SAMSUNG

Case Study

5G in Korea

Volume 2: Korea's 5G Continues Exceeding Expectations

Contents

Persistence pays off for Samsung Networks in becoming a major 5G radio access network vendor.

Samsung Networks has done well in raising its profile with several high-profile 5G network deployments. This success did not come overnight, nor did it start with just 5G. Samsung has been working for many years - investing in 5G technology and use case development along with building operator relationships - to get to where it is today. Today's 5G success is built on more than 40 years' effort by Samsung Networks in delivering cellular networks and building operator relations.

Daryl Schoolar, Practice Leader for Service Provider Technologies at Ovum

1. Introduction

Korea's launch of commercial 5G service on April 3, 2019, is proving to be a fantastic benchmark for the new technology. While network deployment is vital to the success of 5G, even more important is the availability of a dynamic and growing ecosystem that that drive revenue. The ability for three mobile carriers to simultaneously launch, operate, and expand their 5G networks is proving that Korea is a unique country that has all the facets of 5G ecosystem; infrastructure, service and subscribers. From UHD video to immersive gaming, the 5G network is powering capacity that transported a record 25.9GB of average monthly data traffic per user in September 2019.[1]

Korea is home to one of the world's most densely populated areas, numerous skyscrapers and a complex infrastructure. Its largest cities are examples of concentrated metropolitan areas that create the right blend of wireless network attributes to explore new services on modern networks. 5G in Korea continues to demonstrate the high demand services that are driving network expansion across the country and proving to be a benchmark for global operators to explore.

This case study looks at the changes in the Korean telecommunications market six months after the 5G commercial launch and lessons learned in the commercialization process. You can find the volume 1 of Korea 5G launching case study, along with those published about other cases, at: https://www.samsung.com/global/business/networks/insights/?white-paper+case-study

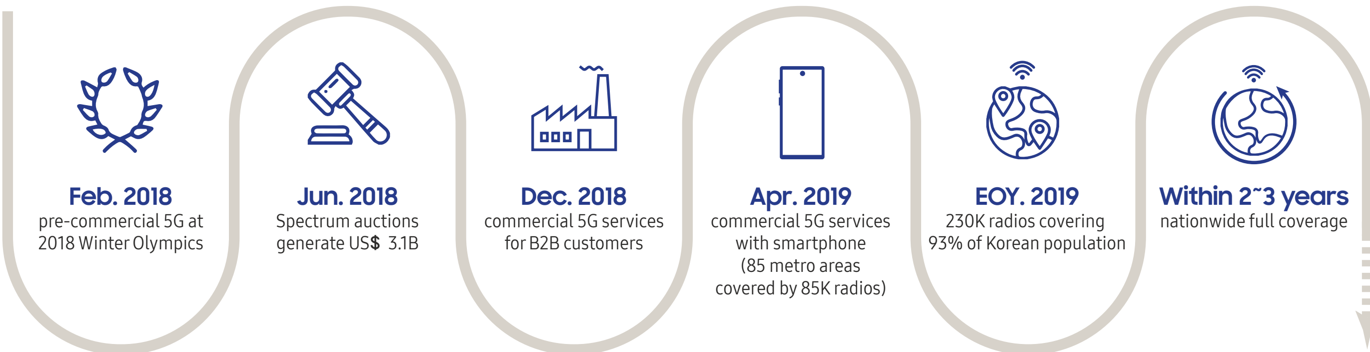
1.1 Korea's 5G Launch – An Overview

From early deployments, like the 2018 Winter Olympic Games, pre-commercial services provided a great preview of the possibilities that 5G would bring to consumers and businesses. Demonstrations of the capabilities of real-time, low-latency connectivity at the Olympic venues allowed spectators to immerse themselves into the future promises of entertaining experiences. These exhibitions created an intriguing level of excitement and energy regarding the possibilities that 5G could offer.

