of short-range communications technologies, such as Wi-Fi, ZigBee, Bluetooth, and Z-wave, continues to rise in the CIoT market. Products released by innovators like Sigfox and LoRa have kicked off the global deployment of IoT networks, which have quickly become established in a number of markets. With IoT becoming a new driver of growth, how can traditional operators respond to the challenges of competition and opportunities offered by this blue ocean market?

NB-IoT: CIoT's cutting edge

High-speed CIoT applications include video surveillance and vehicle-mounted multimedia. They require high speed, high capacity, and relatively high levels of power. With ubiquitous coverage, high-speed connectivity, security and reliability, today's 4G networks are more than capable of supporting such applications and are thus the best choice.

Low speed or LPWA applications include smart meters, smart parking, and asset tracking. These applications require broader networks of sensors and information collection, but require ultra-low pricing alongside very high network performance.

Low-power NB-IoT saves gas company "T" millions

Over a two year replacement program, gas Company T in country J planned to replace its legacy gas meters, which had already been in use for two decades. Requiring a specific type of 2400 mAh battery, the lowest price for new smart meters was a few US dollars, which was too expensive. So, Company T sought to reduce the number of batteries per meter.

Due to the high-power cellular technology, each meter needed a minimum of three batteries for a 10-year lifecycle. However, a low-power CIoT network would only require two batteries per meter, thus saving millions of dollars. Delivering a low-power network would also give the telco supplying it a competitive edge against other low-cost technologies on the market, something that would be difficult to achieve with current 2G, 3G or 4G networks.

Enter Narrowband IoT (NB-IoT) and its excellent low-power functions: Power Saving Mode (PSM) and Extended Discontinuous Reception (eDRX). PSM is a new type of deep sleep state for IoT terminals. Terminals in PSM have a current

As the NB-IoT solution is based on narrowband technology, NB-IoT's Power Spectral Density (PSD) is 10+ dB higher than 2G, 3G or 4G at equivalent transmit power.

intensity of only 0.005 mA, compared to 1 mA in traditional idle mode. Some IoT applications, such as water meters, which only need to report data once a day can enter PSM state between reporting intervals and consume ultra-lower power.

eDRX mode meets the requirement of applications that need to support downstream control messaging and uphold certain latency requirements – gas meters, for example, must provide remote shut-off with two minute-latency. In DRX mode, terminals cycle through idle and paging reception states, allowing for a fast response but at the cost of high power use. eDRX mode enables terminals to enter PSM state after several cycles. A timer triggers re-entry into paging reception state to balance response latency and power consumption.

With these technologies and the low power consumption enabled by NB-IoT chipsets, gas Company T was able to power a smart meter for a 10-year lifecycle with just two batteries, giving the telco a powerful competitive edge.

NB-IoT deep dives for Company S

Due to high labor costs, water Company S in country A wanted to introduce smart meters to slash OPEX from manual meter reading. In Country A, meters were deployed in two main types of scenarios – houses and apartments. Company S was therefore looking for a technology that could support deep coverage because, in apartment blocks, water meters could be deployed up to two stories underground in basements or pipe shafts.

The telco needed a CIoT technology that supports deep coverage to prevent rivals from providing company S with IoT services: NB-IoT provides excellent deep coverage. As the NB-IoT solution is based on narrowband technology, NB-IoT's Power Spectral Density (PSD) is 10+ dB higher than 2G, 3G, or 4G at equivalent transmission powers. NB-IoT also features LTE 4R, UL CoMP technologies, and supports higher repetition, giving it 20 dB more coverage than 2G, 3G or 4G. NB-IoT provides better deep coverage than other competing technologies, and doesn't have the complexity of a short-range two-hop network.

Implementing the NB-IoT solution only required an upgrade to the operator's legacy network, and so deployment was fast. This met the requirements of Company S for rapid commercial application and provided a powerful competitive advantage for the operator.

Competition in the LPWA IoT market continues to intensify, requiring operators CIoT networks to be technologically leading-edge to meet the demanding technical requirements of different applications. Offering deep coverage, low-power consumption, low cost, and large numbers of devices, NB-IoT meets requirements for LPWA applications and can give operators a competitive shot in the arm in the CIoT market.

NB-IoT: Helping operators transform CIoT

With NB-IoT entering more verticals, operators will need to transform and change their CIoT operating models. For one thing, service diversification means that IoT operations have become more complex. As the number of NB-IoT application types increases, operators have seen a significant cost hike as a result of aligning IoT network protocols between verticals and the differences between their service systems.

To sail on IoT's untapped blue ocean market, mobile operators will need to transform beyond pipeline services and tap into higher-value terminals and cloud operations. The NB-IoT E2E solution provides an IoT platform that increases operators' operating capabilities. The platform provides a unified IoT operations architecture that adapts to network protocols in different IoT service systems, and integrates the functions of infrastructure layers, including SIM management, device management, asset management, and security authorization.

Integrating the operations of different verticals into a unified platform reduces customization and maintenance costs for customers, with the core service modules of different verticals still independently deployed for service differentiation. Operators can then move from being a pipeline to being a support service provider.

The IoT platform's virtualization and openness enhances operators' IoT capabilities, enabling service providers to build support capabilities targeted at verticals, including service metrics, process definitions, and other public sub-services. Vertical industries can also leverage the platform's cloud-based services and open interfaces to dynamically call for or share data resources, enabling cross-industry service integration and operations and creating new business value.

Operators can also quickly and easily develop and bring online thousands of services that multiple operators can swiftly replicate and which verticals can swiftly deliver without needing to invest in network or application infrastructure.

Facing competition from LoRa and short-range technology solution providers, which use internetized operating models, traditional mobile operators need to improve their operations support systems and models. The NB-IoT E2E solution and its IoT platform can help operators transform their CIoT to help operators overcome these challenges and tap into the available opportunities.

Working together on NB-IoT

The commercial deployment of NB-IoT will be a step-by-step process for operators. They'll need to think about upgrading their cellular networks to provide ubiquitous NB-IoT services, and move deeper into vertical industry applications, integrate and improve existing services, and discover new potential CIoT applications.

As a leading ICT solutions provider, Huawei is the industry's most complete and advanced provider of NB-IoT solutions. When it comes to CIoT construction, tapping into vertical industry markets, and IoT operations, Huawei is the best partner for operators. With its understanding of operator CIoT strategy, strong E2E product and solutions capabilities, and global business and terminal resources, Huawei knows it can give the shot in the arm operators need for successful NB-IoT network construction and development.

All about the user with U-vMOS

Huawei's U-vMOS is an E2E mobile video solution for measuring, planning, and optimizing viewing experience. It helps operators build video-centric mobile broadband (MBB) networks that makes the most out of the world's increasing appetite for video.

By Zhang Yongshun

Video on the move

Research by mLAB shows that 51.4 percent of mobile subscribers watch video between one and three times a day. YouTube corroborates this trend, stating that more than half of its users watch video on their phone. Meanwhile, an even greater proportion of Facebook users – 75 percent – watch videos on the go.

Despite this, no unified standard exists to evaluate user experience. At the Huawei Global Analyst Summit 2016, Yang Kun, from the IP Multimedia Commission under the China Communications Standards Association, summed up the current situation: "Users don't like frame freezes and erratic displays at a lower price, preferring instead to pay a moderate price for excellent quality. The industry needs a complete set of evaluation standards to measure video service quality scientifically. Researchers have evaluated video picture quality before, but only in lab conditions. It's doubtful that this reflects actual user experience."

Traditional networks that center on capacity and coverage are no longer up to the job, not least because networks with good KPIs can still provide a bad user experience. Therefore, network construction must involve a unified standard for evaluating video quality from the user perspective. Operators must consider how to define and evaluate user experience and how to build and manage experience-centric networks given the increasing demands on network performance.

Huawei's U-vMOS helps operators build video-centric mobile broadband networks that enable them to plan, measure, and optimize user experience.

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U-vMOS: Subjective and objective

ITU-T's objective assessment model defines the conditions for objective experiments, as well as measurement methods and evaluation standards. Its subjective assessment model uses an algorithm to define a set of parameters based on objective inputs to estimate multimedia quality.

Using the ITU-T standard assessment models, Huawei identified the top three impact factors on which to base U-vMOS: quality, interactivity, and viewing experience. U-vMOS covers videos on demand (VOD) in mobile scenarios, live videos, and VOD services in fixed scenarios, and provides network indicators for each impact factor.

In partnership with Oxford University and Beijing University, Huawei mLab fixed three measurable qualitative network indicators affecting video experience: resolution, initial buffering delay, and stalling ratio. For quantitative measurements, they created a unified model that combines users' subjective scores with the objective scores from perception measuring equipment. By applying machine learning for model training, the team devised a computational formula for U-vMOS in mobile scenarios. To measure experience, U-vMOS gives a score from 0 to 5.

U-vMOS smashes bottlenecks

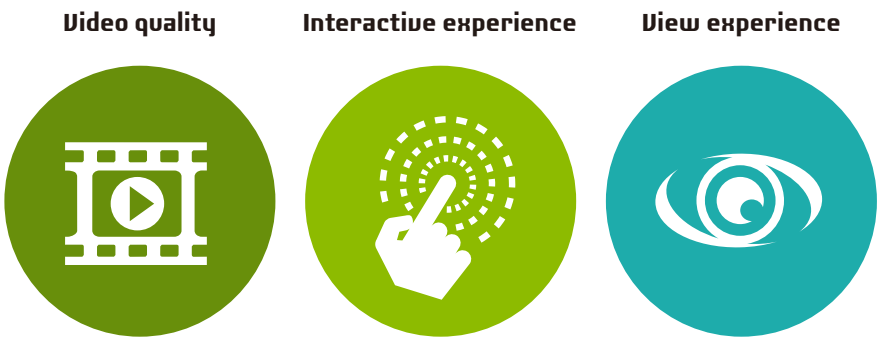
To simplify video experience evaluation, Huawei developed three U-vMOS testing tools: a user-level test app, a network-level data analysis tool, and a U-vMOS SDK for integrating third-party testing tools.

The user-level test app SpeedVideo allows users to test the video experience on their smartphones. The app displays the U-vMOS score, showing users the network's current video quality and giving the option to improve their experience. Available on Google Play and the App Store, users in over 140 countries have downloaded SpeedVideo, creating over 700,000 test samples.

Operators need to know whether users are satisfied with their video experience, and be able to identify what's causing any problems. Therefore, they have to evaluate video experience on the entire network, which cannot be done using a DT tool because they can only test a limited number of samples for analysis. The network-level U-vMOS, however, can analyze every video service in an entire district. The Huawei iDART/PRS tool supports network-wide U-vMOS evaluation, and provides geographic displays and grid-level displays with 50x50 m precision based on measurement reports (MR) and call history records (CHR). It's a professional-grade tool for identifying video experience bottlenecks and problem demarcation for analysis.

