5G-Oriented Indoor Digitalization Solution White Paper

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A GSA White Paper Input with Huawei

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Preface

Mobile Broadband connectivity has now come of age. 4G/LTE, which is the fastest growing mobile technology of all time, is delivering, and continues to increase, the user's experience of anywhere, anytime, fast delivery of services and content while mobile.

4G/LTE and its technology incarnations to LTE-Advanced and LTE-Advanced Pro will be with us for many years and will be the bedrock that 5G is built upon. 5G will also bring the expansion of spectrum made available for mobile. Much of this spectrum will come from the millimetre band, which will present its own challenges with regard to indoor coverage. It is a challenge the industry and GSA member companies are focusing on and is also outlined and discussed in this white paper.

Indoor coverage is something the mobile industry will need to succeed at. The growth of demand in data usage is only expanding – and as yet there is no sight of this letting up.

——Joe Barrett, GSA CEO

Overview

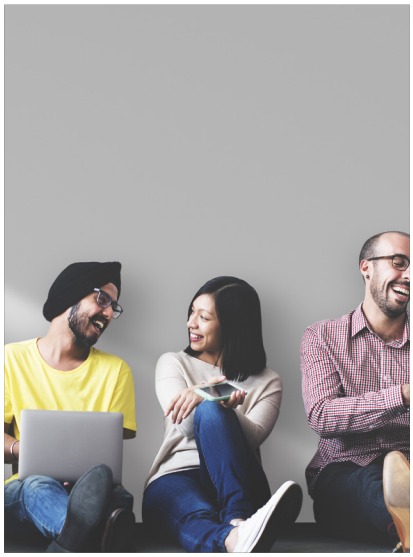
Mobile communication is developing rapidly. Cisco VNI Mobile data shows that the mobile data traffic will reach 11 Exabytes per month in 2017, two times of that in 2015, and this figure is expected to reach 49 Exabytes by 2021. According to the forecast of the International Data Corporation(IDC), a premier global consultation service provider for information technology, the worldwide shipment of smartphones will reach 1.52 billion units by 2017. The rapid development of mobile market has a higher requirement on network capacity, experience, speed, and ROI.

Statistics show 80% of 4G mobile services takes place indoors. Considering the diversified 5G mobile services and expanded mobile industry boundary, this figure will increase to 85%. Therefore, the quality indoor network will be the core competitive edge of mobile operators in 5G era.

How will mobile operators build 5G-oriented indoor mobile network? What are the network deployment criteria and benchmark services capabilities? What are the 5G evolution path and roadmap? These issues are now hotly discussed in the industry. This white paper tries to address these issues..

When the network evolves from 4G to 5G, it will face multiple challenges in indoor mobile network, such as user experience, capacity expansion, network coverage, intelligent O&M, and spectrum efficiency. Among the current mainstream indoor mobile network solutions, which one can better address the needs of future? Based on the overall technical analysis and comparison, this white paper concludes that digitalization is the way out for 5G indoor mobile work. The digitalization criteria and network deployment suggestions are also presented.

In parallel, this white paper points out the important role the industry chain should play for indoor digital transformation. Currently, the mobile operators, equipment vendors, integrated delivery providers, and services providers all come to understand that indoor digitalization is the way forward to 5G indoor network. All the involved industry partners need to work together to incubate the Small Cell technology innovation and strengthen joint cooperation, to prosper the better future of indoor digitalization industry.



5G Evolution Challenges of Indoor Network

3.1.Service Requirements

Traditional mobile network focus on voice and data services. 5G mobile network must address a diverse type of services, which present challenges in multiple dimensions as listed in Table 1.

a. High Speed

New services over 5G network, especially virtual reality (VR) and high-definition (HD) video services, are bandwidth heavy, with 100 Mbps required per connection.

b. High Flexibility

In hotspot areas, the resource demand of 5G services varies greatly from time to time, which requires network to be extremely scalable for dynamic and smart capacity expansions.

c. Massive Connectivity

In the 5G era, mobile services fuelled by growing the Internet of Things (IoT) will create an enormous number of ultra-high-density wireless connections, making interference and O&M issues even more challenging.

d. Latency Sensitive

In 5G, low-latency services featuring the Tactile Internet, e-health, and smart manufacturing increase challenges for network transmission. In the worst cases, the latency of below 1 ms is required, which is merely 1% of that in 4G. This requires a drastic change to the network architecture of 5G.

e. High reliability

5G network feature single-site short-distance communication. This makes reliability a demanding issue, particularly when it comes to high-speed mobility scenarios.

f. Openness

For expansions to public domains and vertical industries, 5G network must be open and friendly to support network slicing and diverse demands.

Table 1 5G Mobile Service Scenarios

Category	Characteristics	5G Mobile Service Scenarios		
Immersive Reality	High speed	Virtual Reality	Augmented Reality	Massive Content/ Video Streaming
Intelligence	High flexibility	User centric computing	Crowded area Service	
Omnipresence	Massive onnectivity	IoT	Smart City	LBS (Positioning)
Low Latency	Latency sensitive	Tactile Internet	Remote Surgery	Smart Manufacturing
Mobility	High reliability	Drone	V2X/Smart Transportation	Robot Teleoperation
Publicness	Openness	Disaster monitoring	Emergency service	Public safety/ Private safety

Source: 5G Service Roadmap 2022, 5G Forum, 2016

3.2. Explosive Capacity Growth

Mobile internet is rapidly developing. Huge bandwidth and capacity are already rigid demands for various new mobile services, including IoT, HD videos, and AR/VR. As shown in Figure 1, the data traffic over smartphones is expected to increase by 1100% by 2021. According to Cisco's VNI September 2017 report, the global mobile data traffic will grow by a compound annual rate of 47% in the next five years. By 2021, this amount will reach 49 Exabytes per month, in which equates to 250 million DVD disks. This high level of increases in capacity poses unprecedented challenges to mobile network.

At the same time, Cisco VNI reports forecast that above 79% of data traffic will be carried over 4G network by 2021 (Figure 3). This implies that 5G deployment and the massive penetration of 5G terminals are still a long time away and will require 5 to 10 years to take shape. This makes 4G network capacity expansions only available option to sustain fast capacity growth. Therefore, 4G network must be architecturally flexible to support fast and enormous capacity expansion for a smooth transition to 5G.

