Small Cell Network White Paper

November 2016

A GSA White Paper with input from Ericsson and Huawei

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1. Forward

As Society enters the 4th Industrial Revolution – the migration to cyber-physical systems – digitalisation and ubiquitous mobile connectivity will result in a re-engineering of many industries. There will be substantial shifts on the demand and supply sides of these industries due partially from increased transparency of business processes and alternative engagements with customers due to new patterns of consumer behaviour. These shifts in many cases are built upon access to mobile networks and data and are compelling companies to modify how they design, market, and deliver products and services.

The wireless industry will also need to evolve as mobile connectivity expands to address multiple use cases from wireless sensors to robotics and autonomous transportation. Mobile operators will therefore need to grow their networks using creative network design techniques as well as advancements that are being made in new radio technologies.

The exponential growth in data traffic and the billions of predicted connected "things" means operators will have to consider alternative mobile network architectures to deliver more coverage and more capacity, at the right time and in the right places. The deployment of Small Cells as part of a mobile operator's overall coverage and capacity strategy therefore makes economic sense. Capacity can be targeted to where the demand is and in-building coverage is easier to plan, deploy and manage. The availability and reach of mobile services will eventually expand into all corners of the world and deliver a ubiquitous service, 24/7, helping operators address new business areas and business models for a broader and more diverse and discerning customer base. Small Cells will be a core part of those networks.

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Global mobile Suppliers Association

2. Preface

In today's society, Mobile Broadband (MBB) is fully connected to our everyday lives and routines. Since the early part of this century, MBB has developed dramatically, significantly improving pre-existing networks and structures and has helped create our modern society. The propagation of MBB services continues and is evolving as the mobile industry develops new technologies to meet the current and future needs of customers. As indicated by the figure 1, MBB services will continue to grow as demands for mobiles data traffic intensifies. We are already seeing significant changes in our way of life through the effects of mobile music, mobile video and mobile payment. While the development of MBB has improved dramatically, new requirements for MBB networks will continuously arise, such as ubiquitous coverage, ultra-wide bandwidth, ultra-high capacity and the support for flexible & compatible services.

Figure 1 compares the global mobile traffic patterns of 2015 with the projected patterns of 2021. It suggests MBB services are likely to grow dramatically through use of user equipment (UE), especially the adoption of smartphones.

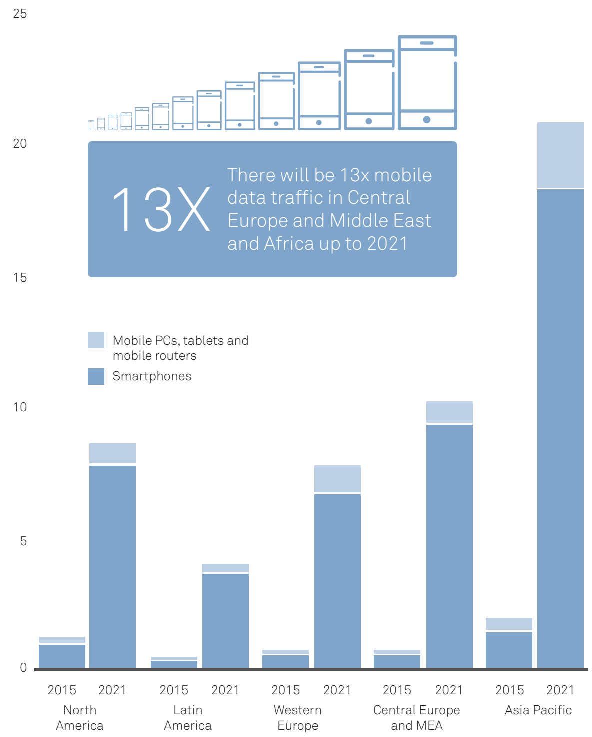


Figure 1: Global mobile data traffic (monthly Exabyte) [1]

Small cells are likely to play an important role in meeting the network demands of the future. The increasing numbers of massive hotspot areas with demanding capacity and connections requirements has seen a rise in popularity of small cell solutions.