Operators have already started using Huawei's U-vMOS SDK, which is designed for third-party testers and assessing OTT service integration. In January 2016, an operator in Nanjing used WorkTour – a drive testing tool with U-vMOS testing functions developed by DingLi, one of

Top three factors influencing video watching experience



The target of traditional MBB network construction used to be pipelines, but it's now moved to core service experience.

China's largest testing equipment manufacturers – to carry out U-vMOS testing on a commercial network in six different scenarios. The test results helped the Nanjing operator understand the user experience of its network for precise network optimization, and expanded tests are planned.

Covering all sides

The target of traditional MBB network construction used to be pipelines, but it's now moved to core service experience. Huawei's Video Coverage planning method for MBB networks helps operators build ubiquitous HD MBB networks. It comprises three steps:

- Evaluate networks and set goals: identify key areas for network planning using quantitative measurement of mobile video performance and analyze video consumption habits using objective indicators.
- Analyze gaps and causes: define problems and classify root causes in areas where video experience is poor.
- Implement solutions and optimize iteration: perform coverage and capacity planning based on the causes of substandard results, including solutions such as carrier expansion, sector splitting, adding sites, and deploying new features. Iteration planning can continually improve network experience.

Video Coverage has been used for

In the MBB era, video is gradually supplanting voice as a new core service for mobile operators.

network construction across the world including Australia, South Korea, the United Arab Emirates (UAE) and Saudi Arabia. A leading UAE operator proposed a video-centric traffic strategy to provide a superior HD video experience, opting to use the U-vMOS evaluation system for analysis in target areas to provide 1080p online video services.

After the mobile video solution was deployed, the proportion of grids with a U-vMOS above 3.8 increased from 60.9 percent to 82.4 percent. Initial video buffering delay was reduced by 0.49 s, fulfilling targets and improving user experience. As a result, data traffic consumption shot up by 38 percent within three months, and encouraged overall network improvements that have boosted other services.

E2E mobile video for better business

Huawei's E2E mobile video solution features multi-carriers aggregation, 4x4 MIMO, and 256QAM advanced modulation techniques for increased last-mile capacity. A two-level TCP proxy reduces initial video buffering delay on the wireless and PS sides, while the distributed Content Delivery Network (CDN) cuts the distance between the content source and user. A video QoS mechanism ensures a good experience and minimally impacts other services, and medium and heavy video load scenarios prompt the load optimization function. Huawei's mobile video solution also supports network capability opening and fully flexible billing, helping operators and OTT players to collaborate and encouraging new business models. Operators can open up network information like available bandwidth for subscribers and their location information so OTT companies can accurately transmit suitable bitrate and deliver a much smoother video experience.

Jiangsu Mobile worked with iQIYI to move the CDN downstream to the Evolved Packet Core (EPC) gateway and open up user location information, allowing the gateway to better carry location information using the HTTP header, so iQIYI could carry out precise CDN node selection. This doubled average user download speeds and boosted U-vMOS scores by more than 20 percent.

With the flexible charging policy, operators can deploy different charging modes based on levels of video experience, video types, time periods, and content. For example, a combination of a free basic experience and charging for HD experience can attract more users to try a video service, while backward charging and targeted OTT plans can boost profits.

In the MBB era, video is gradually supplanting voice as a new core service for mobile operators. Huawei believes in openness and cooperation. We work with operators and partners in the video industry to build an internationally recognised evaluation system for video that's agreed upon in the industry, optimize user experience, and safeguard operators' investments. Huawei strives to support operator and OTT cooperation by opening network capabilities, thus boosting the mobile video industry as a whole.

Broadening horizons with MBB Open Interconnect

With increasing ICT service convergence, MBB Open Interconnect opens up connectivity capabilities and network information. It can help mobile broadband (MBB) operators drive service growth, introduce new business models, and create new revenue streams.

By Liu Jian

New opportunities with ICT convergence

Over the last decade, there has been a continual value shift towards Internet IT services in the communications market. Yet despite the explosive growth in mobile data traffic, operators haven't seen a proportional rise in revenue. In response, they've sought to internetize their operations and form ICT businesses that converge CT and IT. In recent years, the growth of mobile Internet, cloud computing, and the Internet of Things (IoT) has significantly boosted the development of converged ICT services.

Mobile internet

Due to the rise of mobile Internet, traditional industries are incorporating Internet tech into their operations, creating new ecosystems for banking, transportation, medicine, and education. According to Ralph Haupter, Microsoft CEO for Greater China, "In the future, all companies will be software companies." Enterprises will increasingly use APIs to integrate with and provide services for each other. In e-commerce, for example, businesses might use China UnionPay's online payment API to make payments. Or a loan company might invoke a telco's payment records API to find out a user's credit score. Service diversification means that operators will have many opportunities to leverage their telecom capabilities to tap into this enterprise services market.

Cloud computing

Cloud computing technology, in particular Network Functions Virtualization (NFV) and Software Defined Networking (SDN), is driving telecoms networks to be software based. Network functions have been decoupled from customized hardware, and are now operated in cloud data centers (DC), greatly speeding up version iteration and innovation, creating agile networks, and facilitating new business.

IoT

The growth of IoT technology has increased different types of connectivity requirements. Different types of services have led to varied requirements on connectivity, from real-time capabilities for the Internet of Vehicles to a low-power requirement for smart meters. This will make it increasingly difficult to strip away network connectivity capabilities from IT services.

With increasing ICT service convergence, mobile broadband (MBB) operators can act as a key pipeline for mobile Internet by transmitting data from services to terminals, providing ubiquitous connectivity, and collecting big data on network information. By opening up these connectivity capabilities and network information, operators will drive service growth, introduce new business models, and create new revenue streams. This is known as MBB Open Interconnect.

In recent years, numerous operators and enterprises have trialed MBB Open-Interconnect models. Successful cases include opening up a billing API to allow OTT providers to issue free data offers through backward charging, which quickly attracted many new users and drove service growth. 51 Credit Card Manager is an example of a financial service that checks users' payment records by invoking operator billing information API and issues small loans based on users' credit scores.

Putting telecom capabilities to use

Today, ICT products and services are becoming more diverse, with an increasing

number of different types of businesses moving into the ICT industry. Operators have a chance to take advantage of this and leverage telecom network capabilities and pipeline big data, thus playing an important role in the ICT industry ecosystem in the future. There are currently five types of network capabilities that can be opened:

QoS-class APIs

QoS-class APIs deliver network acceleration and QoS guarantees. For example, mobile games that involve real-time multiplayer battles require very low latency. If latency increases due to network congestion or in places where coverage is weak, users can invoke network acceleration functions to quickly lower latency and maintain user experience.

The network acceleration function can be packaged as an in-game tool and sold to players. Network acceleration can also be used in other application scenarios to improve the chance of success, for example, purchasing tickets for popular events, opening WeChat red envelopes, or trading mobile stocks.

Billing APIs

Billing APIs enable sponsored data functionality. Enterprise users can invoke a billing API to add, modify or delete sponsored data plans that give users free traffic packages as part of a promotion.

Location APIs

Location APIs include real-time location APIs and location history analysis APIs. Application scenarios for real-time location APIs include indoor positioning, navigation, and car parking. Indoor real-time positioning technology, such as Apple's iBeacon, has received widespread attention in areas like guided shopping and electronic fence advertising for shopping malls. Compared to iBeacon, using mobile networks for indoor positioning is low cost and easy to set up.

The application scenarios of location history analysis APIs include managing crowd congestion, analyzing population movements, assessing outdoor billboard value, and selecting retail shop locations. Another important application is big data. Governments and commercial organizations have wide-ranging requirements for location-based big data applications, and operators can provide the most reliable sources of data.

User/network context information APIs

User/network context information encompasses information such as user account type, billing status, device model, available bandwidth, mobile and session status, and cell congestion status. Google's Congested Cells API, for example, obtains cell congestion information from operators to optimize services, including video bit rate selection. The online payment company Danal partnered with AT&T on anti-fraud user authentication, making use of information such as user ID, account information, real-time location, and device model.

Third-party app integration

Operator pipelines are not the only source of pipeline capabilities. Third-party partners are also able to provide pipeline capabilities, such as TCP optimization, video optimization, URL filtering, and firewalls. This can help operators increase pipelines' capabilities and extract more value. In a win-win situation for both parties, cloudified multi-service integrated platforms allow third-party software vendors to easily access operator pipelines and quickly create value-producing services.

Huawei's solutions light the MBB Open Interconnect fire

Huawei's CloudMSE (Multi-Service Engine) for third-party app integration and CloudUIC (Unified Intelligence Center) can open network capabilities to help

operators develop the MBB Open Interconnect industry. Huawei has partnered with numerous operators and third parties around the world in successful commercial trials of these solutions.

Sky plc's integrated video optimization service

With video optimization technology, operators can perform real-time video transcoding to provide low bit-rate video to users affected by insufficient network bandwidth, guaranteeing the video playback experience.

Sky used Huawei's CloudMSE solution to integrate Opera's dynamic transcoding software, and can now flexibly provide video optimization services for users, increasing user satisfaction.

Guangdong Mobile joins forces with Tencent in mobile game acceleration trial

For online games, network speed is critical. Even 50-ms latency can be a disadvantage in certain types of games. Mobile game acceleration enables mobile gamers to maintain low latency even in low-signal or congested spots.

Leveraging Huawei's CloudVIC platform, Guangdong Mobile and Tencent Gaming carried out a joint commercial trial of game acceleration for WE FIRE, giving users who purchased the tool an advantage.

Operator "Z" tests fraud prevention methods

If a hacker attempts to use a stolen account to carry out a mobile payment, the back-end payment system calls the operator API to discover the real-time location of the user's mobile phone. If this differs from the payment location, a payment confirmation message is sent to the user, preventing the unauthorized payment from proceeding. Credit card payments can also be protected in a similar way.

Operator "Z" has run commercial trials of this service using Huawei's CloudVIC.

A bright future for Open Interconnect

Huawei predicts that by 2025 there will be 100 billion connections worldwide, 8 billion of which will be smart terminals. At this time, average daily data usage will be 1.7 GB per user. This will create a huge number of opportunities for mobile operators – they'll be the platform for this data and a vast range of industry applications. If operators can organize and open up their pipeline capabilities and data to third parties, they will attract thousands of industry partners with whom they can team up to provide better services for enterprise and individual users.

The MBB Open Interconnect industry must be rooted in CT and rely on IT to open up. The development of the industry must be shaped by the current development status of MBB networks and continually seek new opportunities in enterprise application requirements and industry trends. To drive the development of the MBB Open Interconnect industry, Huawei has developed short-term, medium-term, and long-term goals.