Figure 1 1100% growth of global data traffic over smartphones by 2021

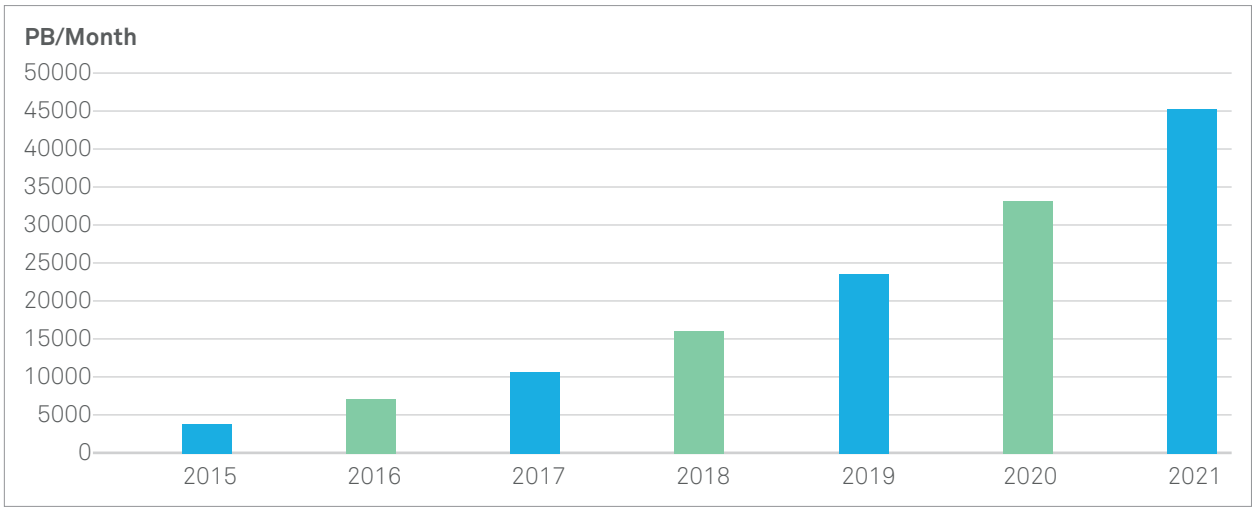
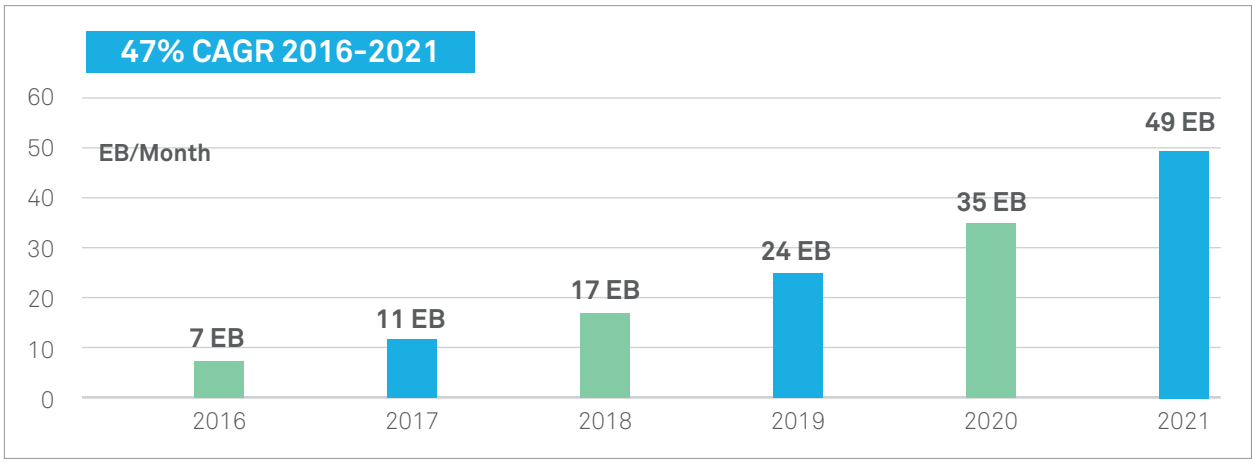
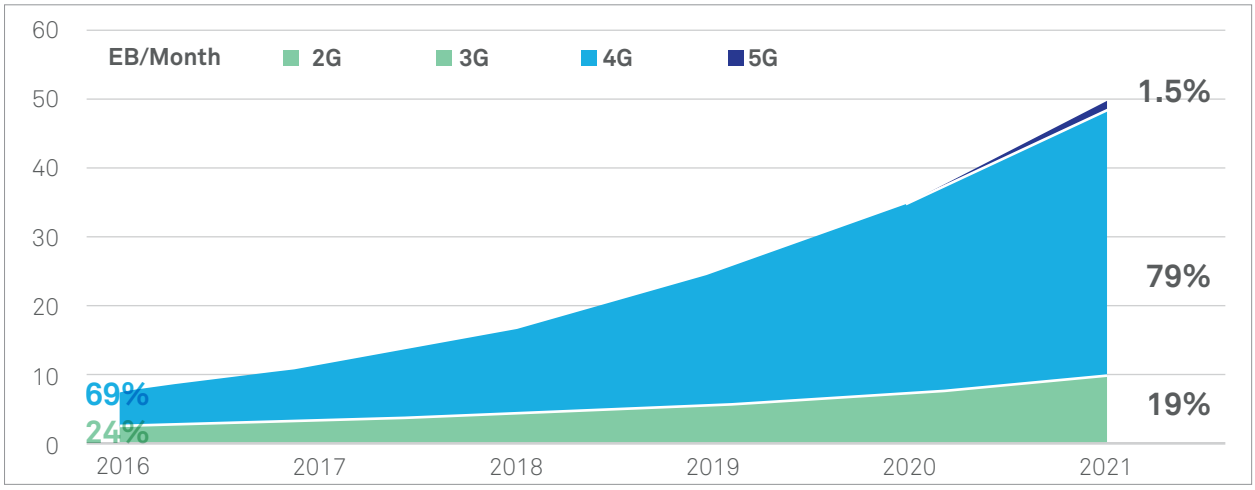


Figure 2 Monthly mobile data traffic forecast by 2021



Source: Cisco VNI, 2017

Figure 3: Global mobile traffic by connection type

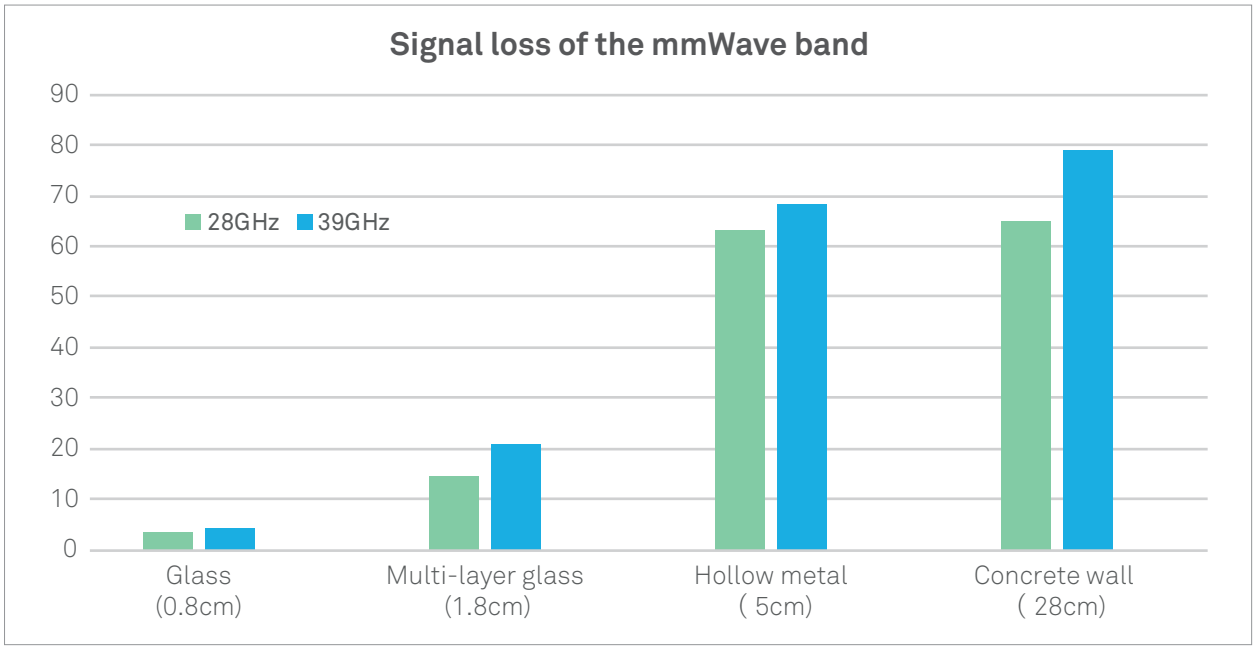


Source: Cisco VNI, 2017

3.3. High Band Leads to Weaker Indoor Coverage

5G mobile network use C-band and mmWave that are on much higher frequency bands than 2G, 3G, and 4G counterparts. Higher frequency bands lead to greater link losses. For example, outdoor signals on the C band will be subject to an 8 to 13 dB link loss when penetrating through one concrete wall. The signals on the higher mmWave band will experience difficulty in penetrating through a wall as the link loss exceeds 60 dB (see Figure 4). It is a considerable challenge for outdoor 5G macro signals to cover indoor areas, and dedicated network will be required for indoor environments. 5G dedicated network for indoor settings must be built in parallel with outdoor 5G network to meet the potentially huge bandwidth demand while ensuring superb 5G services.

