HUAWEI

Five Trends to Small Cell 2020

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Table of contents

CONTENTS

Introduction

With the surging popularity of wearable and implantable devices and the growing penetration of smart devices, the number of global MBB users is set to grow from 3 billion in 2015 to 6.7 billion in 2020. The rising popularity of 2K and 4K videos, HD VoLTE, and VR will create a tenfold data volume consumption per user increase and hundredfold rate increase to 1 Gbps. The accelerating urbanization, particularly in China, Southeast Asia, and South Pacific, will surely create even more hotspots. In these hotspot areas, data traffic is 3 times the average for the entire network, rising to 20 times in extreme conditions such as sports stadiums.

Figure 1-1 Challenges for MBB networks by 2020

Post-industrial societies are best characterized by their tertiary industries, of which the service, entertainment, and healthcare sectors hold dominant positions. Mobile broadband (MBB) networks play an important role in the service sector. Radio communication networks are moving toward cellular Internet of Things and capability openness. This trend presents amazing opportunities to tap the full potential of network infrastructure and allows for new service models that help further increase revenues.

These demands represent formidable challenges for the capabilities and construction modes of existing cellular networks.

- MBB networks must provide copious traffic bandwidth, extensive coverage, and cost-effective connectivity to countless devices.
- New service models require a new industry ecosystem. MBB networks must help redefine business models to present considerable benefits to partners of the industry chain.

Small cells feature greener, more efficient deployment. They facilitate network convergence, and have already proven optimal to improve spectral efficiency and user experience in hotspot areas. Their commercial deployment over the past few years has demonstrated the potential of small cell solutions. In scenarios, indoor and outdoor alike, such as sport stadiums, transportation hubs, shopping malls, CBD areas, residential areas, and commercial streets, small cells significantly improve user experience and fully unlock the potential of service creation. Small cells help lay a sound foundation for sustained, rapid growth of MBB traffic and offer big returns to operators.

Small cell networks register rapid growth and play an increasingly important role in the entire network. To find small cell solutions that best support network development is already a focal issue of the industry. This document concentrates primarily on five major trends of small cells toward 2020 from the perspective of technical evolution and business modes.

- Trend 1: A shift toward digital solutions will facilitate the transformation of indoor coverage systems to accommodate high definition voice and video services to sustain and further improve upon MBB industry growth.
- Trend 2: Small cells will achieve higher integration, allowing for multimode, multiband deployment to leverage site

resources. Small cells are able to provide wireless backhaul, which allows for better blending into surroundings while facilitating site deployment.

- Trend 3: Support for licensed-assisted access (LAA) and LTE +Wi-Fi link aggregation (LWA) allows for combined deployment of licensed and unlicensed spectra to maximize spectral efficiency and rapidly improve user experience.
- Trend 4: Small cells will be deployed closer to end users, which allows for increased value-added services, while creating new business models and contributing to the construction of a new industry ecosystem.
- Trend 5: Small cell network controllers will be constructed on new architecture and allow a large number of small cells to be supplemented on existing networks at reduced TCOs to provide added "pipe" services.

Trend 1: Indoor Digitalization to Drive MBB Upgrade

Increasingly diverse MBB services are changing the patterns of user behavior significantly. Indoor scenarios are seeing constantly growing traffic and connections. More and more new service models are emerging indoors. This is especially true in indoor traffic hotspots, such as stadiums and airports, where the traffic is dozens or even hundreds of times the traffic found in suburbs. Approximately 80% of traffic over the entire network is generated indoors, of which 70% to 80% is carried over outdoor macrocellular networks. In these scenarios, numerous walls and other physical obstacles weaken indoor coverage, adversely affecting user experience and reducing traffic. In-building coverage systems are constructed for a very small proportion, approximately 1%, of hotspot areas. New developments, such as the Internet of Things (IoT) and the smart home, are breeding huge markets for indoor mobile broadband networks.

Cellular networks, which were originally designed for voice services are inadequate to satisfy the growing requirements for HD voice and video and future digital services. A shift toward digital networks in indoor scenarios will be inevitable for long term MBB network development. Indoor digital networks, just like running water and electricity, will be regarded as an indispensable prerequisite during the planning and selection of buildings.

