MSA:

A key technology for the evolution of future wireless networks

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Table of Contents

Executive Summary

Operators worldwide must prepare for massive mobile broadband (MBB) network traffic growth as the industry moves away from voice-and-text, pure-pipe services to an era of data diversity and new vertical market revenue streams. Total network traffic is widely forecasted to increase at least 1,000 times over the next decade.

Meeting such unprecedented growth in demand for mobile services will require taking advantage of more than one wireless network technology to ensure a top user experience can be provided, maintained and continuously enhanced with interworking combinations of macro and small cells. Multi-Stream Aggregation (MSA) leverages the centralized integration of multiple radio access technologies (RAT), carriers and intra-carrier ports to help grow network capacity needed for providing a No-Edge network user experience.

A combination of a layered network architecture and MSA in future networks will enable users to enjoy high-speed and highly reliable mobile services anytime and anywhere. A layered network architecture includes a host layer which provides a basic user experience and ensures reliable network coverage, and a boost layer which increases network capacity and provides the best possible user experience. MSA is a key technology for integrating the capabilities of both of these layers.

Current network challenges

For current network deployments, different RAT standards such as UMTS, LTE and WiFi are typically deployed and managed independently and access the network through their respective core network gear. With such a "mono-layer" architectural approach, User Equipment (UE) can only utilize data services from a single cell site through a single RAT at any one time (see Figure 1 below). This results in poor resource utilization, and redundant network infrastructure investment.

Heterogeneous network (HetNet) deployments involving coordinated macro and small cell coverage have been a common means of improving capacity for a mono-layer approach. But as the number of deployed cells increases, so does the number of cell edges. At these cell-edges, end user experience can be significantly impacted by frequent handover (HO), increased HO failure rate, and low throughput.

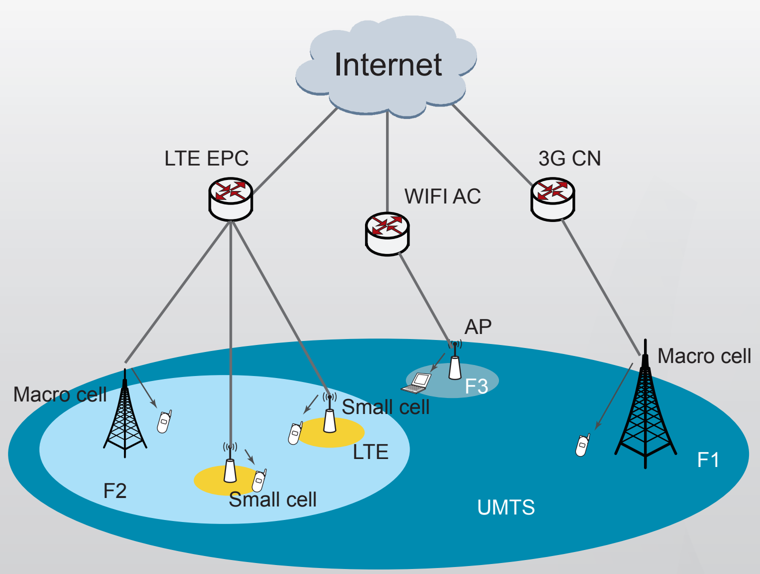

Figure 1: Mono-layer network architecture

Handovers

With dense network deployments, frequent and/or ping-pong HOs have become major obstacles to providing a top-quality user experience. Figure 2 below gives an illustration of the geographical distribution of Reference Signal Received Power (RSRP) before and after small cell deployment. As shown under the same red line area, before small cell deployment, UE signal attenuation becomes slower with increases in distance, but after small cell deployment, UE signal strength near the small cell is significantly improved but the signal weakens considerably with distance, especially around street corners.

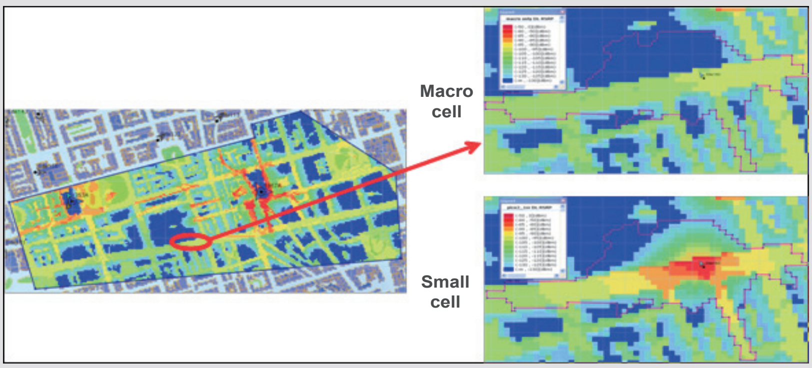

Figure 2: RSRP geographic distribution before and after small cell deployment

Due to small cell fast channel fading and interference, HO failure rate for HetNet is generally higher than that for macro cell networks, especially for HOs from small cells to macro cells (S2M in HetNet, see Figure 3 below).