Figure 4 Path loss of 5G mmWave signals when penetrating various walls (Source: Huawei X-Labs)

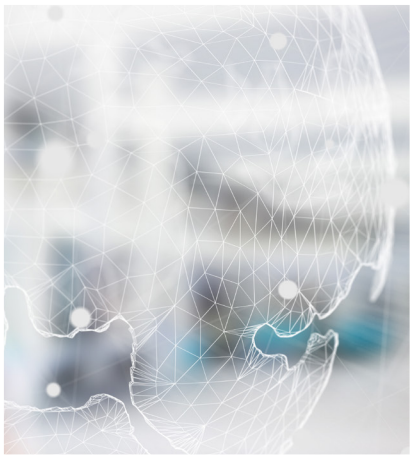


3.4. Intelligent Network O&M

Indoor network deployment requires coordination with property owners for site access, complex installation and commissioning, and costly on-site maintenance. Traditional indoor network do not support visible monitoring. In this context, fast deployment and visible O&M will be basic requirements in indoor environments. In 5G, dense deployment will be common, and this will result in a drastic increase in the amount of network equipment. How can the massive number of head ends in indoor network and the status of other network elements be monitored in real time? How can network resources be assigned as well as automatically optimized in response to user density and channel conditions? How can visualized O&M, fault diagnostics, and self-healing be realized? The answers will certainly have a direct bearing on labour costs and network operating expenditure (OPEX) of operators. In this sense, smart O&M will be one of prerequisites for future indoor network.

3.5. Summary

To address the various challenges of indoor mobile network in 5G, operators need to take proactive approach to plan and design the current network at the most cost efficient manner, so as to provide the best user experience and maintain the competitive edge.



5G-Oriented Indoor Evolution Solutions

Looking ahead, operators must address the paramount challenges of meeting the demand for proliferative mobile data traffic, constantly denser connections, increasingly shorter latency, and growing accuracy of positioning while achieving a smooth evolution to 5G.

4.1. Target of Indoor 5G Network

» 4.1.1. Specifications of Indoor 5G Network

The ITU Radio-communication Sector (ITU-R) proposed that future's 5G network must meet the following minimal requirements, as listed in Table 2. These aspects will help ensure a consistent service experience in both indoor and outdoor environments.

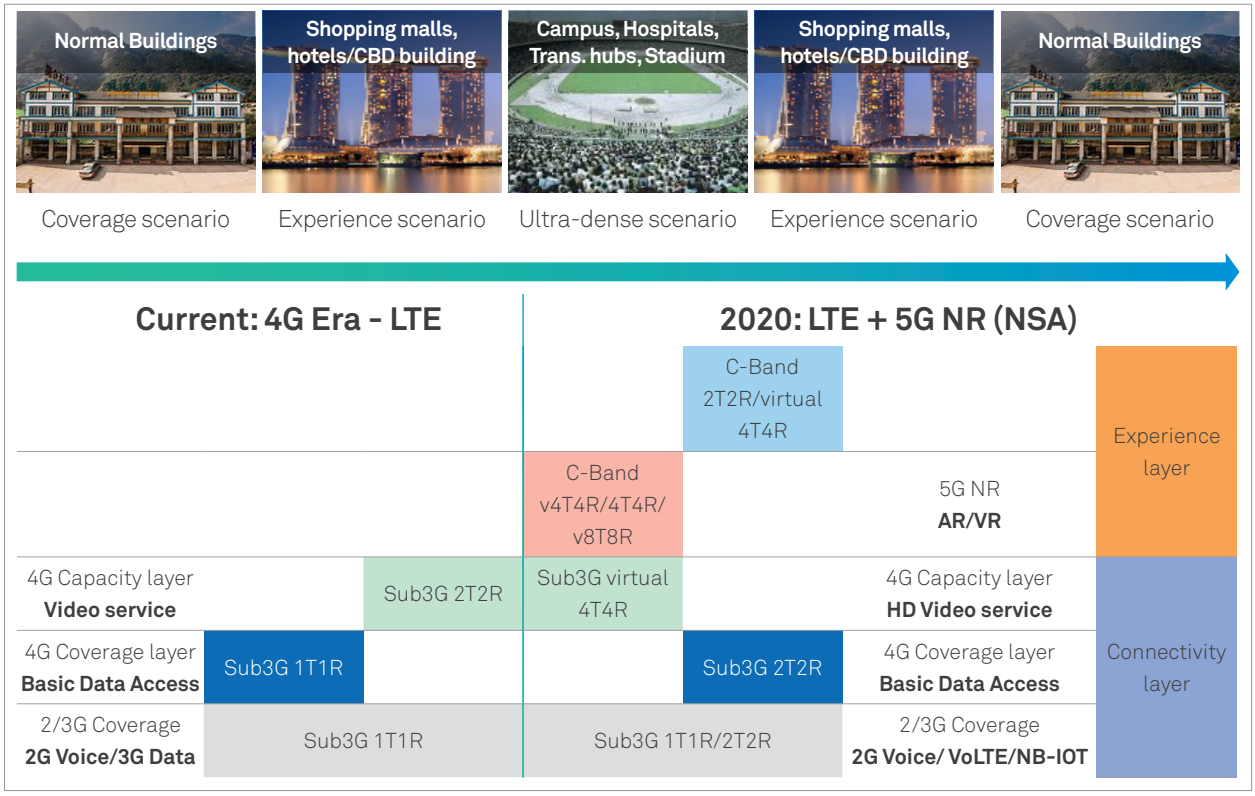
Table 2 New ITU Report on IMT-2020 Minimum Requirements

Metric	Requirement	Comments
Peak Data Rate	DL: **20 Gbps** UL: 10 Gbps	Single eMBB mobile in ideal scenarios assuming all resources utilized
Peak Spectral Efficiency	DL: **30 bps/Hz** (assuming 8 streams) UL: 15 bps/Hz (assuming 4 streams)	Single eMBB mobile in ideal scenarios assuming all resources utilized
User Experienced Data Rate	DL: 100 Mbps UL: 50 Mbps	5% CDF of the eMBB user throughput
Area Traffic Capacity	Indoor hotspot DL: 10 Mbps/m^2	eMBB
User plane latency	eMBB: 4ms URLLC: **1ms**	Single user for small IP packets, for both DL and UL (eMBB and URLLC)
Control plane latency	20ms (encouraged to consider **10ms**)	Transition from Idle to Active (eMBB and URLLC)
Connection Density	1M devices per km^2	For mMTC
Reliability	99.9999% success prob.	32 L2 bytes within 1ms at cell edge
Bandwidth	>100 MHz; up to **1 GHz in > 6 GHz**	Carrier aggregation allowed

» 4.1.2. Indoor 5G Network Layering

In the forthcoming 5G era, network will comprise an infrastructure layer and an experience layer. The infrastructure layer will use the sub3G bands and exist for a long period of time in the form of 2G, 3G, and 4G network to provide access to voice and basic data services. This will allow the remaining newly introduced C-band spectrum resource to provide air interface access.

Figure 5 Network layering of indoor 4G-to-5G evolution



4.2. 3 Steps Toward 5G Network

Over the course of smooth evolution to 5G, there are steps for operators to ultimately build fully comprehensive 5G indoor network.

a. Bring 5G features into current indoor network

For current indoor network, 5G-centered transition can be characterized several aspects. They include a peak data rate at the Gbit/s level, a traffic density at the Mbps/m2 level, active antenna, visualized O&M, fibre-based transmission, and support for value-added services. Transitioning to 5G from current indoor network will be the most feasible solution to protect operator's investments and meet the needs for new services.