Indoor Scenario	In-building System Penetration **Y2014**
Office/Corporate Campus	0.70%
Retail/Shopping Malls	0.80%
Healthcare/Hospitals	2.20%
Airports/Train Stations	3.20%
Manufacturing/Industrial	0.40%
Hotels/Resorts	2.40%
Sports Venues/Stadiums	1.30%
Universities/Educational Institutions	0.40%
Government/Municipal	0.50%
Parking Structures/Underground/Tunnels	0.50%

Table 1-1 Indoor coverage market opportunity
Source: Statistics from Huawei mLAB

• Traditional DAS Falls Short of MBB Development

Distributed antenna systems, originally designed for indoor coverage enhancement, support voice services and basic data services, and do not allow for smooth evolution to deliver high definition (HD) voice and video services. DAS requires demanding reconstruction to support MIMO and achieve LTE-level spectral efficiency. As diminishing spectral resource become an increasingly important issue, operators are experiencing varying levels of difficulty in the provision of additional carriers and frequency bands to DAS systems to respond to growing service requirements.

Traditional DAS is an analog system that uses a huge number of combiners and power splitters. This architecture does not support node-level monitoring and accurate traffic map, which proves to be an insurmountable challenge in the implementation of accurate capacity expansion. Traditional DAS systems do not support new indoor services like location-based service (LBS), which restricts MBB development and network capacity growth, and adds further challenges to network management, maintenance, and evolution.

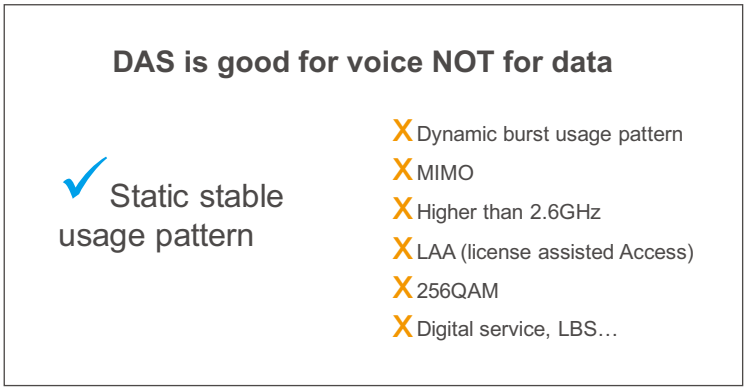


Figure 1-2 Support for data service development by DAS

• Digital Upgrades for Indoor Scenarios

Indoor scenarios are inherently more complex in comparison to that of outdoor ones. Indoor scenarios typically include large and medium public locations, small and medium enterprises, and homes, which vary in service requirements and need diverse solutions to cater for these requirements.

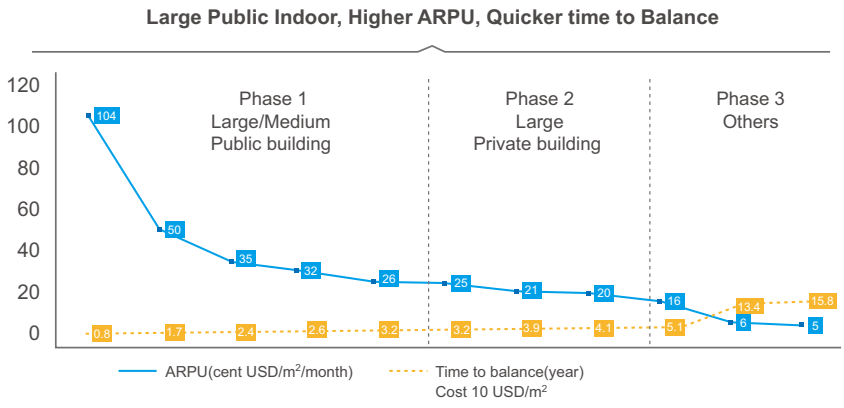
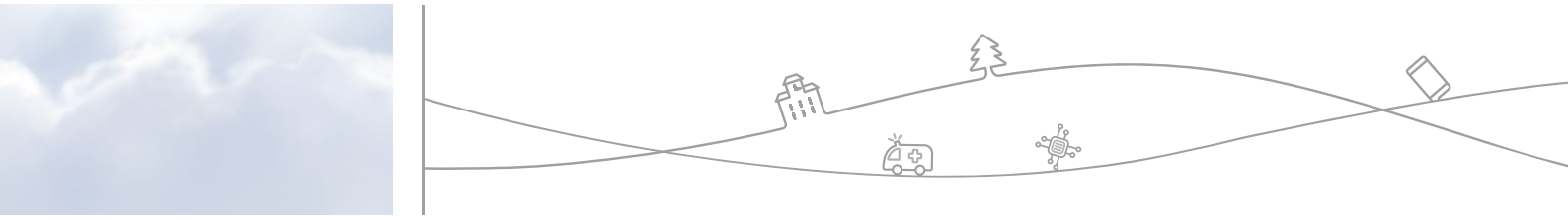