In the short-term, Huawei will focus on mobile network QoS experience guarantees and billing for OTT applications. The medium-term goal is to research how MBB networks and OTT applications can be leveraged to enhance applications' network usage efficiency.

Long-term research will be shaped by evolutionary trends in networking. It will explore how to incorporate innovative Internet services based on future network architecture.

Keeping safe with 4.5G broadband trunking

LTE-based broadband trunking is perfect for delivering broadband data services. It provides emergency communications technology that can enhance efficiency and ensure safe cities, making broadband trunking the new choice for public safety communication networks.

By Lin Peng

The face of the future

Public safety services have traditionally used private network trunking systems such as TETRA and P25. However, these kinds of communications systems are no longer able to meet growing public safety requirements – be it network coverage, service experience, or maintenance costs. Limitations include transmission speeds, dispatch capabilities, and inconsistent trunking system standards.

Traditional private network trunking only supports narrowband voice and SMS, but not broadband data services like video and HD surveillance. This degrades public safety services, leaving user experience stuck in the 2G era. As a former New York police chief puts it, "The wireless communications capabilities of a teenager's smartphone far surpass what police and auxiliary police are equipped with."

With today's proliferation of broadband networks, LTE-based broadband trunking represents the future of emergency network solutions.

Broadband trunking: A new chapter in public safety

LTE: standards and future evolution of broadband trunking networks

Traditional private network trunking standards were jointly developed by a number of standards organizations, including TCCA, OMA, and ETSI. Oriented toward private users, the system's overall framework is completely loose-coupled and the industry chain is relatively closed. There are significant issues

with interoperability between different vendors, leaving no scope for evolving the technology to support broadband data services.

In cooperation with trunking standards organizations, government regulators, and operators, 3GPP formulated a new Work Item (WI) focused on public safety. The WI created an entirely new public safety standards framework based on LTE network architecture, enabling Mission Critical Push to Talk (MCPTT) services on LTE.

3GPP's R13 set out new standards for an end-to-end standards framework in 2015. Using standardized and opened interfaces solves the issues of interoperability between different vendors and the closed industry chain. R13 defines key LTE public network trunking functions, including MCPTT, IOPS, GCSE, and proSE. It also enables emergency video and calling services on operator networks. With the freezing of R13, operators now have new commercial opportunities.

Rebuilding the capabilities to build safe cities

As of 2015, more than 30 countries around the world had started assessing, planning, or deploying LTE public trunking networks with a view to building new communications capabilities for safe cities. The progress of these projects in various countries is as follows:

United States: FirstNet, a national public safety broadband network, was planned for 2012 using the LTE 700 MHz spectrum with a US$10 billion investment. In March 2014, 231 sites were built in Los Angeles as part of the first phase of the project at a cost of US$175 million.

United Kingdom: A national public safety broadband LTE network is planned for construction from 2015 to 2020, which will allow operators to build public safety networks over the LTE public network spectrum. The first phase of construction began in 2015 with an investment of £1.2 billion.

South Korea: In 2014, the country began building a national broadband emergency disaster prevention network with a total investment of more than US$2 billion. The first phase kicked off in 2015, with the aim of constructing 205 base stations and distributing 5,000 terminals in Pyeongchang County at a cost of US$40 million.

New model for public safety networks

The UK Home Office announced in December 2015 that it would partner with the UK's largest wireless operator EE to build a public safety network. EE's 4G mobile network will provide public safety services for the UK's 330,000 public safety workers, including police, fire, and ambulance crews. Carrying broadband trunking services on a public LTE network for the first time will represent a historic step.

The decision by the UK government to replace the existing TETRA network with

an operator's public network to provide public safety services, with very stringent requirements, was not made lightly. A specialist company was commissioned to carry out detailed comparative analysis and feasibility studies on carrying broadband trunking communication services on TETRA vs LTE public networks. The research concluded that using a public network offered obvious advantages in terms of coverage and service experience, and would be able to meet demanding requirements on dimensions such as latency.

Estimates show that deploying a trunking system on an LTE public network will save the UK government £1 million a day compared to a private network. Over five years, the new solution will see network construction and maintenance costs fall from over £2 billion to £1.2 billion. At the same time, with government investment, EE will be able to improve network coverage and user experience, and boost its brand equity.

Brand building

Operators cover large chunks of the population, but public safety services place higher technical and service experience requirements on operator networks, including reliability, coverage, user priority, and emergency communications safeguards.

After winning the contract for building the UK's new public safety network, EE CEO Olaf Swantee said that, "We're immensely proud to be selected to deliver this vital new network...we've worked closely with police, fire, and ambulance crews to show the power of EE's 4G network in helping save time and save lives. We will now work tirelessly to deliver a highly resilient, truly nationwide 4G network to serve all of Britain's public safety workers." EE's wireless network will more than likely become the UK's most reliable network, offering the best coverage and experience, which will in turn provide a huge boost for EE's brand value.

Lighting up new markets with LiTRA

According to estimates, LTE trunking services will have been deployed to 150,000 base stations globally by 2020, creating a market worth tens of billions of dollars. With the rapid growth of broadband trunking services, we're set to see a wave of trunking systems constructed over public LTE networks in the near future.

LTE integrated Trunked Radio (LiTRA) supplants traditional narrowband push-to-talk (PTT) services, including voice and SMS, and provides broadband trunking (e.g. Push to Video) as well, fully leveraging existing operator LTE networks. By utilizing the broadband trunking capabilities provided by LiTRA application servers, operators can quickly deploy national public safety networks and enhance the commercial value and brand of their networks.

LiTRA is based on open 3GPP protocols and uses an open interface. This enables operators to work with more partners to provide a wide variety of services such as telemedicine, video surveillance for major events and incidents, and drones. LiTRA's openness also maximizes compatibility with the mature LTE terminal industry chain, bringing in a large number of partners that operators can work with to build future national public safety networks and safe cities.

With the construction of LTE networks accelerating around the globe, LiTRA will help operators enter the new arena of national public safety network solutions, adding a new string to their revenue-creation bow.

Let's stay indoors for full connectivity

Small Cell is packed with features for full indoor connectivity: E2E digitalized architecture, high capacity, high yield, fast deployment, and strong evolution potential.

By Ding Zhibin, Cui Xiaoying

According to GSMA's recent Mobile Economy 2016 report, the CAGR of mobile data traffic over the next five years will hit 49 percent, and the global average user will consume 7 GB of mobile data per month by 2020. In Europe that will stand at 12 GB, while in North America, it will reach a massive 22 GB each month. More than 80 percent of this will be generated indoors.

The great indoors

Research by Huawei mLab on user dwell time reveals that people spend more than 60 percent of their time indoors. Here, they have higher requirements for mobile services, especially 2K and 4K video and loading times, in stationary or slow-moving scenarios.

We can also expect the first wave of commercialized ultra-broadband

services including virtual reality (VR) and augmented reality (AR) to take place indoors.

The amount of traffic generated in super-high traffic areas during major events can be hundreds of times higher than network averages. On the first day of Mobile World Congress 2016, for example, attendees transmitted 828 GB of mobile data in the convention hall.

Indoor coverage is tough

Big changes in user service models, available spectrum, and the 4G, 4.5G, and 5G eras means that the traditional analog indoor coverage solution – Distributed Antenna System (DAS) – can't make the grade.

Changes in service models: The shift from synchronistic voice services to data services and an accompanying shift in operators' revenues are accelerating, placing greater challenges like service bursts and the tidal effect on DAS.

Changes in spectrum resources: The mobile data surge is pressuring spectral resources, leading to the use of high frequency bands, including 1.8 GHz, 2.1 GHz, 2.3 GHz, 3.5 GHz, and even unlicensed 5 GHz spectrum. Although these bands are now the mainstream in mobile broadband (MBB) network construction, they're not suitable for DAS, which suffers high transmission loss in high-frequency bands through DAS coaxial feeds. High-frequency spectrum is reducing the efficiency of the outside-in model, where indoor traffic depends on outdoor macro network absorption because it increases building penetration losses in outdoor macro networks. This is also intensifying DAS's capacity bottleneck.

Accelerated technological evolution: 1G-to-2G evolution took 20 years, 2G-to-3G evolution 10 years, and 3G to 4G just 5 years. Over this time, speeds have evolved from tens of Kbps to several Mbps. The pace of evolution of new technology is accelerating in the 4G era, and subscriber speeds have evolved quickly from several Mbps to hundreds of Mbps. Meanwhile, the commercial application of some 5G tech in 4G networks has caused a speed leap from megabits to gigabits. DAS's analog radio frequency (RF) architecture makes it extremely difficult to incorporate it into multi-antenna and high-order technologies without large-scale changes to existing networks.

As a traditional indoor coverage solution, DAS can meet the demands of 2G/3G era voice and mid-to-low-speed data services. But against a surge in indoor MBB requirements in the 4G/4.5G era, DAS has become a developmental bottleneck for indoor MBB due to the lack of network capacity, scalability, and poor evolution potential, limiting demand for subscriber services. In the future, DAS will even restrict the evolution of operator networks. With E2E digital architecture, high capacity, high yield, fast deployment, and evolvability, Small Cell is the new linchpin technology for building a fully connected indoor world.

Small Cell is the new linchpin technology for building a fully connected indoor world.

Huawei's indoor vision: From x to y

Digitalized network architecture: From centrally placed signal source of the analog system to RF digital processing elements extended to the front end in digital systems. The high number of passive components in analog systems causes high interference and limits capacity, while expansion requires onsite re-modification, but digital systems can greatly lower interference, improving MIMO performance and enabling on-demand capacity expansion through software-defined frequency ranges.

Digitalized O&M: From the black-box type management of analog systems to the precise monitoring of faults and service volumes on each node to enable O&M and visualization across the whole indoor system, improving O&M efficiency.

Digitalized service capability: From a focus on voice services and meeting coverage the demands of analog systems to focusing on digital services, meeting capacity demands, and providing value-added service capabilities. This will increase operator revenues through opening the capability of their digital pipelines and fostering cooperation with application developers.

Sustainable future evolution: From analog's difficulty with upgrades to the smooth software upgrades of digital. This enables new technologies, such as distributed MIMO, 256QAM, LAA, and the latest 5G-oriented wireless cloudified architecture, so spectral efficiency and network capacity can constantly improve.

Flying high with LampSite

Indoor scenarios are more complex and diverse than outdoor ones. Network construction in indoor scenarios must also be more closely aligned with owners, requiring diverse solutions to meet the varying service demands of different segments.

Medium-to-large public areas, such as stadiums, transportation hubs, conference centers, and shopping malls, are priority areas for operator investment due to their size and high crowd densities. Digital solutions based on CloudBB architecture like Huawei's LampSite are the best choice for many operators worldwide in this kind of scenario. LampSite supports multiband multimode, large capacity, flexible expansion, rapid deployment, E2E management and control, and long-term smooth evolution with new technology.