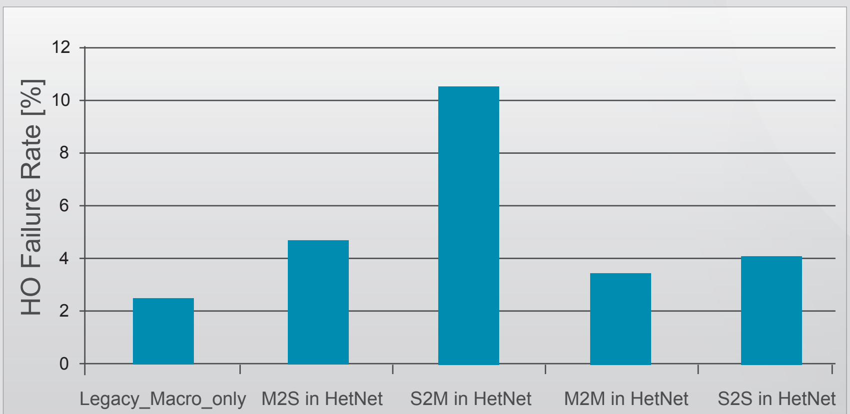

Figure 3: HO failure rate comparisons

Interference

Small cells deployed within a macro cell's coverage are often subjected to intra-frequency interference from the macro cell, which in turn contracts a small cell's coverage depending on how close its position is to the center of the macro cell. Figure 4 below shows how a small cell's coverage changes when deployed in different locations. Near the macro cell's edge, the small cell's coverage may span over 100 meters from one small cell edge to the other, but closer to the macro cell's center the small cell's coverage may only reach as far as 10 meters. What's more, intra-frequency interference also significantly hinders UE throughput.

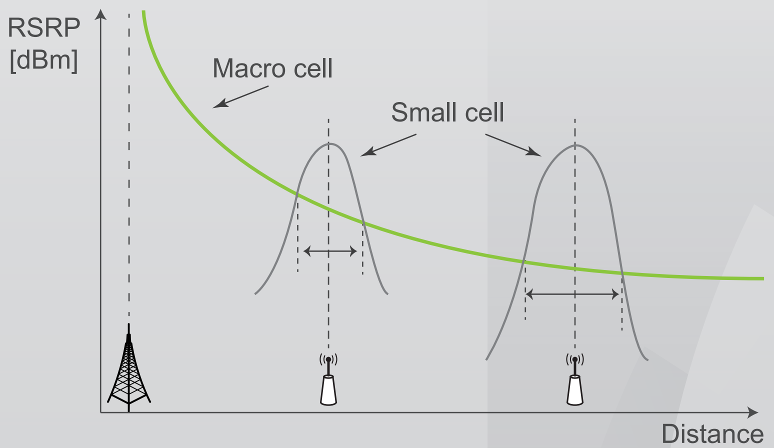

Figure 4: Small cell coverage contraction due to intra-frequency interference

Resource Utilization

Inefficient and inflexible utilization of network resources is a major operator concern given that traffic load imbalances between macro cells and small cells are prone to sudden and dynamic changes. For traditional "mono-layer" HetNets, resources can't be shared between different cell sites, causing stark differences in quality of experience (QoE).

Figure 5 below illustrates a scenario whereby four UEs (UE1, UE2, UE3 and UE4) are being provided mobile services by a macro cell while UE5 and UE6 are being separately provided mobile services by two small cells.