Figure 1-3 In-building system construction starting from large and medium buildings



Large and Medium-Sized Public Places

Large and medium-sized public places are typically characterized by vast coverage area and a high density of end users. Common examples are sports stadiums, transportation hubs, and shopping malls. Indoor systems designed for these locations must allow for high capacity, high mobility, and easy O&M. Based on cloud BB architecture, LampSite, a micro-powered distributed base station system, offers the following features to ensure user experience in this type of scenarios:

- Software-based configuration to provide scalable capacity planning
- End-to-end (E2E) graphical O&M to improve O&M efficiency
- Support for smooth evolution to, for example, distributed MIMO (D-MIMO)

User behavior heavily influences indoor MBB experience demands in comparison to outdoor experience. Indoor digital networks must have higher integration to ensure the increased utilization of frequency resources, particularly on high bands and unlicensed bands in particular, can be supported. Indoor examples must support software-defined radio (SDR) to facilitate smooth evolution. Unlike in outdoor scenarios, the radio environment of the air interface in indoor scenarios allows for use of more sophisticated technology, such as D-MIMO, 256 QAM, and LAA to improve network performance.

Following the deployment of LampSite, Beijing Capital International Airport, the world's second largest airport, registered a significant improvement in user experience and a considerable increase in data rates. The average data rate under the LampSite networks is five times higher than obtained using traditional DAS solutions. The network traffic increased by 27 times within one year of the LampSite deployment. Therefore, LampSite helps unlock subscriber demands and lays a solid foundation for rapid MBB development.

Small and Medium Enterprises

Small and medium enterprises (SMEs) typically encompass a coverage area below 5000 m^2. Common implemented examples are cafés, retail shops, and restaurants. In these types of indoor scenarios, the primary concern is to achieve a balance between network performance and TCO. Pico has proven to be an optimal choice for such scenarios. Synergy between Picos and between Pico and macro base stations is required to ensure network performance.

Due to varying rates of MBB development across regions, UMTS will continue to play an important role in the near term, and UMTS terminals still represent the mainstream in the following two years. Designed for hotspot coverage, Pico must support both UMTS and LTE and allow for use of software-based baseband technology to implement smooth UMTS evolution to LTE.

Network performance is the lifeline of operators. Pico must be constructed on Iub architecture to provide excellent mobility management and interference control between micro and macro base stations, as well as between Pico base stations. Such features constitute an important guarantee for network performance as a vast number of base stations are added to live networks.

There are significant capacity requirements in the SME scenarios despite having a relatively small coverage area. Due to technical and standard constraints, Wi-Fi is not a recommended choice for MBB services driven by HD voices and videos, especially in large-quantity user scenarios. Cellular networks can considerably address Wi-Fi issues and also improve the efficiency of unlicensed spectrums using LAA and LWA technology.