The world's largest deployment of LampSite is at Beijing International Airport, the world's second largest airport, with 220,000 passengers per day and nearly 84 million a year. Deployment was completed in three months, with 2,200 LampSite pRRUs providing comprehensive 4G coverage of the terminal departure and arrival halls, baggage claim hall, VIP lounge, office area, and even the airport parking lot and basement area. Total deployment time was reduced by more than two-thirds compared with traditional DAS deployment. The new solution delivers peak user download speed of 140 Mbps, with figures showing yearly data traffic 27 times higher

after deployment, indicating greatly enhanced user experience and thus profits for the operator.

Other successful examples where LampSite has been successfully commercially deployed include exhibition halls for the Barcelona Mobile World Congress, Beijing National Stadium, China's National Centre for the Performing Arts, Beijing Workers' Stadium, Zhengzhou Railway Station, Jakarta's main airport, Singapore's Marina Bay Sands hotel, and Qatar Villaggio shopping mall. These examples show how this indoor network construction strategy has gained worldwide recognition.

Small and medium businesses, such as coffee shops, retail stores, and restaurants, have comparatively large capacity requirements. Many deploy Wi-Fi networks, but due to protocol and technological limitations, they cannot meet the requirements of HD voice and video-driven MBB services, particularly in scenarios with high numbers of users. User experience tends to be very poor.

The Pico solution leverages multiband multimode to integrate Wi-Fi and single-node fast networks. Based on Iub interfaces, Pico supports automatic network discovery, Plug and Play (PnP), and automatic planning and configuration to re-use existing Wi-Fi AP's sites, transmission, and power supplies to provide optimal MBB services and maximize hotspot value. For these kinds of scenarios, Pico is the optimal solution based on cost-performance ratio.

As LWA and LAA technologies mature, Pico can tap into the potential of unlicensed bands in the future for increased capacity and better user experience.

A Thai operator successfully deployed Huawei's Wi-Fi-integrating Pico solution in its stores. New equipment deployment and service launch was completed in just two weeks in more than 100 of the operator's service centers. This was possible because the solution fully utilizes the existing Wi-Fi AP's site and transmission and power supply resources, and benefits from PnP and zero on-site configuration capability. Following deployment, actual user peak rates exceeded 130 Mbps, greatly improving network user experience. The operator plans to carry out large-scale deployment of Pico in thousands of its other stores, 7-Elevens, and coffee shops in Thailand.

When it comes to home scenarios, immature business models have hampered the success of the Femto home base station solution, despite trials by many mobile operators. In the foreseeable future, Wi-Fi will continue to be the primary home MBB solution.

As well as providing an excellent MBB access experience, indoor digitalized networks yield more value-added services like indoor navigation, visitor flow statistics, and precision advertising. In indoor venues with digital systems, operators and owners can create new revenue streams through opening network capabilities, which in turn enables service innovations such as digital shopping malls, airports, and stadiums, and maximizes the value of digital networks and data traffic.

Upgrading for the win

Indoor mobile networks are critical for operators in the MBB era, not only providing tremendous opportunity but also raising a series of challenges. Upgrading the traditional analog network ecosystem will not be achieved overnight and in isolation. Instead, realizing the concept of indoor digitalization will require a concerted effort, impetus from multiple industries, and even cross-industry partnerships. It will even be necessary to break up the chain of interests in traditional analog networks before the upgrade, so business success can be achieved for all.

China Mobile's oriental pearl shines even brighter with 4.5G

China Mobile has achieved great things with 4G network construction. In three years, the operator has deployed 1.32 million base stations and gained 429 million 4G subscribers. Shanghai has become China Mobile's shining pearl of 4G construction thanks to continual innovation and 4.5G technology.

By Wang Qiang

Shanghai, China's pearl of the Orient, is an international city that stands at the forefront of rapid development in China. Equally, China Mobile is the nation's leading telco. In the span of three short years from when the operator began building a 4G network in 2013, China Mobile has deployed over 1.32 million 4G base stations and its 4G subscriber base has grown to more than 429 million.

Shanghai covers an area of 6,340 square kilometers and has a population of 25 million. Shanghai Mobile has 22 million subscribers, including 10 million 4G users. The operator has built 20,000 4G base stations, which provide 99.5 percent 4G service coverage. Shanghai Mobile is the dominant player in the Shanghai communications market.

Phase 1 (2012-2013)

In the 3G era, China Mobile was constantly playing catch-up thanks to a poor user experience. To turn things around, China Mobile kick-started a 4G expansion pilot project in 2012 on trial networks, Shanghai Mobile deployed 1,000 4G sites, and carried out network verification, accumulating technical expertise and experience. This later helped the operator rapidly implement the widest 4G network coverage in the city. Today, Shanghai Mobile's 4G network service coverage has hit 99.5 percent thanks to a range of innovations.

Capacity of existing macro stations maximized through a collaborative F/D RF solution

Shanghai Mobile's 4G network macro stations cover F (2010-2025 MHz) and D (2575-2635 MHz) bands. Growth in services, especially VoLTE services, led to requirements for deep coverage. But it was becoming increasingly difficult for Shanghai Mobile to acquire macro station sites the traditional way.

Shanghai Mobile worked with Huawei to solve this problem. The partners introduced D-band RRU (remote radio units) that could support F-band signal reception during the network capacity expansion phase. In addition, algorithms were deployed that gave F-band reception capability to the new modules and existing sites that would be used together. This supported 16 upstream channels, increasing the system's reception power and enhancing F-band upstream coverage by 3 dB. This solution greatly boosted F-band coverage. Shanghai Mobile has now widely deployed this solution, ensuring network capability for services such as VoLTE, which require deeper coverage.

Exploring micro station resources to deepen coverage and widen capacity

The cooperative F/D RF solution has helped improve coverage capabilities. However, it didn't meet all coverage requirements. New station acquisition remained a necessary area in which to explore new solutions. As a large international city, Shanghai has many security

Shanghai Mobile's innovative solution involved sharing big data with the Shanghai Public Security Bureau in exchange for poles for site deployment.

and surveillance poles that need a potential platform for new cell sites.

Shanghai Mobile's innovative solution involved sharing big data with the Shanghai Public Security Bureau in exchange for poles for site deployment. By analysing mobile user data in cells in its coverage area, Shanghai Mobile can obtain real-time information on the source, number, distribution, and flow trends of people in the area. This kind of information is also useful for the police and security services.

Shanghai Mobile first conducted a pilot in the Bund area, deploying 20 micro stations on surveillance poles. The pilot helped improve coverage and gave security services valuable information. Following the pilot, the scheme entered its second phase at the end of 2015. Shanghai's public security systems provide over 300 surveillance poles, covering the City God Temple, Xintiandi, and Lujiazui areas of Shanghai.

Phase 2 (2014-2015)

At the end of 2013, China issued 4G licenses, and the mobile market in China boldly stepped into the 4G era. With the big three operators all making a big push for 4G, a question that concerned China Mobile was how to ensure its competitive advantage. The heart of Shanghai Mobile's strategy is user experience. The operator actively promoted the commercial adoption of VoLTE while continuing to leverage new 4.5G technology. The aim was to not only consolidate its lead in voice experience rankings, but also to create a faster data rate experience.

Leveraging mobile spectrum and TDD technology to increase network speeds and build capabilities for the fastest 4G network

In 2014, Shanghai Mobile rolled out 2CC CA in the City God Temple and Xintiandi areas, attaining a downstream rate of 220 Mbps. In 2015, the operator successfully piloted DL 3CC CA, UL 2CC CA, and 64QAM technologies, increasing download speeds to 330 Mbps and upload speeds to 30 Mbps. In 2016, Shanghai Mobile attained a download rate of 1 Gbps and upload rate of 50 to 60 Mbps through the use of 4x4 MIMO and 256/64QAM. By enhancing network speed capabilities, Shanghai Mobile stepped into the Gigabit era in 2016.

China Mobile became the first operator to roll VoLTE out city-wide, enhancing 4G users' voice experience

Voice services are the key to China Mobile's growth and the main part of its business. Developing VoLTE services is a strategic focus for China Mobile in the 4G era. One factor behind this strategy is to enhance user voice experience by increasing voice quality from its original 2G level. Another is to free up valuable 2G spectrum by shifting the 2G network voice load to the 4G network, and thus create a flexible strategic reserve of spectrum for future use.

Shanghai Mobile launched commercial VoLTE trials in 2015, the culmination of a year

of comprehensive preparations in 2014. In 2016, with the rapid maturation and proliferation of 4G handsets, Shanghai Mobile rolled out VoLTE to customers, increasing the number of customers using the service.

Phase 3 (2016-)

Shanghai Mobile currently has 10 million 4G subscribers, which is expected to exceed 15 million by the end of 2016. In some hotspots, it's difficult to meet experience requirements by traditional expansion. This has become a priority issue for Shanghai Mobile as it enters the mature phase of 4G network development.

Shanghai Mobile's solution has been to 4G-ize 5G tech by using future 5G technologies in its current network to increase network capacity fivefold, which will help it easily deal with the challenge of explosive service growth.

Deploying Massive MIMO boosts network spectrum efficiency

Massive MIMO is a key 5G technology that uses a large-scale antenna matrix to support extremely powerful three-dimensional beamforming and algorithms. The technology boosts network traffic capacity to realize a fivefold increase in spectrum efficiency compared to traditional 8T8R networks, greatly enhancing mobile network capability.

Shanghai Mobile carried out the world's first Massive MIMO pilot on a commercial network in September 2015. On the 2615-2635 MHz band, 16 commercial handsets (Huawei Mate 7s) attained total cell throughput of 670 Mbps and 340 Mbps cell throughput when carrying out 50 percent scrambling on nearby networks. Compared to the existing 8T8R network, this was a five-to-sixfold increase in network capacity.

Huawei and Shanghai Mobile worked together to develop an innovative Massive MIMO solution that uses BBU+AAU split architecture. This allowed the parties to leverage their experience of traditional BBU+AAU network deployment, facilitating project implementation and maintenance. In addition, the solution enables the full potential of baseband to be leveraged, enabling subsequent adaptations based on algorithms and network evolution requirements to be carried out to lay the foundation for continual performance improvements and evolution to 5G.

In 2016, Shanghai Mobile will improve the technical requirements of Massive MIMO and further explore commercial scenarios by taking into account real-world requirements and scenarios.

Super base stations and user experience-centric network construction will ensure industry leading user experience

As networks continue to grow, Shanghai Mobile and Huawei will continue to explore ways to continue optimizing user experience on networks in the future by unleashing the full potential of traditional sites. These methods include super base stations, construction strategies for user experience-centric networks, interference suppression technology and algorithms, and flexible site construction solutions.