5G-centered transition in indoor network helps develop user behaviour patterns for 5G services and accelerates industry-wide digital transformation and upgrades. It allows operators to invest on future network and services in advance, which benefits both users and operators. In addition, this can continually add to the improvement in the performance of indoor network infrastructure, while laying a solid base for transitioning to and upgrading 5G network.

b. LTE and 5G NR Co-existing in early 5G deployment

In the early stages, 5G NRs will be overlaid on existing LTE network to cover capacity-hungry hotspots that have a high density of users. As 5G moves on, 5G NRs will be deployed in some parts of an area and progressively be expanded to cover the entire area. It is safe to predict that full 5G network coverage will not take shape within a short period of time. This makes it necessary to continue investing in existing LTE digital indoor distributed network to deliver a high-quality basic coverage network within a specific area. This can also help ensure consistent experience between indoor and outdoor scenarios. In addition, 5G terminals need time to mature and rise in popularity. Before 5G terminals enjoy 100% penetration, existing LTE network can continue to serve 4G users. By integrating with 5G NRs, LTE can still play a huge role in enabling a seamless mobile experience.

c. Converge to Full 5G NR indoor network after 5G terminals are universally available

When 5G terminals are relatively mature and considered completely universal, existing indoor network built using a digital framework can be rapidly upgraded to 5G NR indoor network. Existing digital indoor distributed network deployed during the early phases of 5G can be reused and smoothly transition to 5G network. This can help protect early investment and maximize the return.



4.3. 5G Evolution Support Comparison of Indoor Coverage Solutions

Table 3 lists the support of common indoor coverage solutions in evolution to 5G network.

Table 3 Comparison of various indoor coverage solutions in support for evolution to 5G

Solution	Outdoor-to-Indoor	Wi-Fi	Traditional Indoor	Digital Indoor
Business growth	X	X	√	√
Network capacity	X	√	X	√
Indoor coverage	X	X	√	√
Smart O&M	√	X	X	√
Value-added services	√	√	X	√
Evolution friendliness	√	√	X	√
Investment return	√	√	X	√

2G and 3G network operate on low frequency bands, and this promotes feasibility to use outdoor signals to serve indoor subscribers. In the following 4G era, although outdoor signals can provide coverage in parts of indoor areas, in-depth indoor coverage requires dedicated indoor distributed network. As we move to 5G, there will be an upsurge in bandwidth needs and 5G network will use C-band and mmWave bands. One ensuing result is that using outdoor signals to serve indoor users will no longer be suitable since this methodology cannot meet the requirements of service, capacity, and coverage.

Though Wi-Fi will be used in privately-owned small areas, such as homes and residential areas, this solution cannot ensure interference immunity, mobility, coordinated networking, low latency, and network O&M due to inherent defects. When used to provide 5G services, it cannot fulfil the QoS requirements in a wide range of other areas.

In public indoor locations, both traditional and Digital Indoor distributed solutions can be suitable alternatives for operators. Traditional indoor distributed solutions, (originating in the era of 2G and 3G), are mainly used to address weak coverage in indoor environments. Traditional solutions require huge reconstruction costs to accommodate the extent and scope of 5G services. Besides, these legacy solutions are limited in terms of capacity expansion, support for visualized and smart O&M, and are simply unable to satisfy the needs for high-precision LBS. If traditional solutions are used, a smooth evolution to 5G network will be certainly an insurmountable task to complete.

Major equipment vendors are all launching Digital Indoor distributed solutions, such as Huawei's LampSite, Ericsson's Radio Dot, and Nokia's FlexiZone. The new solutions can provide premium MBB service experience for users and allow operators to deliver network capability openness and IoT connections. These solutions are also easy to install and maintain during operations. The clear advantages ensure that these solutions are an optimal choice for operators to build competitive, future-oriented indoor distributed network while boasting the most flexibility to later evolve into future 5G network.

In indoor environments, global operators face a series of short- and long-term challenges. As technology and solutions continue to innovate, operators and equipment vendors are working hard to strike a perfect balance among multiple dimensions of network performances in indoor distributed network.

4.4. Characteristics of Digital Indoor Distributed Network

The typical characteristics of Digital Indoor distributed network include active antenna head ends, transmission over ethernet and fibre optic cables, visualized O&M, and service diversification. With these features, Digital Indoor distributed network can respond well to the needs of 5G.

a. Active antenna

5G indoor networks must support a peak data rate of 20 Gbit/s for eMBB and a traffic density of 10 Mbit/s per square meter. This requires 5G indoor networks to provide a bandwidth of at least 100 MHz. 5G networks must support high frequency bands (such as C-band and mmWave bands) to achieve maximal spectrum efficiency through large-scale MIMO deployments. These networks must further support dynamic cell splitting, CA, and high-order modulation to address unbalanced traffic among different periods within a single day. Networks must on average deliver speeds exceeding 100 Mbit/s among terminals. With passive antennas, these requirements cannot be adequately met. The solution involves the use of active antenna head ends on indoor distributed networks to help realize massive MIMO and E2E networking that includes high and low frequencies.

Figure 6 Passive and Active antennas

b. Transmission over Ethernet cable or optical fiber

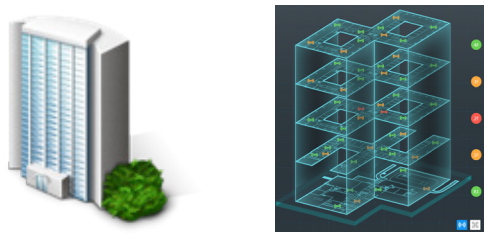
In targeting a switch to 5G, the architecture of indoor networks must allow 5G NRs to be rapidly overlaid onto LTE networks for integrated networking and 5G-like new services. Traditional RF cables and indoor network couplers do not support new frequency bands of 5G NRs (including the C-band and mmWave bands). Deploying new RF cables in indoor areas is costly and in a number of unique cases can prove impossible due to a lack of extra room for new cables. Operators must use transmission cables that are easy to deploy and deliver high bandwidth. One option is to use Ethernet cable or optical fiber to replace RF cables.

Figure 7 RF cables vs. network and fibre optic cables

c. Visualized O&M

In indoor distributed network, coordination with building owners and complex installation and commissioning results in costly O&M. In 5G network, fast deployment and visual O&M are regarded as basic requirements. This is because visualized O&M allows for real-time monitoring for the status of the massive number of head ends and other network elements. It also allows Mobile AI to help realize automated network resource allocation in response to the conditions of adjacent channels and fluctuating user densities. In the event of network faults, automated diagnostics and self-healing can be performed to minimize manual O&M costs and maximize return on investment by lowering network OPEX.

Figure 8 Improved efficiency with visual O&M



Inorganic | Organic

d. Service Diversification

The development of mobile internet and wireless communications allows users to enjoy not just voice and short message services. HD videos, wireless VR/AR, precise indoor locating, navigation, and big data based services will certainly become the mainstream trend. This requires mobile indoor network to support a diverse range of services. Take indoor locating services as an example. With Digital Indoor distributed network, the positioning accuracy can be 5 to 7 m or higher as opposed to cell-range 50 to 100 m with legacy equipment. Interfaces can be opened up to third parties to turn indoor network into an application development platform. This will enable third-party partners to develop new mobile services, including these based on LBS, by leveraging this level of high precision of indoor locating.

Figure 9 Diversifying telecom services in the new era

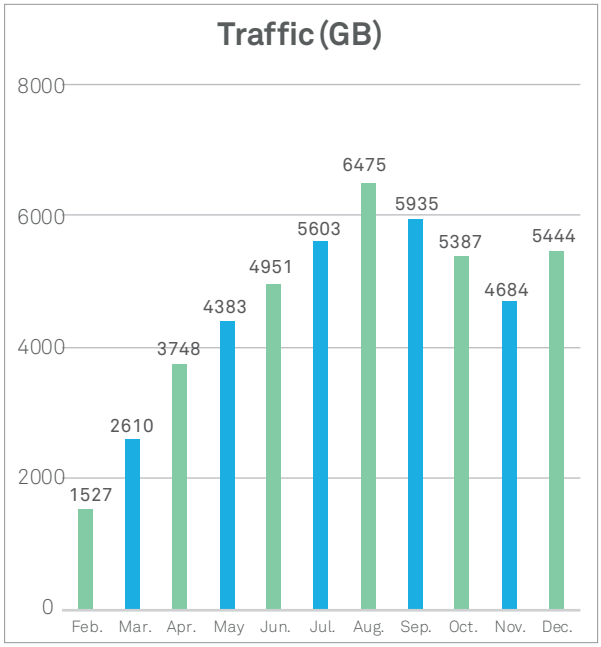
4.5. Addressing the Needs for Evolution to 5G

Digital Indoor distributed network can fully address the multidimensional needs for 5G network, including service growth, capacity expansion, seamless coverage, visualized O&M, value-added services, smooth transition to 5G, and operator investment protection.