Pico must support multiband multimode deployment, network self-discovery, plug and play (PnP), and self-planning and configuration. Pico must be incorporated with Wi-Fi functions and can be deployed by reusing site, transmission, and power supply resources for Wi-Fi sites. This can allow operators to offer high-quality MBB services while maximizing the value of site resources.

Pico accommodates future network deployment by providing the following features:

- Support for multimode, multiband deployment and smooth network evolution
- Support for Iub-based architecture to guarantee network performance
- Incorporate Wi-Fi functions to allow for combined use of licensed and unlicensed spectral resources

Homes

Wi-Fi is still expected to be the mainstream MBB solution for home scenarios. Due to a lack of mature business models, mobile operators, despite a number of enthusiastic attempts, are still yet to enjoy substantial success in Femto solutions. LTE-based Femtos are emerging on the market over the past two recent years, but are still confined to existing business models. Although small amounts of success can be made in a number of specific cases, Femto is still in its infancy and is currently unable to replace Wi-Fi as the mainstream home-purpose solution for the immediate foreseeable future.

Trend 2: Multimode, Multiband, Backhaul Integrated Outdoor Small Cells to Match Diverse Site Resources

With rapid LTE development in recent years, users have a higher expectation on HD voice and video service experience. According to a forecast of 2K and 4K video service growth, guaranteeing optimal user experience will require a hundredfold increase in cell-edge data rates in 2020 from its rates in 2015. This will place greater demands on the network functions themselves and on the interconnection among networks.

Recently, an increasing concern over the radiation safety of macro base stations burdens the site acquisition for their deployment. Despite a potential 100% increase in the total number of global sites from 2015 to 2020, a huge portion of these sites are planned for small cells. With more high-frequency bands to be used, just deploying macro base stations will still leave a lot of areas uncovered. It is inevitable to use small-sized, low-powered small cells to improve user experience, particularly in cell-edge areas.

• Multimode, Multiband Small Cells Supporting Wireless Backhaul

According to studies, excluding small cell equipment, site and transmission resources constitute the largest proportion of total outdoor small cell deployment cost. Outdoor small cells can be deployed in large quantities only when the cost of site and transmission resources is significantly reduced.

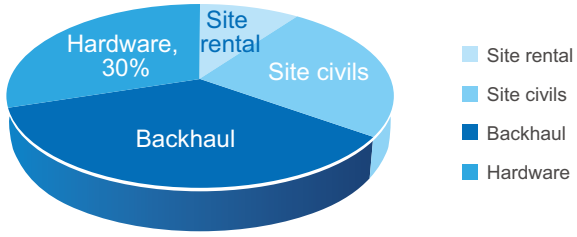


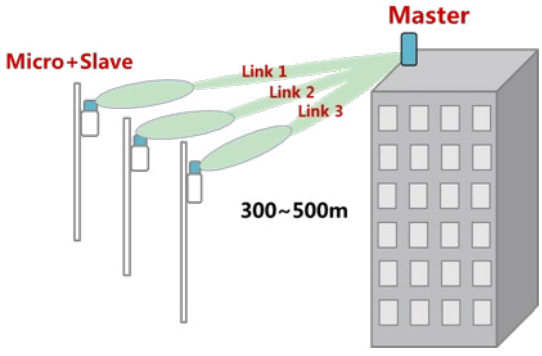
Figure 1-4 Cost structure of outdoor small deployment

Wireless backhaul

Transmission resources have been a key bottleneck for the deployment of outdoor small cells. In densely populated urban areas, it is difficult to achieve wired transmission for all sites. In this situation, we can use QoS-guaranteed wireless backhaul to reduce the deployment costs and difficulties, thereby speeding up the deployment of outdoor small cells. In non-line of sight (NLOS) scenarios, sub-6G wireless backhaul does not require new spectrum because macro cells with wide coverage can provide backhaul for small cells. This allows for flexible site acquisition for small cells. Wireless backhaul is integrated into base stations, site requirements are significantly lowered and the sites can better blend into their environment.