Continuous innovation has helped Shanghai Mobile to solidify its competitive advantage. The operator dominates the market, with close to 80 percent of mobile subscribers and almost 90 percent of 4G subscribers in Shanghai. It's also made significant improvements in terms of user DOU and average revenue per user. China Mobile's shining oriental pearl, Shanghai Mobile, has continually tapped into the power of 4.5G. Through continuous innovation, it's consolidating its network capabilities, building a superior experience, and developing new site mode. The operator's wireless communications business will continue to go from strength to strength.

Philippines Globe: New network configuration, new MBB gains

The Philippines has a population of more than 100 million and a rapidly growing base of mobile broadband (MBB) subscribers. Like everywhere else, MBB subscribers enjoy surfing the web, playing online games, and using social media. The local mobile operator, Globe Telecom, is delivering a better broadband experience by deploying multi-sector networks that greatly increase network capacity.

By Ashish Pilani, Senior Technical Advisor of Wireless Engineering & Implementation, Globe

New MBB services, new subscribers

There are 121.8 million mobile connections (GSMA Intelligence) in the Philippines, with mobile broadband penetration hitting 45 percent and growing at an ultra-fast rate. In 2013, Globe began attracting more subscribers and encouraging them to use data services by providing special promotions for popular social media platforms like Facebook and Viber. Globe also launched highly attractive packages to gain more subscribers and boost data usage, triggering demand for data services to surge. Data services since then have turned into Globe's main revenue growth driver. According to forecasts, Globe will serve almost 60 million MBB subscribers by 2020 (GSMA Intelligence), with the number of 3G subscribers increasing by 1.6 times and 4G subscribers by 6.5 times over the 2015 figures.

However, this rapid growth in data services has placed enormous pressure on the operator's wireless network capacity. In Manila, a large number of 3G sites experience a resource utilization rate of over 80 percent during busy hours, which leads to lower than desired user experience. The network was in urgent need of capacity expansion due to the growth of new services and the need to improve user experience.

A quick-win and efficient solution was needed to address this challenge.

The Huawei 6-sector solution increases network capacity by utilizing special antennas to split a 120-degree sector into two 60-degree sectors, thereby doubling the number of cells and air interface resources. This technology has the advantages of higher capacity gains, lower cost, and a shorter deployment cycle compared to other solutions, such as adding new sites.

New network, new competitiveness

Globe and Huawei jointly planned the deployment of the 6-sector solution across the entire network in the Manila area to increase individual site capacity by 70 percent and thus cater for the requirements of rising MBB user numbers and traffic growth.

If 3-sector sites are reconstructed to 6-sector sites in a piecemeal, patch-it-up fashion, only short-term demand can be met and the network will be unable to accommodate growing capacity demands. To improve the value of sites and consider future needs, Huawei and Globe jointly aligned Globe's whole network with future demand in terms of spectrum, infrastructure, and new technology. In this way, Globe could deploy 6-sector as a benchmark for UMTS sites in urban areas, changing its strategy from passive capacity expansion to the whole network deployment of 6-sector. The 6-sector deployment approach lays a solid foundation for future network growth.

Three types of sites were targeted for the 6-sector upgrade: congested sites, high-profile customer service sites, and sites with the potential demand for high capacity. The initial plan was to reconstruct over 80 percent of sites in the Manila area to 6-sector sites, and thus increase network capacity. In sites where 6-sector was already deployed on UMTS 2100 MHz, a large traffic boost was observed: downlink data traffic grew nearly by 50 percent, uplink data traffic by 74.73 percent, and voice traffic by 31.69 percent. In addition, the drive test results showed that user throughput had improved by more than 100 percent, greatly boosting user experience.

A good quality network that provides a better user experience attracts more subscribers. In May 2016, the number of active HSDPA users in Globe's network grew by 68 percent over the same period last year.

Systematic deployment

When it comes to whole-network deployment, there are still many challenges facing the 6-sector solution such as complex deployment, un-targeted delivery progress, and strong interference. The situation was worse in urban areas where radio frequency (RF) issues occurred on targeted sites, affecting capacity gains and network KPIs.

The Huawei 6-sector solution is an end-to-end (E2E) solution that covers the whole delivery procedure, from planning and execution to optimization. In the planning stage, accurate site planning (ASP) meets the requirements of special scenarios to mitigate the potential network impact after deployment. In the execution and optimization stages, site optimization tools such as automatic cell planning (ACP) and SmartRNO accelerate deployment and reduce potential RF issues.

With the help of these tools, over 1,000 6-sector sites have been successfully launched in the highest-value area (the capital area).

Smooth evolution to LTE multi-sector

As the prices for LTE terminals are decreasing and LTE penetration rises, LTE capacity bottlenecks in some regions will occur in the short term. By splitting sectors and sharing user numbers, deploying 6-sector on LTE networks can also alleviate future pressure on capacity and guarantee user experience. The whole-network deployment of 6-sector in urban areas is a simple capacity expansion solution that provides many years of value.

The whole-network six-sector solution in Manila area has provided Globe with a solid foundation for developing new services and subscribers, monetizing data traffic, and improving user experience. It has addressed network capacity pressures and provided valuable lessons for deploying 6-sector, which will be incorporated into future whole-network 6-sector deployment.

More importantly, the whole-network 6-sector solution in urban areas has set a new network deployment benchmark for the industry to develop 6-sector network topology.

WTTx gives Sri Lanka wings to soar

WTTx deployment has narrowed Sri Lanka's digital gap with the world, introduced the nation's people to a new dawn of broadband services, and helped it businesses hop on to the fast track to growth.

By Li Quanling, Xu Changqing

Located at the southern tip of the Indian subcontinent, Sri Lanka is famous for the beauty of its natural environment and friendly people. This pearl in the Indian Ocean has a population of approximately 20 million, and despite its status as a developing country, education levels are high. Due to the civil war that ended in 2009, Sri Lanka's infrastructure is underdeveloped; however, since the war, the Sri Lankan government has moved quickly with economic reconstruction, placing a particular focus on developing ICT, having developed its national broadband policy and e-Sri Lanka strategy.

Rapid advances in communications

technology based on the Internet and social media have made people's lives better. However, broadband penetration is only 2 percent, far below the global average of 9.3 percent, meaning that many people are excluded from digital dividends. This is because the rate of urbanization is relatively low, with some 80 percent of Sri Lankans living in the countryside, where population density is low and the provision of fixed-line broadband coverage is very expensive. Small and medium enterprises (SMEs) are particularly affected. SME users have a high need for broadband, but the slow speed of 3G broadband technology is unable to meet their needs. This impacts the growth and efficiency of businesses. Developing broadband for home and SME users to bridge the digital divide is a high priority for Sri Lanka's government and telecoms industry.

WTTx deployment bridges the digital divide

Sri Lanka's mobile communications market is relatively mature, with five major mobile operators providing mobile communications services in a fiercely competitive environment. Even Sri Lanka's leading mobile operator, Dialog, has felt the profit squeeze in the mobile market. Dealing with competition and finding a sustainable way to make money is a problem facing all operators in this space.

Dialog understands the strengths and benefits of wireless broadband (WBB). In 2010, the operator launched WiMAX WBB services to satisfy the need for broadband access for some home users. In the last few years, with the TD-LTE industry chain rapidly maturing, Dialog has recognised the value of evolving from WiMAX to LTE and TDD spectrum. So in 2012, the operator acquired 75 MHz of TDD 2.3 GHz spectrum after acquiring the broadcast company Sky TV; then, in 2013 it partnered with Huawei to roll out Sri Lanka's first home broadband service based on TD-LTE using a WTTx (wireless to the x) access solution.

WTTx offers low network construction costs and rapid deployment. By leasing customer premise equipment (CPE) to users, the operator can reduce the initial broadband service fee, lowering the threshold for accessing broadband services. Compared to the high initial deployment costs and equipment usage fees of fixed-line

By leasing customer premise equipment (CPE) to users, the operator can reduce the initial broadband service fee, lowering the threshold for accessing broadband services.

broadband, the competitive advantages of WTTx are clear.

Dialog's WTTx operating strategy

Before stepping into the broadband services arena, Dialog formulated several key strategies after extensive research, including where to develop WTTx services, which users to target, and how to provide high-quality services. Detailed research on aspects such as Sri Lanka's broadband market, population distribution, per capita income, and data traffic distribution helped Dialog compile a top 10 list of target areas, which included the capital Colombo, Galle, and Gamphaha. This answered the question of where to develop WTTx services, so Dialog quickly deployed a network and rolled out its WTTx service.

As for which users to target, Dialog also had a unique strategy: First, the operator quickly deployed WBB and rapidly attracted users who had no fixed-line broadband coverage by lowering initial broadband costs with measures like Buy & Plug & Play, operator subsidies, and leasing CPE to users.

Second, Dialog offered flexible tariffs to target different types of users, for example, setting fees for plans with voice services 30 percent fee higher than those with no voice services. The operator also used a differentiated QoS strategy to attract high-ARPU subscribers and SME users. To provide enterprise solutions for SME customers, Dialog offered packages that included voice, VPN, and multi-user broadband access. The tariff was six times higher than for a normal home user plan.

Third, it adopted strategies to increase user stickiness and reduce churn such as cultivating pre-paid users and bundles for CPE and equipment, TV and broadband services, and Wi-Fi and WBB services. Fourth, it launched new innovative services for WBB, such as the Dialog Video App. Fifth, Dialog set up experience areas in customer service centers to let customers experience the convenience of WBB services first hand.

This series of measures helped Dialog rapidly attract users. Dialog also focused on deploying new technologies, including 8T8R RRU, indoor and outdoor CPE, and 4x4 MIMO and CA. These innovative software and hardware solutions helped the operator provide an excellent broadband experience for subscribers.

WTTx deployment has narrowed Sri Lanka's digital gap with the rest of the world, introduced the Sri Lankan people to a new dawn of broadband services, and helped Sri Lankan businesses hop on the fast track to growth.

Consolidating WBB market lead

Dialog deployed the WTTx network in 2013, quickly meeting the need for some SME

and home users for broadband, with the number of Dialog WTTx subscribers quickly breaking the 100,000 mark in less than two years. In 2015, Dialog adopted 2CC CA to deal with the rapid growth in data traffic. At the end of 2015, the operator's broadband subscriber base had surged to 300,000, and its mobile broadband market share had grown to 10 percent.

Huawei is a long-standing partner of Dialog, helping it stand at the forefront of the WBB arena and achieve continuous commercial success. Looking to the future, traffic on mobile broadband and home broadband networks is set to grow at an astonishing rate, as smartphones and HD TV services proliferate. In 2016, Dialog and Huawei launched a joint 4.5G (TDD+) trial. Dialog's aim is to provide users with a faster and better user experience by leveraging new technology. Huawei and Dialog's collaboration reaches a new level every year, and the two jointly developed an optimal WTTx business model to achieve commercial success.