» 4.5.1. Unleashing Suppressed Traffic to Sustain Traffic Growth

Traditional indoor distributed network focus on weak coverage and do not allow huge capacity. It is alarming to consider that 90% of indoor distributed network still use SISO solutions. As a result, mobile MBB traffic is suppressed in most indoor scenarios, making it impossible to sustain a nearly 50% compound annual growth rate (CAGR) of mobile data traffic. After a digital indoor distributed network was used in an airport, suppressed data traffic was significantly unleashed, with average traffic growing by 3 to 4 times (see Figure 10).

Figure 10 Sharp traffic increase in an airport after the indoor digital network is deployed



Digital Indoor digital distributed network use network or fibre optic cables for data transmission. They support MIMO and cell splitting to realize flexible capacity adjustment and allows resources to be allocated as needed according to the changes in traffic needs. This allows suppressed traffic demand to be unleashed and various service requirements to be fulfilled. The LTE digital indoor distributed network are 4 to 10 times the unit-area traffic of traditional DAS network. The DOU network can also deliver a 5 to 8 times increase in traffic over DAS network.

» 4.5.2. Easy Evolution to MIMO and Multi-channels

In traditional indoor distributed network, RF signals are carried over feeders, and each antenna needs dedicated feeders. This limitation requires multiple parallel RF feeders for multi-antenna solutions. If MIMO is used for extra expansion, new feeders must be routed, leading to a linear increase in engineering and deployment costs. High-frequencies signals are subject to huge link loss when transmitted over traditional RF cables. For example, 3.5 GHz radio signals have a link loss of 8 dB when sent 100 m away on 7/8" feeders. On 1/2" feeders, this figure reaches 15 dBm. Huge link losses means a much narrower coverage area and deteriorated performance. Therefore, it is difficult to use traditional indoor distributed network to increase network capacity.

In digital indoor distributed network, signals are sent over network or fibre optic cables. This transmission is insensitive to high-frequency bands and does not cause attenuations so that MIMO can be deployed for capacity expansion using existing cables. This facilitates evolution to MIMO and multi-channel network. Such deployment does not require the reconstruction of existing network and helps increase flexibility for low-cost network expansion.

» 4.5.3. Easy Installation and Visualized O&M

Traditional indoor distributed network involve a number of devices, including RF feeders, power splitters, combiners, and antenna head ends, complicating project engineering and deployment. In Digital Indoor distributed solutions, only active antenna head ends need to be deployed. Network or opto-electrical cables are used to realize data transmission and power supply. This results in much needed convenience to network deployment.

In digital indoor network, the operating status of various head ends and other network elements can be monitored in real time, making it possible to implement visualized O&M. Resources can be automatically realized in line with channel conditions and user density changes. Fault diagnostics and self-healing can be performed in the case of any malfunctions. This means a huge saving of O&M and operating expenditure and improved return on network investment.



» 4.5.4. Enabling Diverse Value-Added Services

Digital indoor distributed network support capability openness, through which rich value-added services can be enabled. The locating precision of current indoor distributed network is accurate to 5 to 7 m. This high level of locating precision will be a good catalyst for LBS services. In future 5G network, positioning can be even more precise to allow centimetre and perhaps even sub-centimetre measurements. High-precision positioning is set to emerge as a basic feature of mobile network. A number of IoT applications that cannot be implemented at present will eventually actualize and can be applied in a broad range of diverse scenarios. Such examples include transport hubs, large venues, exhibitions, hospitals, campuses, and public locations as well as for specialized groups of users (old and young).

» 4.5.5. Flexible Evolution to Future 5G Network

Using active head ends and transmission over Ethernet cable and optical fiber, the architecture of digital indoor distributed network can ensure evolution to 5G network. CAT6A cables can be routed in current deployments. When transition to 5G is required, 5G NRs can be deployed rapidly using these pre-routed cables. This helps minimize the workload of secondary reconstruction and shortens the time for network deployment.

» 4.5.6. Maximizing ROI for Operators

Digital indoor network are MIMO capable and can be software-upgraded to support 4 x 4 MIMO. This allows operators to conduct phased evolution planning so that network upgrade and expansion can be performed in stages without secondary site visits. For operators, overlapping investment can be minimized and superb experience can be delivered both in indoor and outdoor environments. Particularly, 5G NRs can be conveniently deployed without the need to route new cables or add new sites due to the reuse of existing cables and sites. This can better protect the investment of operators than traditional DAS solutions where high-band frequencies require a huge number of new RRU signal sources, replacements of passive equipment, and reconstructive engineering.

4.6. Summary

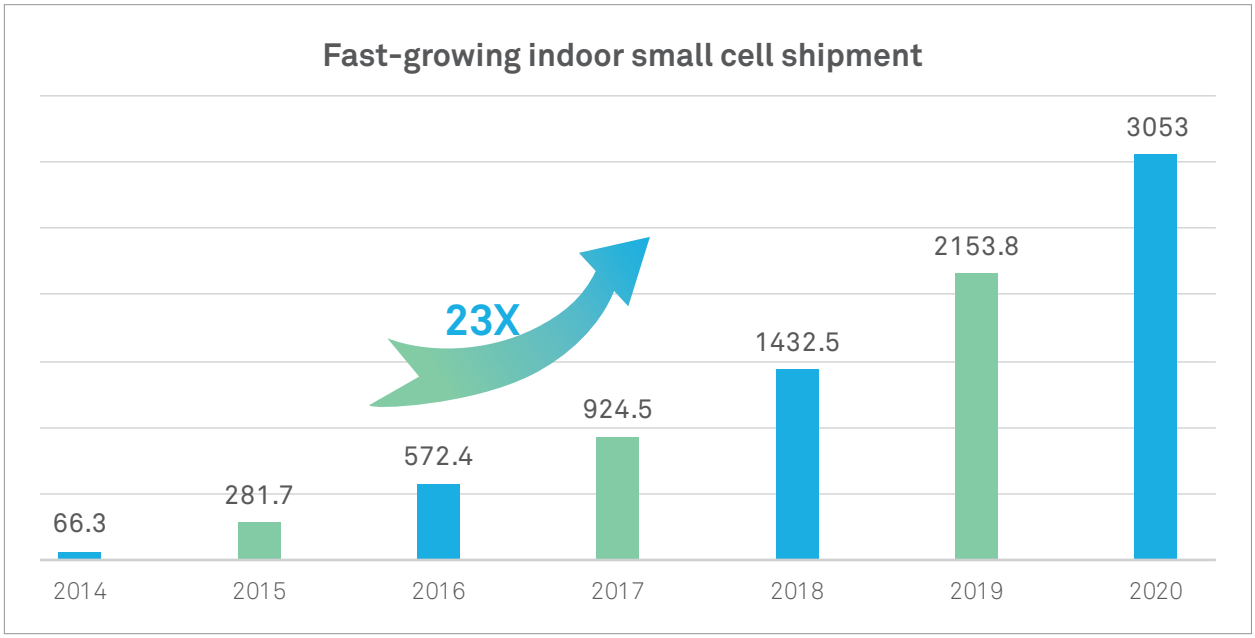
Operators must make current indoor distributed network oriented to 5G deployment to ensure smooth evolution. Digital indoor network use active antenna and network and fibre optic cables to transmit data, which are advantageous in visualized O&M and diversified services. Such network also satisfy the standards of both existing and future 5G network and are able to perfectly meet the needs of 4G, 4.5G, and 5G in terms of capacity, experience, O&M, and services. They can maximize ROI, and from our perspective, are an optimal and also an inevitable choice for indoor network to evolve into 5G.