If the sub-6G spectrum is insufficient or legacy macro cells have high traffic load, the practice of using macro cells to provide backhaul will no longer work as the capacity demand on the macro site increases constantly. Considering the service data rate will reach 1 Gbps by 2020, small cells will need a stable, large-bandwidth wireless backhaul solution. Although the traditional microwave solution features large bandwidth and high reliability, slow deployment and high costs prevent wide scale deployment. In comparison, the V-BAND is easy to acquire and the transmission distance is reasonable (300 m to 500 m). As such, the V-BAND is suitable for small cell deployment in densely populated urban areas.

On the air interface, high-order modulation schemes enable high-performance data transmission, achieving a data rate of 1 Gbps within 300 m. In densely populated urban areas, small cells working together with short-distance high-frequency microwave backhaul based on 802.11ad/ay and mesh networking can resolve the backhaul problem in NLOS scenarios. This scheme dramatically lowers the deployment requirements on backhaul air interfaces and site locations, making transmission networking more flexible for small cells. Beamforming enables accurate, automatic antenna alignment and prevents link disconnections caused by the swaying of pole-mounted sites.



Architecture of Master-Slave for Micro with Wireless Backhaul

Multiband, Multimode Support

Along with rapid growth in capacity demand, network bandwidth is expected to reach 1 Gbps. This requires six carriers to be combined to generate a bandwidth of 120 MHz. Considering the spectrum discontinuity, the occupied bandwidth (OBW) will need to reach 600 MHz or more.

To meet this requirement, both macro cells and small cells must be able to support concurrent multi-band processing so that multiband, multimode deployment can be achieved through a single site visit. This is particularly important for small cells because secondary site visits for them are much more difficult than for macro base stations. As key components such as microchips and power amplifiers mature, small cells will take the lead in ultra-wide bandwidth technologies and in applications using higher frequency bands.

Crowdsourcing-like Site Solution

This solution allows operators to diversify site acquisition for small cells to substantially reduce deployment cost. Conventional cellular network construction revolves mainly around operators, vendors, and service integrators. The number of small cell sites is many times that of macro base stations, which emphasizes the necessity and requirement to introduce a new more efficient network construction mode.

Small cells are lower-powered and take little space, which contributes to significantly reducing the site requirements for deployment and expansion of site selection. Lamp posts, billboards, power poles, charging piles, and other similar assets can be used for the deployment of small cells. Through cooperation with proprietors, operators can obtain a large number of sites for small cells to further increase network construction and reduce exorbitant operating expense.

Figure 1-5 Deploying small cells on poles

Trend 3: Convergence of Licensed and Unlicensed Spectrum to Improve the Spectral Efficiency

Spectrum is a "natural resource" for mobile communications. The natural resource of licensed spectrum from 700 MHz to 2.6 GHz available for single operators is limited. If we rely only on licensed spectrum alone, we will be unable to sustain mobile broadband development over the next five years. However, there are plenty of unlicensed spectrums that we can

use. On the 5 GHz band, for example, more than 400 MHz of bandwidth is available, see Figure 6. Operators need to use appropriate technologies to fully utilize unlicensed spectrum, which is free.

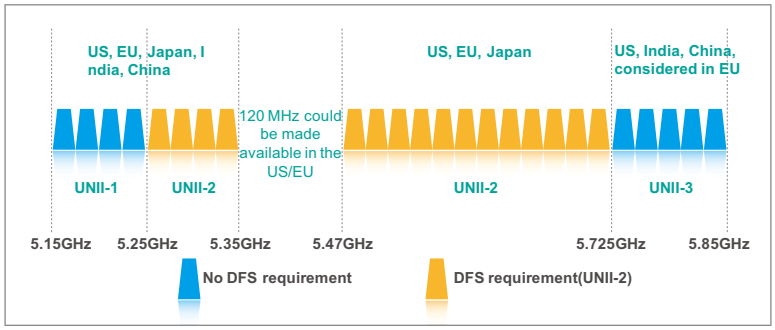


Figure 1-6 Unlicensed spectrum on 5 GHz

Convergence of Licensed and Unlicensed Spectrum Improving User Experience

Convergence of licensed and unlicensed spectrum combines the high-quality user experience delivered by the licensed spectrum with an effective boost of extra capacity from the unlicensed spectrum. On the licensed spectrum, an anchor is set up using LTE technologies, guaranteeing user mobility, service continuity, and transmission of important signaling messages. Meanwhile, unlicensed spectrum is used to provide additional system capacity.