Over the past 3 to 5 years, operators, who invested heavily on small cells in hotspot areas to improve user experience, have profited from small cell deployment. Small Cells will assume a key role in future MBB development because the mobile industry, regulators and institutions are evaluating spectrum resources above 6 GHz which will result in reduced base station coverage. Similarly, digital services are crucial to the current and future development of MBB services. Traditional network deployment is increasingly being replaced by digital services.

According to forecasts from Small Cell forum [2], the global shipment of small cells will reach tens of millions by 2020.

We believe operators need to address the following 4 areas to be successful in the future:

1. How to deal with the challenges from indoor areas, which will generate over 80% of the traffic?
2. How to build an integrated network with Small Cells to meet mobile data demand and expected service performance?
3. How to make full use of unlicensed spectrum resource to improve user experiences?
4. How to develop a flexible Small Cell network architecture to smoothly evolve towards 5G networks?

[1] Source: Ericsson mobility report, June 2016

[2] Source: Crossing the Chasm: Small Cells Industry November 2015, Small Cell Forum

3. Indoor Digitalization to Drive MBB Upgrade

3.1 Indoor Networks Require Small Cell Digital Solutions

Indoor areas have already been high-value markets for many telecom operators. With accelerating urbanization in developing countries, in-depth coverage in urban areas is increasingly complex and network deployment to meet MBB data capacity growth is increasingly difficult.

The traditional analogue indoor coverage solution - Distributed Antenna System (DAS) – is unable to support 4G and 5G era requirements. However, digital Small Cells can provide full connectivity for all indoor scenarios. In particular, mobile traffic is necessary for ultra-dense areas such as sports stadiums, urban avenues, shopping mall, big transport hubs, etc.

3.2 The Challenge of Indoor Digitalization Network

As a traditional indoor coverage solution, DAS can only meet the demands of 2G/3G era voice and mid-to-low-speed data services. With the surge in indoor MBB requirements in the 4G era, DAS has become a restriction for indoor MBB due to the lack of network capacity, scalability and poor evolution potential; limiting demand for subscriber services.

The surge in mobile data is depleting 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 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. The speed in wireless standards has increased rapidly. Evolution from 1G-to-2G took 20 years, 2G-to-3G evolution 10 years, and 3G to 4G just 5 years. The pace of evolution of new technology is accelerating with 4G and subscriber data speeds have evolved from tens of Kbps to several Mbps and from several Mbps to hundreds of Mbps. Meanwhile, the commercial application of some 5G technologies in 4G networks has caused a speed leap from megabits to gigabits. Due to DAS's analogue radio frequency (RF) architecture, meeting this demand with multi-antenna and high-order technologies is extremely difficult without large-scale changes to existing networks – figure 2.

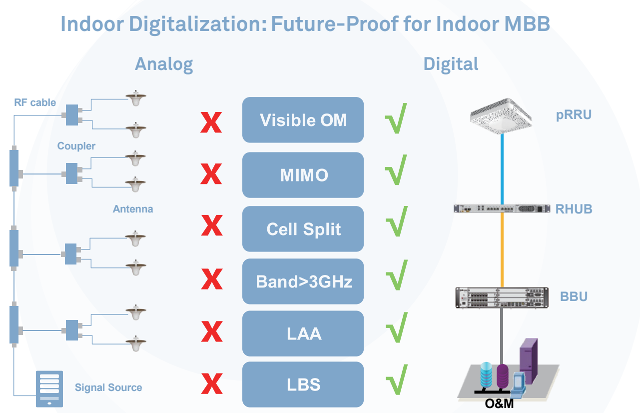


Figure 2: Advantages Comparison of Indoor digitization system and DAS

With end-to-end (E2E) digital architecture, high capacity, high yield, fast deployment and an evolvable Small Cell networks architecture is the new linchpin technology for building a fully connected indoor world.