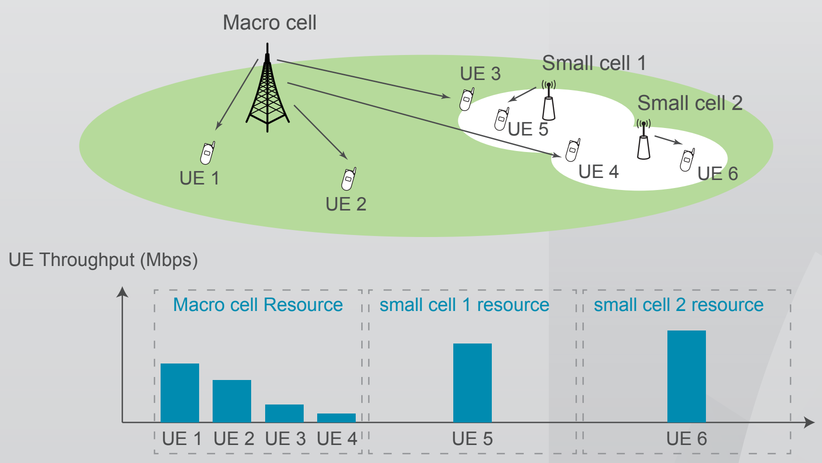

Figure 5: Uneven distribution of UE experience

The macro cell and small cells share the same total resources. Throughput for UEs served by a macro cell is typically lower since traffic loads for macro cells are on average heavier due to the need to provide simultaneous services to multiple UEs over a greater area, while throughput for cell-edge UEs, such as UE3 and UE4, is especially low due to increased channel propagation distance and interference. In general, only a few UEs are served by small cells due to limited coverage, so UE throughput inside a small cell's coverage, such as UE5 and UE6, is comparably higher due to more available resources. A consistent QoE between macro cells and small cells is a considerable challenge to providing a seamless No-Edge network user experience.

MSA: A key to MBB network evolution

MSA leverages centralized integration of multiple RATs, carriers, and intra-carrier ports to resolve the aforementioned operator pain points and provide a significant cell-edge throughput improvement for a No-Edge network user experience. A combination of a layered network architecture and MSA in future networks will enable users to enjoy high-speed and highly reliable mobile services anytime and anywhere.

A layered network architecture includes a host layer and a boost layer (see Figure 6 below). The host layer ensures a QoE baseline and provides reliable MBB network coverage and data services. A "Host Link" is established on the host layer to enable UE signaling and data transmission. The function of the boost layer is to increase network capacity and provide the best possible user experience by using all available resources, and establishing "boost links" to provide UEs with enhanced data transmission.

MSA is a key technology for integrating the capabilities of both of these layers to further enhance user experience and network capacity. MSA has been standardized since 3GPP Release 10 and has been a hot topic for the current Release 12.