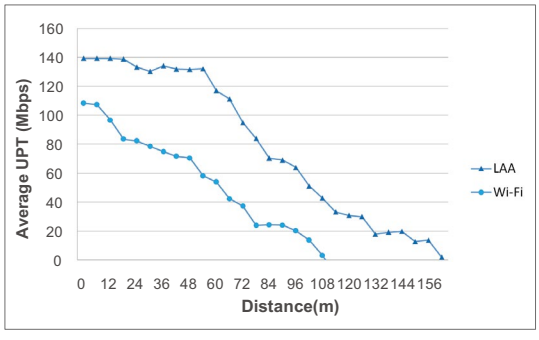
Spectrum Convergence Starting from Small Cells

Transmit power on unlicensed spectrum is limited and the coverage range is similar to that of small cells. Statistics on user behavior have indicated that more and more user connections are occurring indoors, and traditional unlicensed spectrum technologies are applied mostly to indoor scenarios. It makes sense to start converging spectrum in such situations. Spectrum convergence in small cells facilitates network planning and maximizes the utilization of unlicensed spectrum.

LAA Maximizing the Efficiency of Unlicensed Spectrum

LTE provides higher spectral efficiency and better coverage than Wi-Fi. In addition, LTE uses a solid mechanism to guarantee service quality. The mechanism provides differentiated user access policies for different user types and service types, ensuring good user experience. Licensed-assisted access (LAA) is an LTE technology that maximizes the efficiency of unlicensed spectrum, further enhancing the advantages of LTE over Wi-Fi.

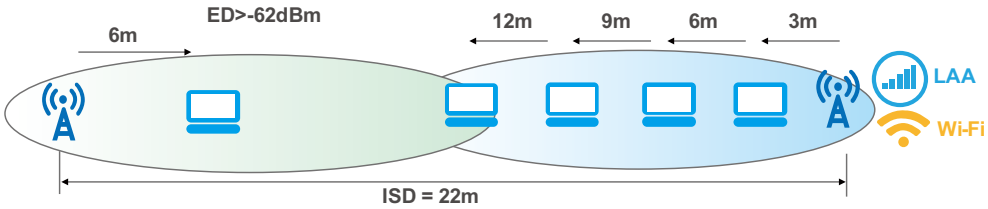
Spectrum convergence enables operators to reuse the legacy evolved packet core (EPC) and the billing system, which reduces costs. Although LAA depends on support from terminals, base stations still must support LAA. Site equipment can share the same boxes, transmission networks, and network management systems. In the future, operators will use software-defined radio (SDR) to enable LAA or LTE Wi-Fi aggregation (LWA).



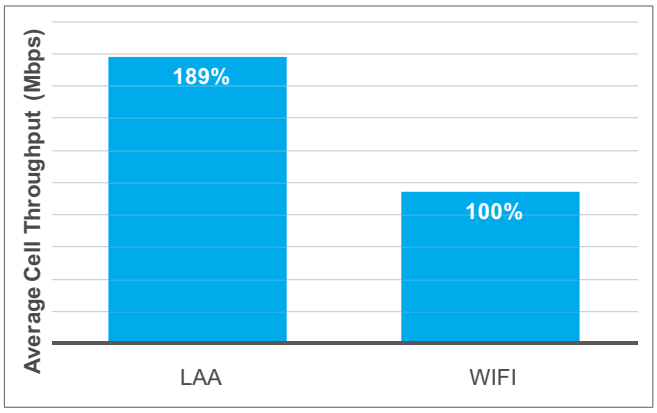
Experimental test results for LAA and Wi-Fi coverage

LAA Working Together with Wi-Fi

Because of a huge legacy market for Wi-Fi solutions, LAA and Wi-Fi will work together for a long time in the future. Therefore, spectrum etiquette must be observed on the unlicensed spectrum. Two LAA features related to spectrum etiquette, Cell On/Off and License before Talk (LBT), have been standardized in 3GPP Releases 12 and 13, respectively. In addition, Huawei and several top operators carried out a joint test, showing that LAA and Wi-Fi are compatible, and the interference between them is even weaker than the interference within Wi-Fi alone.