3.3 Going to Digital Indoor Network Requirements

3.3.1 Digital Architecture

The high number of passive components in analogue systems causes excessive interference, which limits capacity, while expansion requires onsite re-modification and high manpower costs. Although digital systems still require physical deployment, digital systems greatly lower interference, improving MIMO (Multiple Input Multiple Output) performance and enables on-demand capacity expansion through software-defined frequency ranges.

3.3.2 Digital Channel

To ensure excellent indoor MBB experience, indoor MMB networks must meet the requirements of per-user xMbps throughput, MOS4.0 voice services and MOS4.0 for video. Digital channel solutions can provide wider, faster and high capacity network to improve a user's experience, such as better VoLTE (Voice over LTE) and HD (High Definition) video quality.

For DAS, capacity expansion requires additional RRU (??) hardware and physical reconstruction, which is often difficult to complete due to complex coordination with property owners and the incurring high costs. By contrast, digital solutions support flexible cell splitting and remote software configuration. With these solutions, the difficulties associated with traditional capacity expansion can be easily addressed.

3.3.3 Digital Operations & Maintenance (O&M)

Traditional DAS neither supports fault and service monitoring on all nodes or full-system O&M with visual operations, reducing effective cooperation between parties. Digital O&M can precisely monitor each node to enable O&M and visualization across the whole indoor system, improving O&M efficiency.

Over the course of operations, upon experiencing a device fault, indoor digital networks can perform self-optimization in line with surrounding network conditions to mitigate any negative user experience. At the same time, automated fault diagnosis and self-fault recovery are supported to reduce manual intervention and reduce O&M costs as much as possible.

3.3.4 Digital Service

Digital networks improve voice services and enhance coverage demands of analogue systems. Meanwhile Indoor digital networks can support capability openness to application developers and value-added service provider to create added value for property owners while increasing revenues for operators.

3.4 Section Conclusion

Indoor mobile networks provide tremendous opportunities for operators, but also raise a series of challenges. Upgrading the traditional analogue network ecosystem will not be achieved overnight. Realizing the concept of indoor digitalization will require the concerted effort and impetus from multiple industry players and even cross-industry partners. It will also be necessary to break up the chain of traditional analogue networks to achieve new business success for all involved. The opportunities provided by implementing digital networks are vast, are quicker, cheaper and more reliable than traditional methods.

4. Integrated Small Cells Deployments

4.1 Integrated Small Cells

The majority of small cells are deployed in areas where there is already macro network coverage. Outdoors micro cells are often used as capacity boosters in areas with good macro coverage and indoor small cells are deployed in buildings with substantial outside-in coverage from macro cells. Even small cells deployed in modern buildings with metal coated windows and good isolation from the macro coverage must interact with the macro network as people move in and out of the buildings.

It is important to note that small cells are almost never isolated from the macro radio network. Understanding how well the small cells interact with the macro network will determine the overall user experience and costs.

The manner in which small cells are deployed can severely impact user experience and overall network performance of the macro network and vice versa.

Therefore, small cells must generally be deployed and operated as an integrated part of the 3G or LTE radio network. This enables the small cells to provide a consistent user experience while being managed as a part of the overall radio network.

4.2 Considerations for Integrated Small Cells

To build an integrated small cells network, the small cells must deliver the following key functions:

- Good and consistent user experience
- Integrated network operations
- Well planned and orchestrated deployments

Each of these three elements will be discussed in detail below.

4.2.1 High performing and Consistent User experience

Research shows that indoor wireless data traffic will grow more than 600% by 2020 [3] and that network performance is an important factor for selecting a service provider [4]. This combination of network growth and the necessity for high performing networks is a key consideration when deploying small cells.
Providing the same or similar user experience as the rest of the network will be important when deploying small cells. Operators worldwide must ensure they make the best use of their radio networks by integrating their small cells into their overall macro architecture and guaranteeing the transition between the two networks is seamless.