Dialog's WTTx deployment project is a landmark in terms of broadband construction in Sri Lanka and a milestone for the Sri Lankan government's National Broadband Plan.

Continual evolution helps Dialog stay ahead

On April 4, 2016, Huawei and Dialog signed a Memorandum of Cooperation to conduct a joint 4.5G (TDD+) trial to verify the technology and accelerate its commercial adoption. Huawei will soon launch CPE equipment that will provide gigabit peak rates, using Qualcomm 1 Gbps 4.5G chip sets, which were recently announced at MWC 2016. Users will soon be able to enjoy the ultimate zero-latency experience of watching HD TV and virtual reality over the Internet. The wide-scale commercial adoption of 4.5G (TDD+) technology will help WTTx continue to deliver higher capacity and a better experience.

More than 300,000 users in Sri Lanka currently access WBB services through WTTx, enabling many to enjoy the convenience of mobile Internet. WTTx technology will complement fixed-line broadband services and go a long way to achieving the e-Sri Lanka strategy of connecting the unconnected. In the future, WTTx will bring broadband access to even more homes and give Sri Lanka's economic development the wings it needs to soar.

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MBB: Where agility and growth go hand in hand

With the total number of base stations set to double over the next five years, Huawei's MBB 2020-focused GigaRadio and Agile Site solutions can adapt to multiple scenarios and environments, simplifying site acquisition and accelerating deployment.

By Chen Hui, Qi Youjun

To better deliver people-to-things connectivity for mobile users, operators need to build many more new base stations for full coverage and to meet demand for mobile broadband (MBB), which continues to rise.

Globally, mobile base station density is uneven, with the per capita number of sites in densely populated regions such as Asia, Africa, and Latin America far below the global average. As explosive

global growth in MBB continues, projections show that the total number of sites worldwide will double within five years.

The Achilles heel

Optimizing mobile networks requires new sites, but space in cities is increasingly scarce – a conflict that's intensifying. Factors such as public concern over signal radiation and complex site approval procedures add to the difficulties.

In the past, little consideration was given to how traditional base stations fit in with the surrounding environment. Now people care, and operators have to defend existing sites. Studies show a 5 to 7 percent loss in the number of sites per year worldwide, which is a net loss for density.

But, operators are ramping up construction to the extent that investment is disproportionate to income. With power consumption, rental, O&M, and service costs for base stations on the rise, ROI and energy savings are operators' priorities.

Getting agile

With MBB 2020 approaching, Huawei has released its GigaRadio and Agile Site solutions. Delivered with network consulting and analysis services, the solutions provide innovative E2E site solutions and simplified site acquisition. They can adapt to multiple scenarios and environments to improve overall site investment and ROI, and help operators resolve the pain points of increasing site density and building mobile communications networks ready for MBB 2020.

Joint innovation by Huawei and its partners has found that an effective approach to increasing base station density includes the following features:

1. Use existing site resources by providing wireless network consultation and site construction planning services. The agile site construction concept involves fully using existing sites and pole resources to improve network construction topology (super-macro multi-sector/centralized sites + remote simple sites), simplifying sites and transmission, and increasing coverage and capacity.

2. Develop new solutions to acquire site resources. For urban public infrastructure such as street lights and bus stops, site sharing across industries plus faster and bulk site acquisition can be realized through industrial-aesthetic site designs, innovative street light solutions, and Smart

Delivered with network consulting and analysis services, the solutions provide innovative E2E site solutions and simplified site acquisition.

Site Access Node (SAN) solutions.

3. Adopt agile site construction to provide outdoor micro-sites and indoor Small Cell solutions for valuable regions and high-traffic indoor areas to help operators quickly capture high-value areas and increase ROI.

Zero footprint

Centralized base stations simplify site structure, while Huawei's Blade Site solution resolves the issue of limited space for sites with base stations constructed from stackable blades that can be flexibly installed outdoors.

Lite Site/Hub centralized base station: The solution adopts a "1 carry n" mode to streamline simple sites. It lowers acquisition time and electricity supply and transmission costs; simplifies site design, planning, and deployment; streamlines end sites, and increases site deployment agility.

There are two types of centralized sites: The first type is transmission with centralized backup power. This type fully uses existing poles and municipal pipes and wiring, and BBU/Power/Battery centralization and Easy Macro/remote RRU are used to streamline end sites. It suits scenarios where there are difficulties with mains supply and transmission, and where municipal pipelines or overhead wiring are available. The second type is transmission centralized sites. These fully use existing poles, AirHub RRN and RLN one-to-many transmission solutions, and Easy Macro/RRU end site local backup power. This site suits scenarios that have difficulties with wired backhaul and power supply.

Blade Site: GigaRadio provides a complete Blade Site solution, and includes a full series of outdoor BBU, BBU, battery, microwave transmission, and AirHub blades. This enables flexible combinations and modules to be assembled seamlessly on outdoor poles,

making base station installation as easy as fitting together Legos. Site construction simply requires a pole to build a zero-footprint site. Other than standard macro site scenarios, Blade Site provides the simplest site solution for linear coverage scenarios (highways/ high-speed rail), and rural wide-coverage scenarios.

Focusing on form factor

Rapid advances in integrated circuits have reduced the size of equipment, enabling industrial-aesthetic designs. The agile site solution uses unobtrusive site designs to better incorporate equipment into urban environments. Jointly designing and planning base stations and municipal infrastructure creates a new way to acquire sites.

Easy Macro lightweight street-side simple sites: Lightweight sites lie between the level of a macro site and a Small Cell, which account for an estimated 20 percent of all sites. They can be deployed quickly to boost network coverage and capacity. Easy Macro incorporates ultra-wideband RF antennas and can easily be integrated with an attractive design for integration with the surrounding environment, significantly reducing the difficulty of site acquisition.

Street lights and green sites: Open cooperation with the industry chain, such as local municipal and electricity departments or operators, allows the bulk acquisition of sites and utilization or transformation of existing infrastructure. Integrated street light/base station design enables invisible components and cables, as well as completely natural outdoor cooling.

In the UAE, Egypt, South Africa, and China, operators and government departments are working together to use street lights for fast deployment and to create the latest base station platform using open IoT tech to unify planning with smart city systems. Thus, they can maximize site value.

Boosting coverage for quicker returns

High-value areas have long been a key battleground for operators. Agile sites can provide comprehensive indoor and outdoor coverage solutions to help operators capture high-traffic areas and ensure rapid returns on site investment.

Outdoor micro sites: Lighter micro-level base stations are needed to meet requirements for deep coverage in high-traffic urban areas. From single-mode low-power (<1W) in the past to today's various multimode, multiband power (1-10W) sites, the solution can adapt to a wide range of scenarios. These include outdoor utility poles and lamp posts, railway stations, billboards, and telephone booths in central business districts, residential areas, and other locations where site selection or coverage is difficult using macro sites. Projections show that micro sites will account for up to 20 percent of sites by 2020. Outdoor micro sites have a modular design that supports automatic site deployment and utilizes distributed MIMO, 256QAM, and LAA for 4.5G gigabit peak rates.

Small Cell for high-traffic areas: There are a high number of high-traffic indoor areas where MBB traffic has been restricted for a considerable time. The Small Cell indoor digitalized solution comes at the perfect time to meet this need. The solution's indoor RRU/ LampSite and Pico solutions can be adapted to a wide range of scenarios, including airports, stadiums, commercial office buildings, subways, campuses, and residential areas. The solution enables the flexible and smooth multiband and multimode expansion of single cell capacity. It can be flexibly and conveniently installed, including terminal RF coverage visualization and direct network management.

Connecting the 4 billion unconnected with MBB connections, and a 20-fold growth in network capacity are central to the MBB 2020 vision.

Green thumbs

The mobile communications industry uses huge amounts of energy, causing heavy carbon dioxide emissions. Moreover, the vast number of base stations means that operators shoulder gigantic electricity costs, placing pressure on them to cut energy consumption.

Continual improvement of energy efficiency of base stations: High-efficiency power amplification (PA), new materials/chip sets, cooling chimneys, and cooling teeth have increased PA efficiency from 19 percent to 55 percent. With distributed base stations, the RF is closer to the antenna, reducing feeder loss by 3 dB. The outdoor modularization of the Blade Site solution enables natural cooling, removing the need for air conditioners and equipment rooms. Compared to the 3,000W of power required by traditional 2G base stations, SingleRAN multimode base stations reduce power consumption to below 1,600W, but give dozens of times higher capacity and connectivity capability.

Maximized site energy efficiency: Existing network equipment rooms have a large number of old power (and backup power) supply and air conditioning components that operate at around 80 percent efficiency. Replacing them with high-efficiency ones that run at 96 to 98 percent efficiency can reduce energy waste and OPEX. For example, during a modular transformation project, British Telecom replaced 10,000 equipment rooms and 30,000 sets of old modules, saving £22 million in OPEX annually.

Mixed new energy: Adding multi-energy scheduling to power-hungry sites can increase site-level efficiency to 94 percent. In areas where mains supply is poor or unstable, mixed power supply can reduce power consumption by 50 to 70 percent. In areas where mains supply is good or energy prices are high, adopting site power overlay can also reduce OPEX. For example, in a project in Pakistan, low-power base stations and high-efficiency power, cooling, and mixed power supplies helped the client reduce OPEX by 80 percent and TCO by 56 percent in five years.

New growth

Constructing base stations that are closer to people and objects and have greater capabilities, connecting the 4 billion unconnected with MBB connections, and a 20-fold growth in network capacity are central to the MBB 2020 vision. As a valuable asset of operators, base stations are critical to increasing network capacity and a cornerstone of achieving this vision.

Huawei's series of innovative agile site construction solutions, such as Blade Site, Easy Macro, Micro Site, and LampSite – a joint innovation with operators – can simplify the site construction process, beautify site locations, and reduce network TCO. These solutions will help operators quickly increase site density and boost MBB coverage and capacity, creating new room for MBB growth and paving the way for MBB 2020.

UMTS+: Adding up to success

Over the last 10 years, UMTS networks have proliferated in many countries. Mobile Broadband (MBB) adoption has grown rapidly around the world since 2008, when smart devices first emerged and sparked the first MBB revolution. Today's surge in devices and social media use has seen UMTS network traffic skyrocket.

By Wang Mingxuan

Operators have seen their growth increasingly hindered by a number of practical issues, including the explosive rise in data, limited spectrum, and insufficient number of sites. Intense market competition has forced operators to consider approaches that can maximize returns from existing assets like spectrum and sites. The UMTS+ solution was developed in response to these requirements in this new era. Encompassing Spectrum+, Site+, Subscriber+, and Experience+, the UMTS+ solution enables operators to extract value from existing assets to maximize ROI and boost revenues.