Very-dense indoor deployment for LAA and Wi-Fi co-existence



Experimental test results for LAA with baseline LBT and Wi-Fi co-existence

Continuous Improvement in the Efficiency of Unlicensed Spectrum

In the future, diversified spectrum technologies, especially dynamic spectrum sharing modes such as LSA, SAS, and CR, will make more unlicensed spectrum resources available, improving spectral efficiency. The licensed spectrum, licensed shared spectrum, and unlicensed spectrum will be better converged for small cells, helping operators deploy mobile networks with the best possible user experience.

Trend 4: Small Cells to Build Brand-New Business Models and Industrial Ecosystem

Small cells must blend into their environment. They are installed at lampposts, bus stations, billboards, and in buildings such as airports, shopping malls, stadiums, and office buildings. These sites are installed in locations owned by municipal authorities and building owners. Therefore, site deployment for small cells requires permission from property owners. This requires a business model much different from those for macro cells. Traditionally, property owners are not interested in site deployment and reconfiguration, because network coverage is not closely related to their main businesses.

When small cells create values for property owners, a new business model emerges. Property owners are encouraged to help improve network coverage and consequently the total cost of operation (TCO) for operators can be reduced. The open platform of small cells and indoor cellular Internet of Things are mission-critical in the new business model.

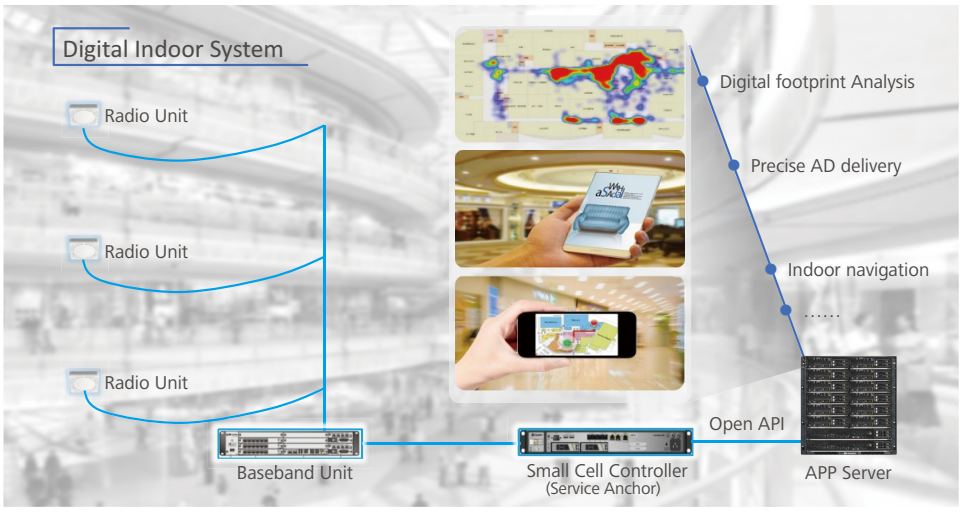
- Enabling network openness, providing value-added services, creating values for property owners

The open platform of small cells will build up a bridge upon which small cells and property owners provide value-added services to end users.

In the network planning of smart shopping malls, the indoor UE positioning capability on the open platform will be used by the third-party application developers or service integrators to provide indoor navigation, intelligent parking, and accurate information pushing services for consumers. In addition, consumer-based big data can provide analysis of passenger traffic and user consumption habits for store managers. In this way, a win-win industrial ecosystem can be created among operators, property owners, service developers, and service integrators.

- Indoor cellular Internet of Things adding values to network connections

Small cells are deployed close to end users, and therefore have natural advantages in the future Internet of Things. Extensive small cell deployments connect devices onto communication networks, helping operators build a successful Internet of Things. In the future, data transmissions for water supply valves, power supply switches, surveillance probes, and office devices will be carried on small cells. This means small cells will carry more network connections and increase the network value, raising revenues for operators.