4.2.2 Integrated Network Operations

Network operators spend major time and effort optimizing their networks to ensure quality user experiences and the best utilization of network resources. Both manual and automatic optimization procedures can be used and performance is constantly monitored by measuring network KPIs (Key Performance Indicators) such as call set up success rate and call retention.
As indicated above, small cells should not be independent of the macro network, allowing for optimization of concurrent systems. An integrated approach allows for a common network management platform, which avoids independent systems that could pose additional costs and be more complex to operate.

4.2.3 Planned and Orchestrated Network Deployments

The planning of small cells deployments should be detailed and precise and must consider both how macro cells handle traffic as well as how they generate radio interference. Small cells installations affect the macro network as the needs for capacity are moved to the small cells layer.
In many cases, joint backhaul for small cells using a macro base station as hub is the most cost efficient solution.

4.3 Integrated Small Cells Requirements

The following functions are required in small cell products to build a network with integrated small cells:

- Optimizes end user experience – including application coverage and mobility
- Enhances network operations – including KPI measurement and Network Operations
- Deploys and delivers a seamless network

4.3.1 Optimizing User experience

Application Coverage

The concept of application coverage is to provide high performing and consistent mobile broadband data throughput to meet all users' application requirements. Macro networks around the world are now being upgraded to deliver high-speed (up to 1Gbps) LTE services using technologies such as 4-way MIMO and carrier aggregation (CA). Due to their integration with the macro network, integrated small cells are also able to implement these same features and deliver the same high speeds. Integrated small cells can be optimized for a robust and high performing end user experience, using advanced features like CA between low frequency macro cells and high frequency small cells, as well as uplink CoMP (Cooperative Multi-Point) enabling the most optimum paths for uplink and downlink traffic.
In addition, radio coordination features, such as soft handover for HSPA and similar LTE uplink functions, are shown to at least double end-user data rates. Many options for coordination exist and generally the tighter the baseband coordination the better the gains that can be obtained.

Mobility

Mobility without any connection drops is critical for a guaranteed user experience. Mobility is an important element for MBB service and becomes even more critical for voice and VoLTE.

To enable mobility, network operators can leverage spectrum usage with low and high bands to minimize inter-frequency handovers, effectively reducing the risk of connection drops. Common traffic management such as coordinated decisions to move terminals across radio access technologies, frequency bands and cell layers also helps to secure quality end-user performance and network efficiency.

4.3.2 Enhancing Network Operations

Secure Network KPIs and Maximize Network Utilization

With several small cells radios running from the same baseband the combined cell function can be used. The combined cell feature limits the interference between the radios and reduces the number of small cells that are managed since all the radios in a combined cell group are handled as one cell.

A well working X2 interface between integrated small cells and the macro network will also enable mechanisms, such as dual-connectivity, X2 based ICIC (Inter-Cell Interference Coordination), RRC (Radio Resource Control) re-establishment, Reduced HO (Hand Over) oscillation, and load balancing, to improve user experience and network utilization.

Single OSS System and Set of Handling Procedures

Managing macro cells and small cells from the same OSS and NMS (Network Management System) can jointly perform network analytics and network optimization performed for all cells. Monitoring of Network KPIs will also be network-wide for all cell types. Through this combined system, node and software (SW) management is harmonized to common work structures for both macro and small cells networks.

Under this common network management, network operators are able to adopt a performance-driven network that requires only a single architecture. This single architecture provides full visibility of agreed end-user KPIs and coherent tools to take correct remedial action when needed.

4.3.3 Network deployment

Planning

When small cells coverage is planned, the macro network should be considered both related to coverage and interference especially since small cells deployments can positively affect the macro network. For example, the introduction of indoor or outdoor small cells can remove "bad" users with poor radio conditions from a macro cell, considerably improving the total user experience in the network.

Installation and commissioning

Common SON (Self Optimising Network) functionality should handle small cells and macro cells to correctly configure and maintain neighbour cell relations and PCI codes.