Due to large user numbers and the late development of MBB, a huge latent demand for MBB exists, promising enormous potential demographic dividends for operators. According to GSMA, the number of UMTS users will grow to nearly 4 billion between 2016 and 2020, a threefold increase. And most of these users will be in developing countries.

The rising popularity of new social media applications like Instagram and Snapchat has seen users leaving more established brands like Facebook and Twitter in developed markets, spurring the latter to invest in emerging markets. However, today's Facebook is more than the simple message-based social media platform it once was, as it now incorporates new types of media such as video ads and live broadcasts.

This has led to a surge in network traffic in developing nations. According to Huawei's projections, MBB traffic in these markets will see a sevenfold increase over 2016 levels by 2020.

Ubiquity with Spectrum+

Spectrum scarcity has become a major challenge for developing nations. According to Huawei's statistics on spectrum resources around the world, developing countries can only provision half as much spectrum as developed ones. Moreover, 42 percent of the world's operators have only 8 MHz of spectrum at the golden 900 MHz spectrum. Operators urgently need new tech that can enhance spectrum utilization to help them increase ROI.

The low-frequency 900 MHz band is crucial for MBB broad coverage. Traditional technology requires at least 7.4 MHz of spectrum for 2G and 3G to coexist on the 900 MHz band. Huawei's Spectrum+ solution utilizes powerful narrowband and broadband interference suppression technology to enable 2G and 3G subscribers to coexist on a minimum of 5 MHz of spectrum. The solution boosts MBB capacity by 40 percent or more on the same amount of spectrum, meaning that operators never have to choose between 2G and 3G.

Agile sites with Site+

Globally, there are on average 1,000 sites per 1 million people, but

in some developing countries this number drops to as low as 100 to 200. Indeed, the biggest obstacle to expanding MBB coverage in emerging markets is the lack of sites and difficulty of deploying new ones. Huawei's Site+ solution was designed with such situations in mind, applying sector splitting technology to maximize single site efficiency. The split antenna multi-sector solution can increase the number of sectors in a cell from three to six, or even nine, boosting capacity by up to 2.2 times. With 3D-sector technology, capacity can be enhanced by as much as four times, greatly increasing single site capacity. The solution has been deployed by over 70 operators around the globe, boosting UMTS network capacity by an average of 70 percent.

The Site+ solution also includes agile site addition capabilities to facilitate new site deployment, reduce equipment and labor costs, and simplify site acquisition. The solution offers a number of different types of sites, including street light and underground sites. Street light sites are installed inside the existing municipal structures. Underground sites make use of underground-type APM30 cabinets that contain equipment, including the RRU RF module, power supply, and batteries.

By using the underground site solution, VIVO Brazil was able to obtain a site construction license in a month, 95 percent quicker than normal. It was then able to complete site deployment in 15 days, 75 percent faster than normal. Site construction costs and site rental fees were halved. The underground cabinet solution helped VIVO improve its network capacity by more than 30 percent, without negatively impacting the visual environment around the Olympic sites in Brazil.

Demographic dividends with User+

At Mobile World Congress 2016, Facebook CEO Mark Zuckerberg called for the development of network infrastructure to bring the Internet to more people, showing his awareness of the vast potential of developing countries. As of 2016, 40 percent of people in emerging markets are still unconnected to the Internet, with the vast majority still on 2G networks. Quickly migrating 2G subscribers to MBB networks would increase operators' demographic dividends.

Huawei's User+ solution uses visualization tools to identify the high-value customers that operators should prioritize for migration. Subscribers who consume large amounts of data every month, even on 2G networks, have demonstrated a willingness to use MBB. Another type of potential MBB subscribers are those using 3G handsets on 2G networks. With reasonable tariffs, this type of customer will also quickly migrate to 3G.

Several operators have adopted the User+ solution with great success. Thailand AIS completed the migration of 5 million 2G subscribers to 3G in five months using a subscriber migration strategy with four main measures: 1) Network level: increase coverage in areas of poor coverage and reduce 3G subscriber fallback; 2) Flexible planning: set different plans for

different user groups to appeal to more subscribers. 3) Precise user migration: employ telephone consultants or over-the-air technology to migrate subscribers using smart devices. 4) Economical MBB terminals: work with vendor partners to launch low-cost smartphones.

The entire migration process went without a hitch. A survey showed that 81 percent of subscribers enjoyed an improved 3G network experience post-migration, and 97 percent were satisfied with the migration process.

HD and more with Experience+

As IMAX cinemas show, users will pay for great quality. Similarly, operators are switching focus from KPIs to user-oriented KQIs. A good network today is not simply one that lets subscribers connect or doesn't drop calls; it must also be able to deliver a great voice and data experience, including HD voice and video.

Immersive HD voice

In developing countries, up to 80 percent of operator income still comes from voice services. However, with the rise of OTT apps, they aren't the only choice. Moreover, apps are available that test network quality, while independent testing organizations and government bodies also regularly test network quality, with voice quality being the most important metric.

Huawei's Experience+ solution leverages the 3G wideband AMR codec, together with "crystal-clear voice seamless coverage" and "crystal-clear deep coverage" software capabilities, providing subscribers with an MOS 4.0 immersive HD voice experience. In Switzerland, an independent Swiss authority ranked the operator Sunrise first in voice in 2015, up from third three years earlier. It achieved this by quickly improving its network capability with the HD voice solution.

1080p HD for growth

Operators are already switching their focus to video services. Even in developing countries, data traffic from video is surging. In Egypt, for example, traffic from video services grew from 21.5 percent to 30 percent in the span of a year. Huawei predicts that video services will account for over 50 percent of data traffic in emerging markets by 2020. Boosting service experience will help operators raise their brand equity with high-end subscribers.

A common misconception is that HD video requires super high rates. With Dual-Cell High Speed Downlink Packet Access (HSDPA) or Dual-Band (DB) HSDPA, 3G peak rates can hit 42 Mbps, which easily satisfy 720p and even 1080p HD video requirements. The H.265 video standard halves the required speed for HD video, enabling HD videos to be streamed over 3G networks without difficulty.

Peak rates aren't the only factor that impact HD experience for users. Video experience at cell edges is also the key to user satisfaction. A lack of site coordination capabilities in traditional site tech can lead to poor user experience at cell edges, and in particular at site edges. In 3GPP, the X2 interface is a 4G element for communication between eNodeB base stations. In the UMTS+ solution, the technology is used between two 3G NodeB base stations. The UX2 interface supports cross-site DB HSDPA between two NodeB sites and upstream COMP, greatly increasing upstream and downstream throughput, enabling users at cell edges to enjoy 720p and 1080p HD video experiences.

With a huge demographic dividend still up for grabs, UMTS+ represents a milestone in the 3G MBB era. UMTS+ helps operators maximize the value of existing network assets and boost revenues, and builds networks to support MBB 2020 for all. Then, everyone can be connected and enjoy a better MBB experience wherever they are.

Up in the air with 5G

F-OFDM, SCMA, and Polar Code are the three key technologies that underpin Huawei's 5G new air interface concept. F-OFDM is a basic waveform technology that supports a unified air interface and uses flexible numerologies to enable radio slicing. SCMA and Polar Code increase the number of connections, reliability, and spectral efficiency.

By Zhang Dong

Air interface technology is the jewel in the crown that differentiates each generation of mobile communications. It also has the most contending technologies, each vying to emerge victorious as the 5G sky begins to clear thanks to 3GPP 5G standardization. Of these technologies, Huawei's series of new 5G air interface technologies is the star that's shining the brightest.

A matter of design

Requirements guide the goals and direction of 5G research. In June 2015, the ITU-R defined three main 5G application scenarios: enhanced mobile broadband (eMBB); Massive Machine Type Communication (mMTC); and Ultra Reliable & Low Latency Communication (uRLLC). The organization also defined 5G network capability requirements in eight areas, including throughput, latency, connection density, and spectral efficiency.

Future 5G services will be defined by three main characteristics, each of which will place different demands on air interfaces:

1. Diversity: All generations up to 4G focused on people-to-people communication via mobile Internet; but, 5G will need to enable the Internet of Things (IoT) and enhance mobile Internet.

An unparalleled flourishing of services and requirements will occur in the 5G era. We will see remote control applications that require ms-level latency; demand for gigabit broadband to support virtual reality (VR), augmented reality (AR), and ultra-high definition video; and LPWA IoT that will require millions of connections per square kilometer.

Air interface design will have to meet diverse, even conflicting, requirements. Revolutionary new 5G air interface technologies are needed to meet ITU's 5G requirements.

2. Long-tailed: 5G will expand the boundaries of mobile communications by embracing verticals and boosting their efficiency. Verticals have extremely varied requirements on mobile Internet services, and as typical long-tailed markets, bring in much lower revenues. The long tail structure dictates that it will be impossible to develop different air interface designs to suit each type of industry. Instead, it will require the use of different parameters (numerology) or radio slicing, so that the air interface can adapt to the requirements of different verticals.

3. Uncertainty: The next four to five years will bring a lot of uncertainty, and may include services that were impossible to predict. Therefore, we must consider what drives services as well as keeps our technology a little ahead of the industry. Future 5G services will be diverse, long-tailed, and hard to predict. This will require a new unified air interface that has a high degree of flexibility to adapt to different services. The new air interface design will need to improve spectral efficiency – always a goal of air interface design – given its importance in lowering operator network deployment costs and ensuring the maturity and

prosperity of the entire industry chain.

New 5G air interface: key enablers

To overcome the challenges described above, Huawei has proposed a new 5G air interface concept and a series of key enabling technologies, covering fundamental waveform, multiple access schemes, channel coding, access protocols, and frame structures. We've also carried out field tests and verification with pioneering operators.

Superstructure is determined by underlying infrastructure. The same applies in air interface design. This article will therefore explore new waveform, new multiple access, and new coding techniques, the critical new technologies of 5G physical layer design.

Filtered-OFDM: new waveform

Fundamental waveform design enables a unified air interface that supports flexibility and spectral efficiency. To illustrate the case for Filtered-OFDM, it's useful to explore the reasons why OFDM cannot meet 5G requirements.

OFDM modulation converts high-speed data into orthogonal sub-carriers via serial/parallel converters, and uses cyclic prefix (CP) to deal with Inter Symbol Interference (ISI). OFDM was widely used in the 4G era, but the technology's main problem was inflexibility.

In the 5G era, different applications will have very different requirements on air interface technology. The Internet of Vehicles, for example, requires ms-level latency and very short time symbol duration and TTI (Transmission Time Interval), requiring sub-carrier spacing with wide frequency division. In IoT's massive connections scenario, the overall system must handle a high number of connections even though data transmission from individual sensors is low. For frequency division configuration, this will require relatively narrow sub-carrier spacing. For time division, the ISI problem doesn't need to be considered, and there's no need to use CP because symbol length and TTI are sufficiently long. In addition, asynchronous operations save energy at the terminal side.