New value-added service based on Indoor Digitalization

Trend 5: Ubiquitous Small Cells to Drive the Evolution of Network Architecture

With increasing deployment of small cells, the existing network architecture can barely meet the requirements of small cells in the next five years. An entirely new network architecture for small cells is needed. The new architecture will:

- Simplify the deployment and maintenance of large scale small cell networks.
- Improve the network performance and user experience of densely deployed small cells.
- Enable open pipelines, build new business models, and increase return on investment (ROI).
- Optimize the network interfaces and support massive connections from cellular Internet of Things.

To satisfy these requirements, we propose a small cell controller-based network architecture for small cells.

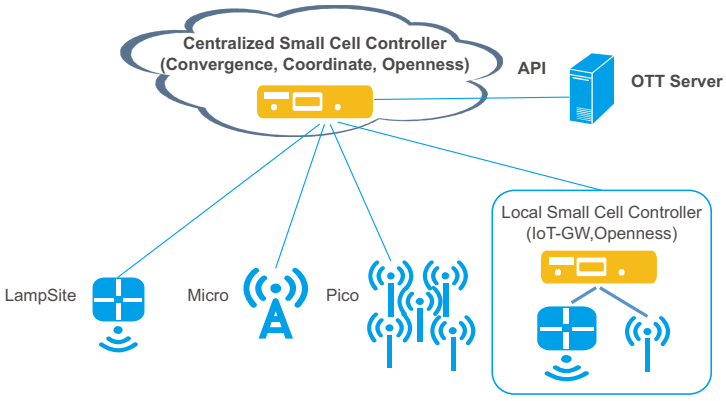


Figure 1-7 Small cell controller-based network architecture

• Small Cell Controller

As a critical node in the architecture, the small cell controller provides the following benefits for operators:

Networking Efficiency

The efficiency of service networking, transmission networking, security networking, and O&M networking for mass small cell deployments is improved.

- Introduction of small cell controllers reduces the need for upgrades of legacy macro cells, upgrades and capacity expansion of the core network, and reconfiguration of the live network. In addition, small cell controllers enable quick and efficient X2 networking.
- Small cell controllers enable small cells to be deployed quickly without the need to make any special allowances for transmission conditions.
- Small cell controllers make network deployment easier and more secure. They integrate the functions of the authentication server, the firewall, and IPsec.
- Small cell controllers organize small cells into groups to allow for centralized management and O&M, greatly simplifying these processes.

Network Coordination

Small cell controllers provide network coordination. This function uses joint scheduling to reduce inter-site interference within small cells, improving contiguous coverage performance. This function also supports inter-RAT network coordination, so that LTE and Wi-Fi can work well with each other to improve user experience by making full use of unlicensed spectrum.

Capability Openness

As a service anchor and interface gateway, the small cell controller forwards valuable data from digital pipelines to application servers, through application programming interfaces (APIs). End users subscribe to value-added services through application servers. This benefit stimulates the creation of new business models, expanding the potential of the wireless industry.

Cellular Internet of Things

Small cell controllers support services of the cellular Internet of Things through the service oriented RAN (SOR). In addition, small cell controllers combine the gateways of the cellular Internet of Things and the core network control units.

Summary

Small cells are playing an increasingly important role in mobile network development. To meet the requirements of future networks, small cells will support:

- Multi-frequency multi-RAT applications and unlicensed spectrum to maximize the site value
- Indoor digital solutions to enable smooth network evolution and improve the O&M efficiency
- Integrated wireless backhaul to improve environmental friendliness and reduce investment
- Controllers to simplify network deployment, improve network performance, enable open pipelines, and to carry the Internet of Things
- New services and business models which create value across a new, extended value chain.

HUAWEI TECHNOLOGIES CO., LTD.
Bantian, Longgang District
Shenzhen518129, P. R. China
Tel:+86-755-28780808

www.huawei.com