In many cases, backhaul from macro sites can be reused for small cells sites. A Typical case is a micro base station which has a first hop as microwave backhaul to a macro base station, where backhaul is aggregated towards the core network.

Small cells are quick and easy to deploy. Collaboration with third party site owners not only provides a quick way to launch and commission small cells but also helps operators to carefully select site locations appropriate to their needs.

CAPEX and OPEX savings for small cells deployed with share baseband and Cloud based RAN (Radio Access Network).

4.4 Section Conclusion

Small cells should be considered as an integrated part of the total radio network and when deployed, integrated and managed in an optimized way .the following advantages/functions are available:

- Optimizes end user experience – including app coverage and mobility
- Enhances network operations – including KPI measurement and OSS
- Deploys and delivers a seamless network

[3] Source: ABI Research

[4] Source: Ericson ConsumerLab

5. The Process of Building in Unlicensed Spectrum

Spectrum is an essential "natural resource" for mobile communication. This resource is quite limited for operators worldwide, particularly in the licensed spectrum from 700MHz to 2.6GHz.

There are abundant "natural resources" in the unlicensed spectrum band; in the 5GHz band alone a total of 400 MHz can be used for mobile communication.

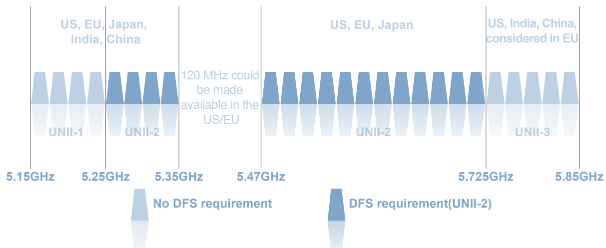


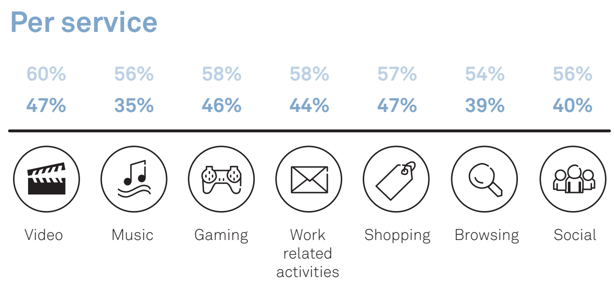
Figure 3: 5 GHz Unlicensed spectral allocations in the 5 GHz band to different regions

3GPP Release 13 concerning LAA (License Assisted Access) standards was finalized in March 2016 and commercial chips supporting unlicensed spectrum are readily available in the market. An increasing number of telecom operators, vendors and chip makers are in close cooperation to develop feasible technologies that can make full use of unlicensed "natural spectrum resources" to improve network capacity and user-perceived data rates.

Due to power constraints, unlicensed spectrum and small cells offer similar coverage capability. Applying licensed and unlicensed spectral convergence solutions to small cells is good for network planning and helps maximize unlicensed spectral utilization. Most operators think that convergence regarding licensed and unlicensed spectrum should start with Small Cell deployments.

5.1 The Drive to Use Unlicensed spectrum Technologies

As demonstrated in figure 4, the demand for mobility continues to expand while wireless spectrum is a finite resource. To deliver higher data speeds and more MBB capacity we require better utilization of existing and new spectrum. Operators can use LTE CA to increase data speeds indoors and outdoors by taking advantage of both licensed and unlicensed spectrum.



Source: Ericsson ConsumerLab analytical platform 2014
Base: Internet users using smartphone, tablet or PC, 23 countries

Figure 4: Users will pay more for better service [5]

5.2 Unlicensed Spectrum Tech Challenge

Unlicensed spectrum technologies such as LAA Enables Better Services

LAA uses carrier aggregation in both unlicensed and licensed bands where the licensed band ensures mobility, service continuity and signalling transferring. If an LAA cell contends for limited resources on the unlicensed band, the cell can still use the licensed band to continue service provisioning.