Accelerating Innovation & Enhancing Cooperation

In recent years, the global sales of digital indoor products have recorded rapid annual increases, and there still remains a strong the momentum of continued growth, as shown in Figure 11. The performance and benefits have been well recognized by a vast majority of operators. The industry is attaching growing importance to the technological innovations of digital indoor distributed network. Major equipment vendors and traditional DAS vendors are switching to invest heavily on digital indoor solutions. Being digital is becoming an indoor network standard among telecom operators. At this moment, enhancing industry cooperation will certainly accelerate the growth of indoor digital network.

Figure 11 Global shipment forecast of digital small cells by 2020



5.1. Latest Technology Innovations

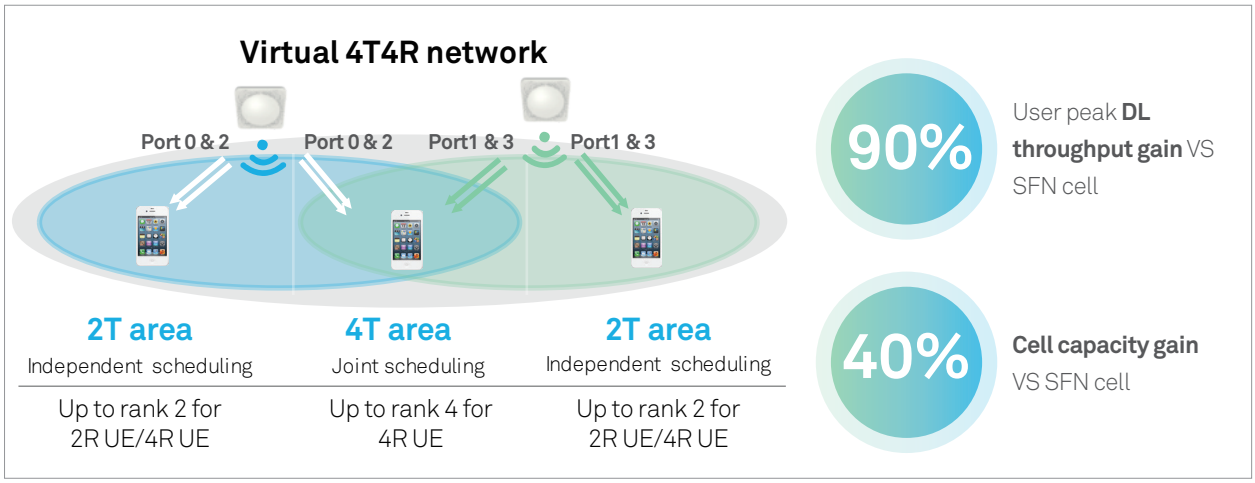
An increasing number of new technologies are applied to small cells, typically nTnR, cell splitting, unlicensed spectrum exploitation, multi-operator network sharing, and mobile edge computing (MEC). This allows operators to slash network investment, improve service experience, enhance indoor and hotspot coverage, and enable value-added services.

» 5.1.1. nTnR

The nTnR innovation brings superb high-speed mobile services to users. At present, most indoor network are 2T2R, which may fail to meet growing experience demand. With nTnR innovations, operators can realize a virtual 4T4R network by using two 2T2R pRRUs without the addition of new hardware to increase capacity and data rate while reducing interference between cells.

The 4T4R network have already been commercialized. As network grow and services continue to increase, digital indoor network will gradually transition to 8T8R.

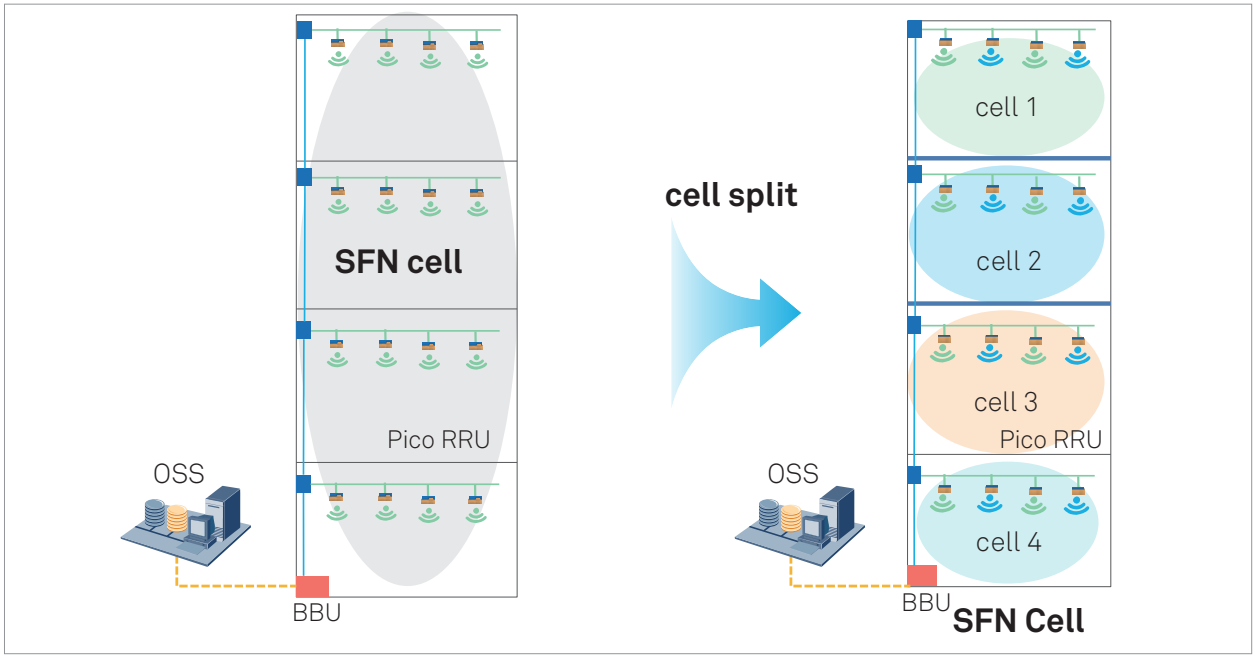
Figure 12 4T4R increasing data rates and indoor network capacity



» 5.1.2. Cell Splitting

It is common that the capacity demand of a network varies from time to time during the course of a single day. In this case, dense deployments mean a waste of resources and result in stronger interference. With cell splitting, the number of cells can be adaptively modified based on user behaviour patterns to match the capacity demand of different times. Meanwhile, accurate coverage can be ensured across the entire cell. One example is in the canteen's network where operators can reduce cells in working hours and increase them in dining time to thus fully address the capacity needs with a minimal amount of capital expenditure (CAPEX).

Figure 13 Cell splitting to reduce CAPEX and adapt to capacity demand



» 5.1.3. Utilization of Unlicensed Spectrum

The amount of unlicensed spectrum is much greater than that of licensed spectrum. The LAA specification in 3GPP Release 13 was finalized in March 2016. Commercial chips supporting unlicensed spectrum were officially launched in 2016. Operators, equipment vendors, and chip vendors are joining research into unlicensed spectrum technology, typically LAA, LWA, and MultiFire to promote commercialization.

LAA is the most suitable solution to the requirements of indoor deployments. It exploits both licensed and unlicensed spectrum through carrier aggregation to provide better services. The licensed spectrum ensures mobility, service continuity, and critical signalling transfer. When the licensed spectrum cannot meet the demand, unlicensed spectrum works to continue service provisioning to all users.