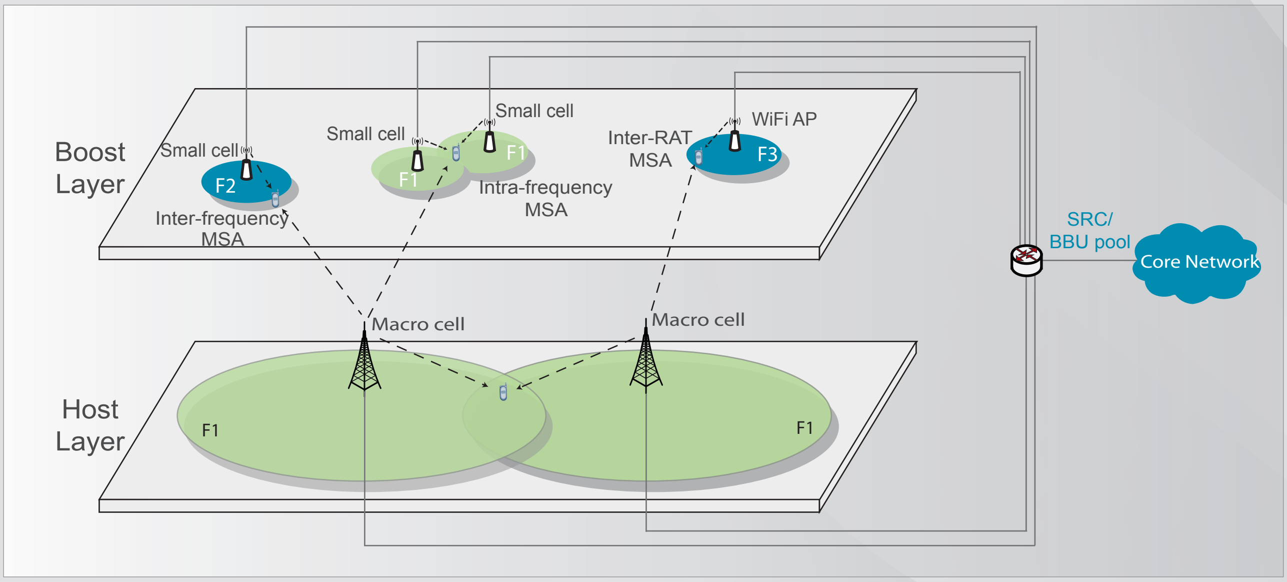

Figure 6: Host/boost network layering with MSA

As a RAN element, a centralized BBU pool or a SRC (Single Radio Controller) can be used as a central node to implement MSA while performing unified control functions such as network layering, traffic steering, and coordinated scheduling.

Figure 7 below shows the performance gains made possible by the combination of a layered network architecture and MSA. In a traditional "mono-layer" HetNet without MSA, a handover is triggered when a UE moves between a macro cell and a small cell, which might affect the UE experience especially in cases of call drops (as shown by blue curve). However, after introducing the combination of a layered network architecture and MSA, handovers and interference are effectively eliminated, system resources are fully utilized, which will significantly enhance UE experience .

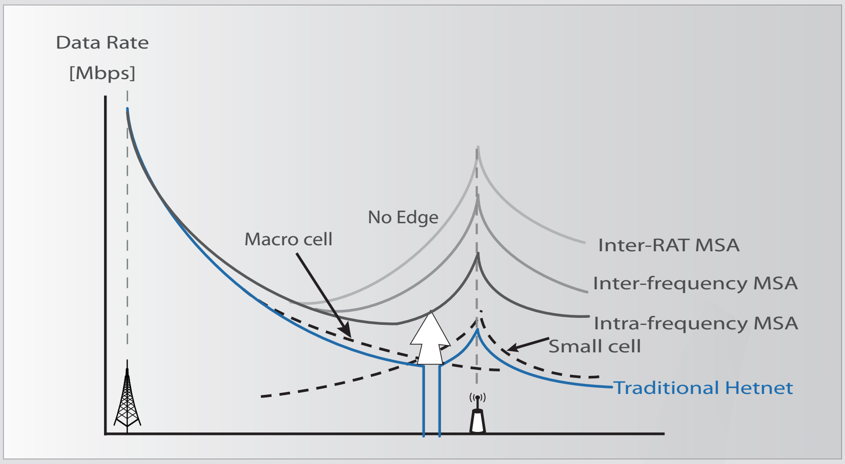

Figure 7: Performance gains from the combination of a layered network architecture and MSA

Host Layer ensures a user experience baseline

The host layer's primary function is to eliminate network performance issues related to HOs and interference to provide an unwaveringly reliable QoE baseline.

Handovers

A drastic reduction in HOs can be achieved for both intra-frequency and inter-frequency scenarios:

• Intra-frequency: All small cells within a macro cell's coverage share the same cell ID as the macro cell, so no intra-frequency HOs will be triggered when a UE moves within the macro's coverage.

• Inter-frequency: A UE is always anchored to the macro cell. Wherever it goes within the coverage area of the macro cell, a host link between the UE and macro cell is maintained so that no inter-frequency HO is triggered.

Interference

With a layered architecture in place, interference can be further divided into intra-layer and inter-layer interference:

• Intra-layer interference: Coordinated scheduling of neighbor cell resources through the host layer can be used to effectively minimize intra-layer interference, which is especially useful for interference-prone UEs.

• Inter-layer interference: Time-frequency resource separation can effectively minimize inter-layer interference. In this way, a portion of time-frequency resources are devoted to SFN (Single Frequency Network) transfers from different ports on the host layer to achieve the best coverage, while all remaining resources are efficiently allocated through spatial multiplexing between the host layer and boost layer to achieve the best utilization efficiency.

The host layer effectively ensures mobile service continuity by eliminating HOs and improving throughput by reducing interference to ensure a QoE baseline.

Boost layer provides best possible user experience

The boost layer enhances user experience beyond a baseline, and MSA is a key technology that works with the boost layer and host layer to make this possible. As for its different application scenarios, MSA can be intra-frequency, inter-frequency and inter-RAT.