Under the same conditions, LAA is advantageous over Wi-Fi in terms of spectral efficiency and coverage performance. According to statistics, when compared to Wi-Fi services, LAA improve coverage by 50% and capacity by 35-55%.

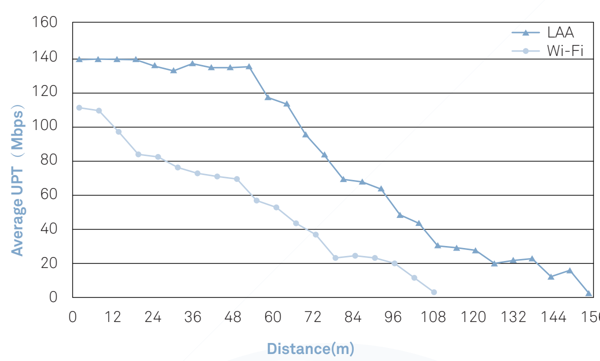


Figure 5: Experimental results for LAA and Wi-Fi coverage [6]

LAA adopts comprehensive mechanisms that enable differentiated access policies based on user and service types to ensure a high degree of user experience. Moreover, LAA supports legacy evolved packet core (EPC) and billing systems, which can help operators reduce deployment costs.

Friendly Coexistence of LAA with Wi-Fi

Over multiple years of development Wi-Fi has developed a massive legacy market, which can be combined with LAA that will observe spectral etiquette on the unlicensed bands to ensure coexistence with current Wi-Fi systems. To this purpose, 3GPP defined a coexistence technology known as license before talk (LBT) in 3GPP Release 13 for LAA.

Starting in 2015, telecom operators and vendors have conducted a number of tests and verifications for a variety of scenarios to test whether LAA affects Wi-Fi coverage when operating in the same band. The results concluded there can be friendly coexistence between LAA and Wi-Fi. In some cases, the coexistence between LAA and Wi-Fi is even friendlier than Wi-Fi within Wi-Fi bands. In September 2016, the Federal Communications Commission (FCC) of the US affirmed that LAA does not cause interference with existing unlicensed technologies, including Wi-Fi and Bluetooth.

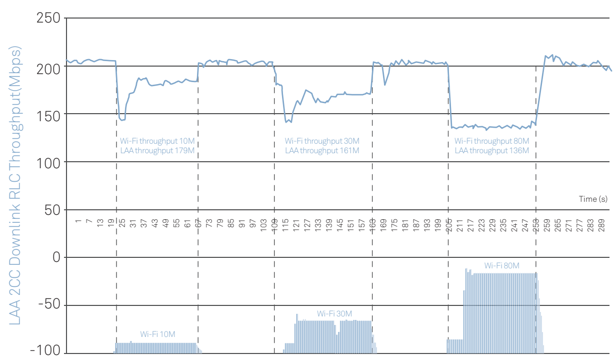


Figure 6: Experimental test results for LAA with baseline LBT and Wi-Fi co-existence [7]

5.3 Section Conclusion

Through utilization of unlicensed spectrum, operators will have more choices to construct mobile communication networks that deliver premium service experience.

- LAA Boosts LTE data speeds with unlicensed 5 GHz band
- 4% or less of 5 GHz band provides up to 150 Mbps boost
- Unlicensed spectrum to be shared fairly between Wi-Fi and LTE
- LTE LAA is on road to 5G

[5] Source: Ericsson November Mobility Report & Ericsson ConsumerLab

[6] Source: Huawei mLAB Experimental test May 2016

[7] Source: Huawei mLAB Experimental test May 2016

6. Cloud-based Small Cell architecture, Towards 5G Networks

6.1 Cloud-based RAN meet Operator's evolution Requirements

Mobile networks are evolving quickly in terms of coverage, capacity and additional features are being continuously pushed by new requirements relating to latency, traffic volumes and data rates.