OFDM cannot meet these flexibility requirements. OFDM's time-frequency resource allocation is a fixed 15 KHz of frequency division on sub-carrier bandwidth, compared with MBSFN, which is 7.5 KHz. Once the sub-carrier bandwidth is determined, numerology such as time division symbol length and CP length are also basically determined.

If the system's time-frequency resources are like a train carriage, the OFDM solution is used to furnish it. OFDM can only provide seats (sub-carrier spacing) of a fixed size for all passengers regardless of whether they are fat, thin, rich, or poor. A train design like this would be illogical, insufficiently user-centric, and unable to meet people's diverse needs.

For 5G, the hope is to provide a variety of train seats (spacing) – hard, soft, sleepers, private compartments – all

flexibly customized based on passengers' height and size (service requirements), with whatever adjustments required possible. This would be like the Harmony Express of the China high-speed rail with its many customizable seating arrangements – this is the idea on which F-OFDM is based.

F-OFDM can provide different sub-carrier spacing and numerology for different services to meet time-frequency resource requirements. Sub-carrier spacing in different bandwidths no longer possesses orthogonal properties, so guard bandwidth needs to be used. For example, OFDM requires 10 percent guard bandwidth. Guard band guarantees the flexibility of F-OFDM, but does it lower spectral efficiency? In the past, there's always been a conflict between flexibility and system expenditure. But the optimized filter design of F-OFDM greatly reduces out-of-band leakage, and the spectrum spent on guard bands between different sub-bands can be reduced to around 1 percent, greatly increasing spectral efficiency and making it possible to utilize fragmented spectrums.

F-OFDM has inherited all the advantages of OFDM like high spectral efficiency and MIMO adaptability, but also addresses some of its flaws by boosting flexibility and spectral efficiency. Thus, it's a key technology for 5G air interface slicing.

New multi-access: Sparse Code Multiple Access

Sparse Code Multiple Access (SCMA) determines the allocation of air interface resources, and is thus a key technology for increasing the number of connections and spectral efficiency. With F-OFDM enabling flexible multiplexing on frequency division and time division and minimizing the use of guard bands, what other domains can multiplexing be applied to that further enhances spectral efficiency?

The two that come to mind are space domain and code domain. Spatial multiplexing MIMO was proposed during the LTE era; it will further flourish in the 5G era thanks to multi-antenna. As for code domain, the technique seems to have been forgotten in the LTE era, so can it be revived in the 5G era? In fact, this is what SCMA does by using sparse codebooks and sparse code multiple access (SCMA) to increase the number of connections threefold.

Returning to the train metaphor, F-OFDM adapts the seats (sub-carriers) according to passengers' needs (service requirements). To further enhance spectral efficiency, more passengers need to fit into a limited number of seats. For example, squeezing six people into the space of four seats sounds easy enough, and would increase the number of connections by 150 percent, but achieving it is another matter.

This is where low-density spread spectrum comes in. In this first key SCMA technology, the user data of a single sub-carrier is spread on to four sub-carriers, with six users using these four sub-carriers. The name refers to the fact that user data is only spread over two sub-carriers, with the other two sub-carriers empty. This is like six passengers sitting on four seats, with each passenger only able to sit over two seats at most. This is what the "sparse" in SCMA refers to. Why must it be sparse? If data were not sparsely spread, it would be spread over an entire sub-carrier. This would mean the same sub-carrier carrying the data of six users and there would be too much conflict and demodulating the data of the six users would be impossible to complete.

However, once six people sit on four seats, the space between them isn't strictly orthogonal. Each passenger occupies two seats, so the passengers cannot be distinguished by seat number (sub-carrier). On a single carrier, conflict

Using nonscheduling technology can greatly reduce data transmission latency to meet 1 ms air interface latency requirements.

still exists between the data of three users, so difficulties with demodulating the data of multiple users remains.

This is where multidimensional modulation (MD) – the second key SCMA technology – plays a role. MD is a very abstract concept because traditional IQ modulation only had two dimensions – amplitude and phase. So what do the extra dimensions represent?

Here we need to engage our imaginations a little. Imagine the process of an Alpha Centaurian alien opening up a proton into a 3D multi-dimensional circuit and then reducing the number of dimensions again. Eventually, a single proton is formed into an all-powerful computer, but the proton is still a proton, except its function has been greatly enhanced.

Similarly, through MD technology, it's still the phase and amplitude that are modulated, but the Euclidean distance between the constellation points of the multi-users is shortened, considerably boosting the performance of multi-user demodulation and anti-interference. Each user data uses sparse codebooks allocated by the system to carry out multidimensional modulation. The system knows each user's codebook, making it possible to demodulate different users when a non-orthogonal waveform is used.

This is equivalent to sticking coloured stickers onto passengers to identify them when it's no longer possible to do so by seat number; the stickers together with the seat numbers make it possible to distinguish the passengers.

In field validation tests under acceptable levels of complexity, a threefold increase in the number of upstream connections compared to OFDMA has been achieved using SCMA and non-orthogonal sparse code division, as well as significantly improved downstream user throughput (over 50 percent) using non-orthogonal code division and power division multiplexing. In addition, because SCMA allows a certain level of conflict between users, using non-scheduling technology can greatly reduce data transmission latency to meet 1 ms air interface latency requirements.

New coding technology: Polar Codes

The ultimate goal of Polar Codes – Shannon capacity: The goal of channel coding is to ensure the reliable transmission of information using the least amount of resources. At a particular error rate, the smaller the amount of resources needed, the higher the coding efficiency, and hence the higher the spectral efficiency. For researchers of channel coding techniques, attaining the Shannon limit is the ultimate goal.

So what is the Shannon limit? Shannon's second theorem states that as long as the information transmission rate is less than the channel capacity, a type of code exists that can enable the information transmission error probability to be made arbitrarily small. In the narrow sense, the Shannon limit describes the minimum signal-to-noise ratio (SNR) required to achieve error-free

transmission using a code. For example, the Shannon limit of an AWGN channel under ideal circumstances is around -1.6 dB. In practice, however, the cost of achieving error-free transmission is too high. In the general definition of the Shannon limit, that's the minimum SNR required for a particular acceptable error rate.

Communications can be likened to logistics. In logistics, the goal is to transport goods to an end point. Take the example of a glass factory, a shipment of glass products needs to be sent from A (information source) to B (information sink). The road between A and B is equivalent to the channel, and the potholes and bumps along the road are channel noises. To reduce the amount of losses due to breakage (errors) during transport, the products need to be packed into cardboard boxes (coding) and then unpacked at point B (decoding). Although packaging (coding) increases overheads and reduces the number of products that can fit into each container (information payload), the method greatly reduces breakage rates (bit error rate). When there is an allowable breakage rate (bit error rate), improving the packaging (coding) method can minimize requirements on the road and transport vehicle (SNR). This minimum requirement (minimum SNR) is the Shannon limit.

Shannon's theorem posits the existence of such a code, but doesn't explain what code can achieve this. This has frustrated coding scientists who, for the past 50 years, have proposed multiple error correction coding techniques, including RS, convolutional codes, Turbo codes, and LDPC codes, which have been widely applied in different kinds of communications systems. However, no code has been able to achieve the Shannon limit, until the introduction of Polar Codes.

Basic principle of Polar Codes: Erdal Arikan, a professor at Turkey's Bilkent University, proposed the concept of channel polarization in 2007. The theory outlines the first known demonstrable channel coding method to achieve the Shannon limit, which Arikan termed Polar Codes. This discovery was a major breakthrough in coding theory. Polar Codes have clear and simple encoding and decoding algorithms, and the error correction performance currently achievable by Polar Codes is superior to the widely used Turbo and LDPC codes.

To understand Polar Codes, we must first understand the concept of channel polarization. As the term suggests, it involves polarization of the channel and refers to a group of independent symmetric binary-input discrete memoryless channels that use the coding method to enable different sub-channel reliability. When the code length is increased, a ratio of the channels become perfect (error-free), while the rest become pure noise channels.

Continuing with the example of the glass factory, the original packaging method (coding method) makes it impossible to predict the location of products that will break during transport. But with a Polar Codes packaging method, it's possible to guarantee that a certain proportion

When standards are defined, all technologies and directions are worthy of respect and remembrance as the produce of wisdom and for their role in driving 5G advancement.

of products in a certain location won't be damaged during transport (perfect channels) no matter how bumpy the road, while the rest in the other locations will certainly break (pure noise channel). This characteristics of channel polarization allows products (information bits) to be placed in the perfect channel and nothing (constant bits) in the pure noise channel location. And because the distribution of the perfect channel is known when the goods are packed, decoding when unpacking them becomes much simpler. In fact, improved Successive Cancelation List (SCL) decoding algorithms for Polar Codes approach the performance of maximum likelihood decoding with acceptable complexity.

The advantages of Polar Codes are: 1) higher gain than Turbo codes: In actual measurements under equivalent error rate, Polar Codes have 0.5-1.2 dB lower SNR requirement than Turbo codes, and higher code efficiency means increased spectral efficiency; 2) Thanks to Hamming distance and strong SC algorithm design, Polar Codes have no error floor and reliability is much better than Turbo codes. (Turbo codes use sub-optimal algorithm, and thus have an error floor). For the ultra-high reliability requirements of 5G service applications (such as remote real-time control and driverless vehicles), Polar Codes support 99.999% reliability, ensuring reliability for vertical industries; 3) Polar Codes use a SC-based decoding scheme that significantly reduces decoding complexity; terminal power consumption is therefore much lower, 20 times lower in fact than Turbo codes under equivalent complexity. This greatly extends the battery life of IoT sensors, which demand ultra-low power consumption.

Some things bear repeating: F-OFDM is a fundamental waveform technology for supporting a unified air interface that uses flexible numerology to enable air interface slicing. In addition to F-OFDM, SCMA and Polar Codes enhance the number of connections, reliability, and spectral efficiency, meeting ITU's 5G capability requirements. These are the three key technologies underpinning Huawei's new 5G air interface concept.

Competition drives 5G

The curtain has just been pulled back on 5G and we stand on the cusp of a great era. In each generation of mobile communications, there are competing directions and candidate technologies.

Ultimately, the best directions and technologies survive the filters of theory, practice, and market. Through integration and validation, they are transformed and proliferate, leaving an indelible mark on the world.

When standards are defined, all technologies and directions are worthy of respect and remembrance as the producers of wisdom and for their role in driving 5G advancement. Let's look forward to the new super connected world of 5G.

Wagenia man fishing in the Congo River

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