Intra-frequency MSA: Utilizing all available intra-carrier ports

In a mono-layer HetNet architecture, a single UE is served by a single port, which is an inefficient usage of system resources. After introduction of intra-frequency MSA, a single UE can dynamically connect to one or more of the best available ports to achieve the best possible UE experience. With intra-frequency MSA, data transmission is made possible without the need for additional signaling, thus maximizing utilization of system resources even when a UE moves between different cell IDs. This resolves issues inherent to more efficient resource utilization, making for a more geographically consistent UE experience.

Figure 8 below illustrates the benefits of intra-frequency MSA for providing a more evenly distributed user experience. UEs located on cell-edges (UE3 and UE4) are served by both the macro cell and small cell for increased throughput while the other UEs in the macro cell (UE1 and UE2) can also increase throughput due to greater allocation of resources. UEs located inside a small cell's coverage (UE5 and UE6) share resources with cell-edge UEs but this has a trivial impact on user experience since the traffic loads of small cells are light in most cases.

Intra-frequency MSA utilizes several advanced algorithms that enable cell-edge throughput gains of 200%, including:

- Interference management with Coordinated Scheduling Power Control (CS-PC)
- Adaptive Coordination Load Balancing (CLB) for maximum spectrum utilization
- Coordinated Multi-Point transmission and reception (CoMP) for dynamic point selection and joint transmission tracking for channel fade variations and unbalanced traffic distribution

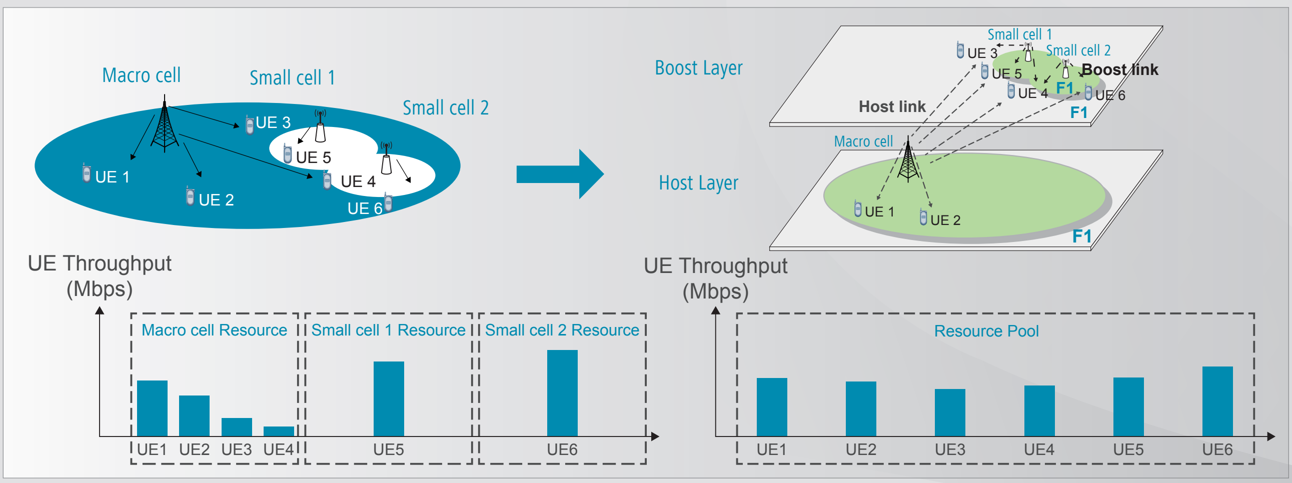

Figure 8: Without and with intra-frequency MSA resource utilization comparison

Inter-frequency MSA: Utilizing all available carriers

In a mono-layer HetNet architecture, when a UE moves between a macro cell using one carrier and a small cell using another carrier, an inter-frequency HO will occur that can adversely affect user experience. However, with inter-frequency MSA, UE is always anchored to the macro cell through a host link even while dynamically connecting to other carriers through boost links for enhanced data transmission. In other words, MSA with different carriers further enhances user experience and increases network capacity. Inter-frequency MSA is applicable for both ideal and non-ideal backhaul cases between macro and small cells. In ideal cases, the backhaul link latency between a macro and small cell is negligible, but in non-ideal cases it isn't. And now, MSA utilizing different carriers in non-ideal backhaul scenarios has become a hot topic for 3GPP Release 12.