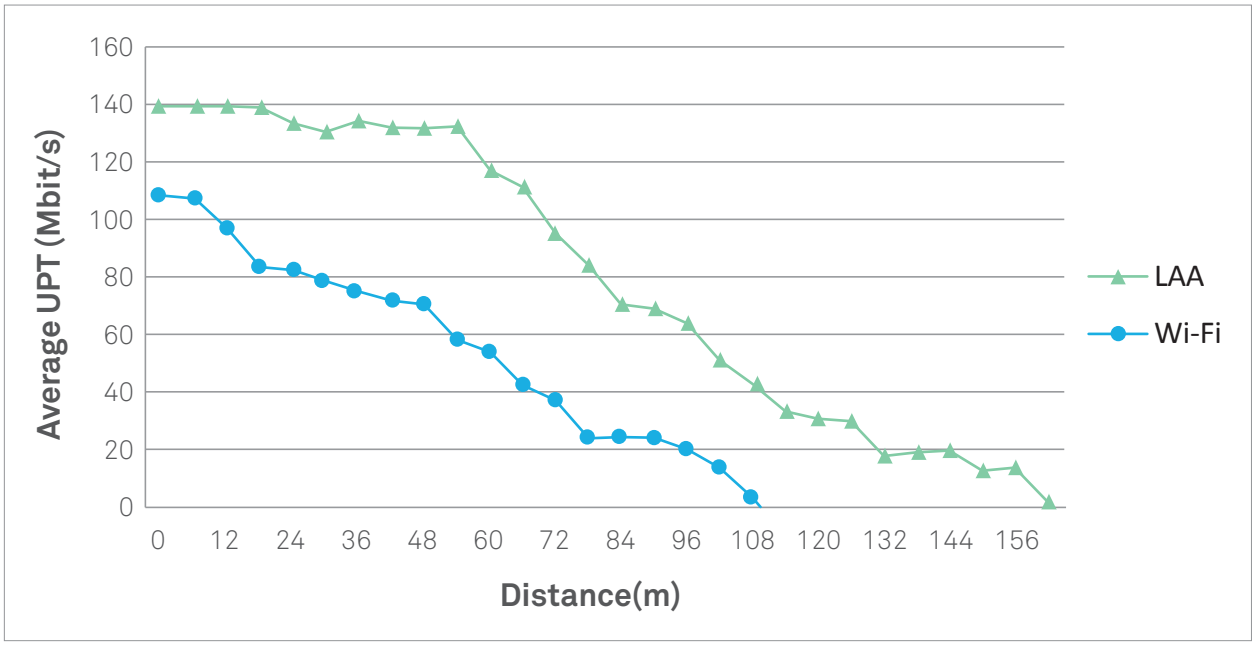
Under identical conditions, LAA is more advantageous over Wi-Fi in terms of spectral efficiency and network coverage. Real-life deployments have proven that LAA can also coexist with Wi-Fi, but remarkably with higher performance than that of Wi-Fi.

» 5.1.4. Multi-Operator Network Sharing

Multi-operator network sharing helps operators build high-performance digital network with a higher return on investment (ROI). With this innovation, operators can share the costs and site resources for network construction, which eases site access difficulties and coordination with building owners while facilitating O&M. It is also important to note that multi-operator network sharing is fast becoming an essential and intrinsic feature of indoor network deployments.

Huawei, Ericsson, and other equipment vendor have all launched multi-operator network sharing solutions. Owing to powerful full-bandwidth features, these solutions resolve the issue of sharing indoor network among operators striving to build ultra-high speed indoor MBB network. At present, these solutions have two modes: neutral host sharing and host operator sharing.

Figure 14 LAA advantages over Wi-Fi

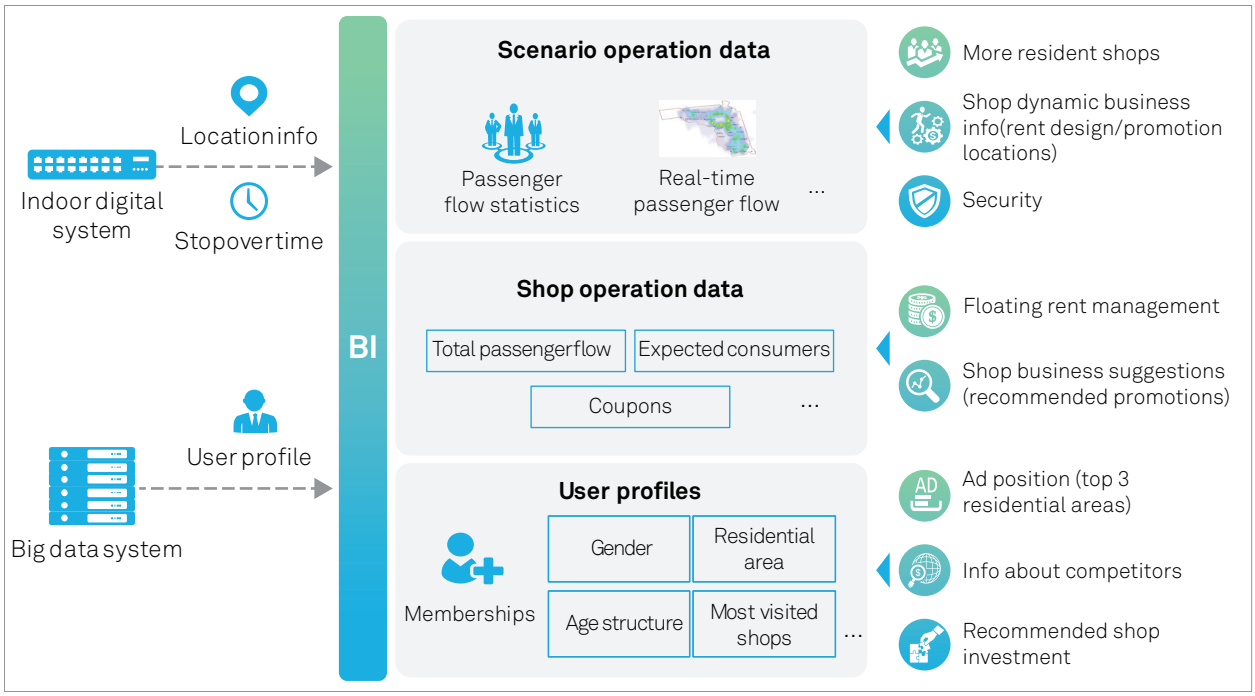


» 5.1.5. MEC-based Value-Added Services

In the MBB era, Internet applications, typically precise locating, instant messaging, e-commerce, and mobile payment have seen increasingly broader applications, and ultra-HD video services are starting to phase out standard HD video services. In the near future, AR/VR, ultra-HD videos, and mobile clouds will enable superb service experience to all mobile users. More importantly, these services will predominantly be available for use in indoor locations.

Digital indoor distributed network enable open, scalable, and coordinative platforms based on mobile edge computing (MEC) and serve as links to Internet applications to provide value-added services. For example, based on high-precision positioning over digital indoor network, user profiling can be realized to facilitate value-added services, such as passenger flow statistics, indoor navigation, security & emergency, precise push, and targeted marketing.

Figure 15 Value-added services on digital indoor network based on MEC



5.2. Mainstream Suppliers Turns to Digital Indoor Solutions

Seeing that digital indoor distributed solutions are all but inevitable, traditional macro network vendors are joining in to launch digital indoor solutions. Huawei took the lead and launched LampSite, the industry's first indoor distributed system based on a digital architecture. Ericsson followed the example with the launch of its Radio Dot solution. Both the two solutions support multi-operator network sharing. ZTE delivered the Qcell solution, Nokia had Flexi Zone Pico, and Cisco, Baicells, and SpiderCloud all offered digital indoor solutions.