By introducing Cloud-based RAN architectures, operators can meet these accelerating demands using Network Functions Virtualization (NFV) techniques and data centre processing capabilities in their networks, which allows for resource pooling, scalability, layer interworking and spectral efficiency.

Cloud-based RAN deployments are well suited for Heterogeneous network deployments with a mix of larger and small cells, offering centralized functionality for radio and backhaul coordination. Indoor small cells deployments can be addressed as small per building cloud RANs.

6.2 Driving of Cloud-based RAN

Driven by greater needs for coordination as well as increasing resource efficiency and advances in network virtualization, Cloud-based RAN architecture allows for the use of NFV techniques and data centre processing capabilities such as coordination, centralization and virtualization in mobile networks. This supports resource pooling (better cost-efficient processor sharing), scalability (more flexible hardware capacity expansion), layer interworking (tighter coupling between the application layer and the RAN) and better spectral efficiency.

More and more small cells' installations need central coordination and aggregated backhaul handling. To boost performance in traffic hotspots such as offices, stadiums, city squares, commuter hubs and other high traffic indoor locations, centralized baseband deployments have become increasingly appealing for operators. In a fully centralized baseband deployment, all baseband processing (including RAN Layer 1, Layer 2 and Layer 3 protocol layers) is located at a central location that serves multiple distributed radio sites. The transmission links between the central baseband units and distributed radio units use Common Public

Radio Interface (CPRI) front-haul over dedicated fibre or microwave links. This CPRI front-haul requires tight latency and large bandwidths.

6.3 Considerations of Cloud-based RAN Small Cells

A Cloud-based RAN should support the following:

- Separation of control and user plane to support flexible scaling of capacity for different functions of the RAN
- A variety of deployment options for anticipated network scenarios, including a wide range of transport network solutions, base station configurations, Heterogeneous network options with small cells and user applications
- Alignment with legacy deployments, which reduces the overall network complexity

Cloud RAN architecture

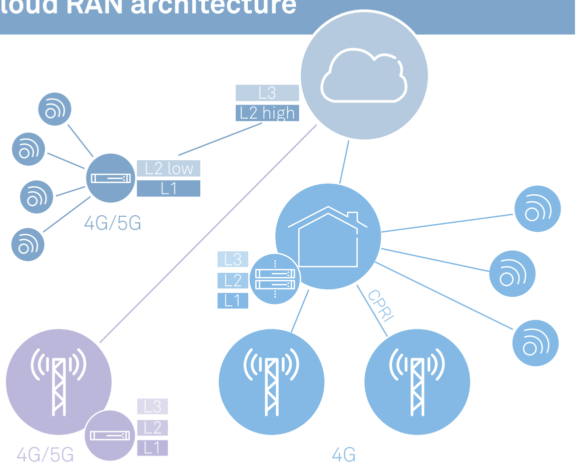


Figure 7: Cloud-Based RAN architecture

Figure 7 is an example of a Cloud-based RAN realization, showing various levels of centralization as well as a new flexible function, allocating the different protocol layers together with virtualization in the cloud. Small cells radio heads are typically integrated with the L1 processing or connected over CPRI (Common Public Radio Interface).

6.4 Section Conclusion

As the need for coordination and aggregated backhaul handling are central to many small cells installations, small cells will drive the use of centralized baseband and Cloud based RAN.

7. Summary

With an ever-increasing demand for indoor voice and data connectivity, service providers must address not only the short-term MBB requirements but also need to consider the future demands for capacity, integration of new technologies, spectrum and architecture options. Small Cells will help operators:

- Boost traffic performance in dense indoor hotspots by Digitalization
- Integrate with Outdoor Networks to optimize user experience and enhance network operations
- Converge Licensed and Unlicensed bands to improve the spectrum efficiency and network capacity
- Drive the Cloud based RAN Architecture to 5G

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Acknowledgements

This report benefits greatly from the insights and experiences kindly contributed by the GSA's members and community, in particular, the Executive Members Ericsson and Huawei.