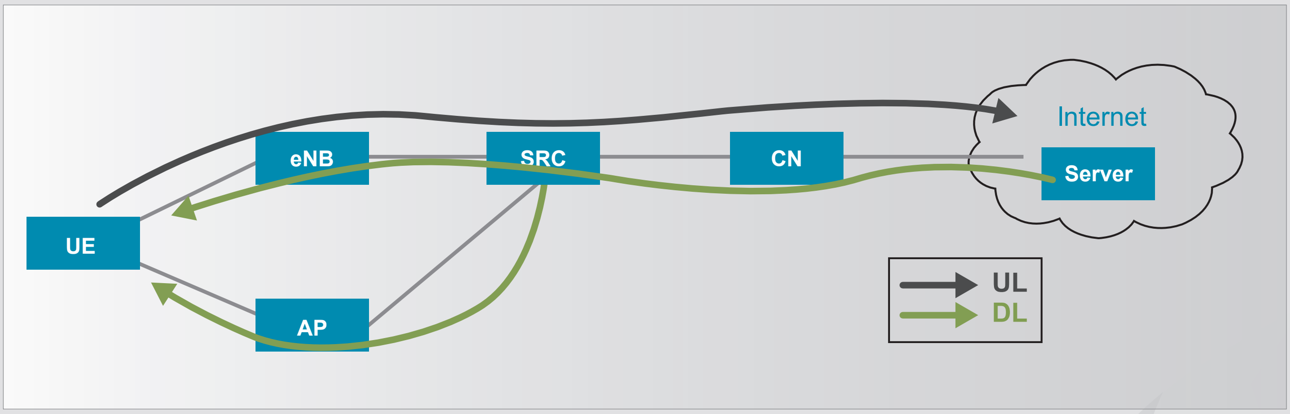

Figure 9: Inter-RAT MSA with WiFi for downlink data transmission alone

Inter-RAT MSA: Utilizing all available RATs

Inter-RAT MSA utilizes different RATs to enhance user experience. In this case, the host layer can be UMTS or LTE, while the boost layer can be LTE or WiFi. For a LTE-WiFi scenario, LTE acts as the host layer and WiFi acts as the boost layer. The former provides basic mobile services to the user, with an LTE host link remaining connected with the UE to guarantee a QoE baseline. WiFi then enhances user experience by providing a boost link between the UE and WiFi Access Point (AP) to boost data transmission rates.

In most cases, downlink data traffic volume exceeds that of the uplink, but allocated resources for downlink and uplink are in approximate symmetry, so other resources are needed to assist downlink data transmission. Furthermore, WiFi uplink suffers from more serious performance issues related to access collision, hidden terminals, and Quality of Service (QoS) that get worse as the number of connected UEs increases. Based on the above two considerations, a more efficient transmission scheme is to use a WiFi network for downlink data transmission alone (see Figure 9 below). In this scenario, SRC flexibly steers traffic from the host link to the boost link through WiFi according to the channel quality, network load, and interference to boost UE experience and significantly increase network capacity.

Conclusion

The continuing widespread growth, diversification and availability of HD mobile services will no doubt severely strain capacity for future MBB networks. In order to meet growth in demand for mobile services, MSA leverages the centralized integration of multiple RATs, carriers, and intra-carrier ports to resolve all aforementioned operator pain points and provide cell-edge throughput improvements of 500%.

A combination of a layered network architecture and MSA in future networks will enable users to enjoy high-speed and highly reliable mobile services anytime and anywhere, in which a host layer provides reliable network coverage and ensures a QoE baseline, and a boost layer increases network capacity and provides the best possible user experience. MSA is a key technology that works with the host layer and the boost layer to make this possible.

At present, all of the aforementioned technologies and solutions have been prototyped on existing product platforms. Significant QoE improvements that help realize a No-Edge network user experience have been successfully demonstrated via a combination of host/boost network layering and MSA outfield trials.

List of Figures Used

Abbreviations Used

AP – Access Point

BBU – Base Band Unit

CA – Carrier Aggregation

CLB – Coordination Load Balancing

CoMP – Coordinated Multi-Point transmission/reception

CS-PC – Coordinated Scheduling Power Control

eICIC – Enhanced Inter-Cell Interference Coordination

HetNet – Heterogeneous Network

HO – Handover

MBB – Mobile Broadband

Mbps – Megabit per second

MSA – Multi-Stream Aggregation

QoE – Quality of Experience

RAT – Radio Access Technology

RSRP – Reference Signal Received Power

SFN – Single Frequency Network

SRC – Single Radio Controller

UE – User Equipment

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