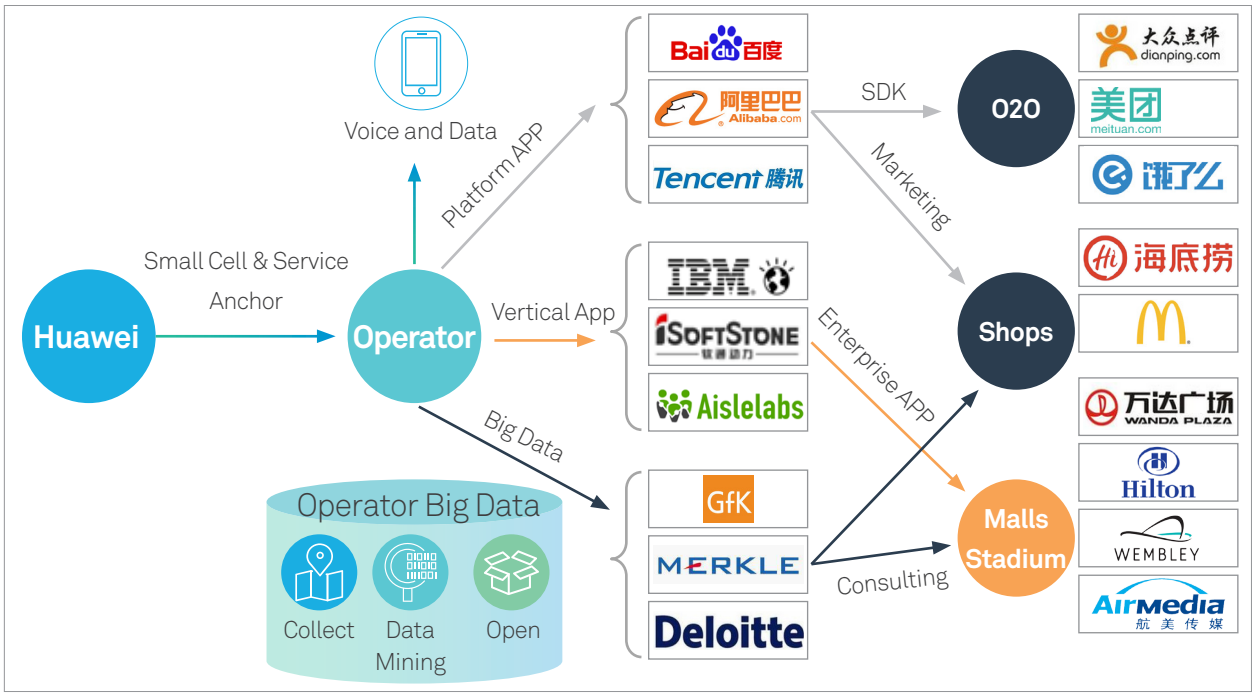
Meanwhile, traditional indoor distributed network vendors are all shifting to digital solutions using active digital devices. For example, Comba launched the new iCell solution, and CommScope launched the ION-E solution.

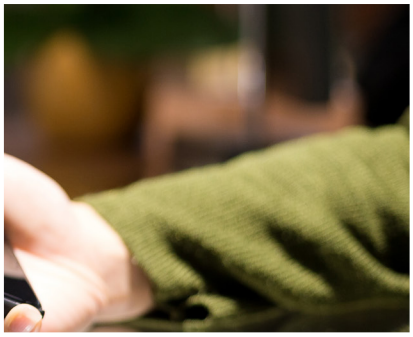
5.3. OTT Suppliers Join the Digital Industry to Provide Rich Applications and Services

The new industries, represented by big data, cloud computing, IoT, industrial Internet, and AI, are rapidly developing. These industries are considered to be inseparable from powerful mobile network. Only digital mobile network can provide high rates of mobile data, huge capacity, high reliability, low latency, precise locating, and continuous coverage to support further development.

In the 5G era, mobile network operators also need to transition over to Internet-based operations and enter the enterprise market. Digital indoor solutions will allow mobile network operators to engage in cooperation with enterprises and industry OTT vendors and provide valuable information, such as big data and precise locations. Enterprises and OTT vendors can then leverage the information to develop and enrich a huge range of Internet applications. In this sense, enterprises and OTT vendors will play a vital part in ensuring that indoor digital industry chains are healthier and growing at a rapid pace.

Figure 16 Business model of operator smart apps





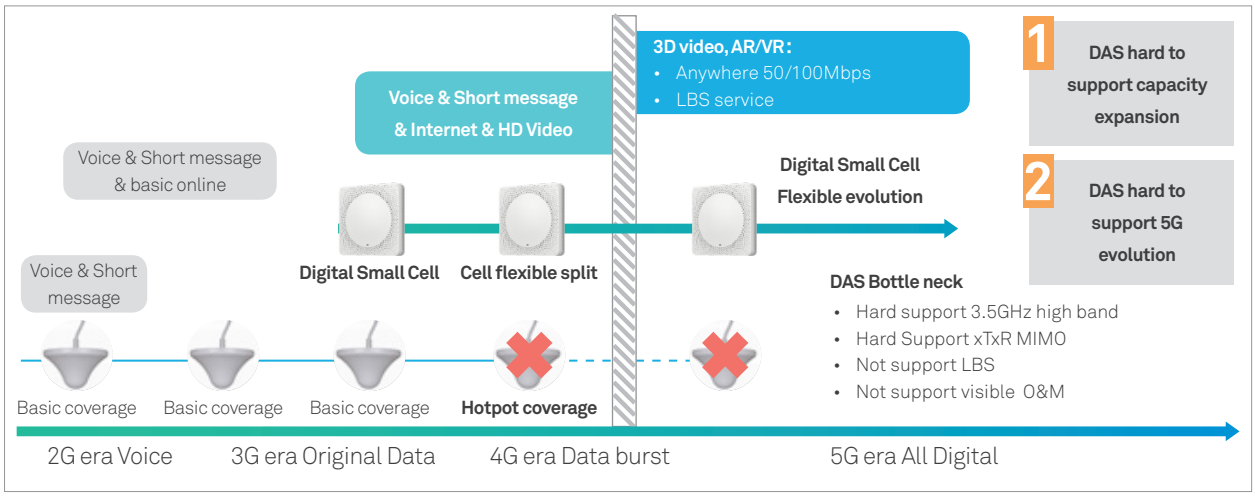
5.4. Digitalization Is Becoming the New Indoor Network Criteria

Mobile operators must deliver leading in-depth coverage to maintain a competitive and ensure brand perception. Indoor coverage is a core component and key to providing superior in-depth coverage.

Traditional indoor distributed solutions started from 2G and 3G, and were initially designed mainly for voice and basic data services. Such systems were the standard for 2G and 3G indoor network. In the 4G era, with the advent of smartphones, mobile network shift to focus on addressing heavy-traffic services and HD and even ultra-HD video demand, driving average data of usage (DOU) to astoundingly high levels. As we enter 4.5G and 5G, single-user ubiquitous data demand will probably reach 50 to 100 Mbit/s, forcing average DOU to higher levels of 10 GB. Due to inbuilt constraints of frameworks, traditional indoor distributed network struggle to meet these demands for capacity and services. These types of network simply do not support the prerequisites necessary for smooth evolution to future network. However, the newly introduced digital indoor distributed solutions are fully capable of fulfilling these demands and are becoming recognized as new standards for indoor network.

Recognizing the challenges of traditional indoor distributed network, an increasing number of mobile network operators are switching to digital indoor network solutions. This is because network operators are beginning to regard these solutions as a new standard that will most likely be selected to become the new indoor coverage criteria for 5G network. With network and optic fibre cables to replace traditional feeders and active devices to phase out passive devices, digital indoor network solutions will have negligible link loss and interference.

Figure 17 Digital Small Cell Solution Evolves Smoothly to 5G



5.5. Summary

With the approach of 4.5G and 5G, the indoor network capacity explodes day by day, the mobile users need better experience and the network need fast evolution. Mobile operators, equipment suppliers, and services providers all realized that indoor digitalization is the way out and started to take concrete measures to transform to this direction.

Conclusion

Let's focus on 5G-oriented indoor digitalization solution:

In service distribution, mobile data services take place mainly indoors.

In service demand, anytime, anywhere 100 Mbps will be a common requirement for indoor 5G services.

In frequency spectrum, C-band and higher band create difficulties in realizing in-depth coverage of 5G via the outdoor-to-indoor scheme.

In network architecture, current network must support smooth evolution to future 5G network.

In network O&M, visualized capability for coverage, interference, and traffic can significantly improve O&M efficiency.

In service diversification, Location-based Services has huge market potential.

In industry development, mobile operators, equipment suppliers, integrated delivery providers, and OTT suppliers all are innovating in digital indoor solutions to embrace digital transformation.

The digital indoor solutions support the smooth evolutions to 5G, and can meet the diverse services requirement and visualized O&M requirement. On the contrast, the traditional DAS architecture cannot evolve to 5G due to limitations in high-band transmission and nTnR capability. It is suggested to plan and deploy the current network using digital solutions, to consolidate the 4G user experience and lay the foundation for 5G smooth evolution.

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