This energy led straight into the spectrum auctions conducted in June 2018. The three carriers spent a collective 3.6183 trillion won[2] (US$ 3.1B) to secure the rights to use segments of both the 3.5 GHz frequency range (sub-6 GHz spectrum) and the 28 GHz frequency range (mmWave spectrum). With the completion of the auction, the three carriers were in prime position to begin their network deployments.
The three carriers immediately took to planning and deploying their networks. In December, the carriers began offering commercial services in Seoul and six metropolitan areas using their sub-6 GHz spectrum to connect 5G Mobile Hotspot devices.

A short four months later, the Korean carriers launched full 5G mobility-enabled services using commercially available smartphones, like the Samsung Galaxy S10 5G, in 85 Korean urban areas. At the April launch, 85,000 radios[3] were in-service across the three network operators carrying 5G traffic.

The uptake of the technology by users of the network is exceeding expectations. Since the launch, services like virtual reality-based immersive applications and high-quality video streaming continue to entice consumers to upgrade to one of the new high-speed 5G networks. Now to support the growing demand, network providers are on track to ensure that 230,000 radios are in service to provide high-speed connectivity to 93% of the Korean population by the end of 2019.[4]



1. Ministry of Science and ICT, 2019. 9
2. Ministry of Science and ICT, 2018. 6
3. Ministry of Science and ICT, 2019. 4
4. Http://www.koreaherald.com/view.php?ud=20190424000702

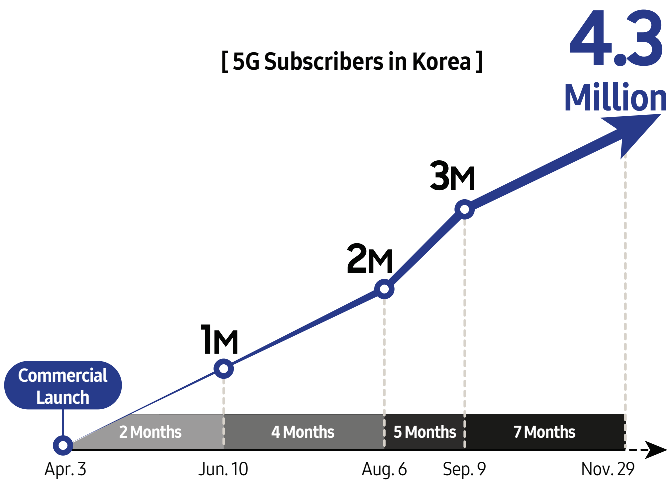
2. Transforming Telecommunication in Korea with 5G Adoption

With the ecosystem successfully supporting new 5G-enabled applications with excellent devices, the uptake of new subscribers keeps growing. Fueled by the excitement generated by these new applications, Korean 4G subscribers continue upgrading to the latest smartphones to join with their friends and colleagues on the 5G network.

2.1 Fast Growing 5G Subscription

The growth of 5G subscribers following the launch is unprecedented. The three networks reached 1 million subscribers in early June, and, in less than two months (57 days to be exact), the systems eclipsed the 2 million subscriber mark. The growth rate from August to September continued to rise, and, in 34 days, the 5G networks were supporting 3 million subscribers. As of the end of November, just 7 months after it was made available, 5G subscribers have surpassed 4.3 million.[5] The increasing rate between each million-subscriber milestone indicates that the Korean 5G market could surpass 6 million subscribers before the end of the year.

Korean carrier SK Telecom said that the number of its 5G subscribers exceeded 1.54 million as of the end of September 2019, after achieving the world first title to surpass 1 million 5G subscriber mark on August 22, 2019. SK Telecom has attracted 1 million 5G subscribers in just 140 days after launching the world's first 5G smartphone on April 3, which is twice faster than its LTE uptake rate.[6]



(Source : MSIT and Carriers)


Samsung 5G MMU

This 5G growth is faster than prior network technology upgrades. A key reason for the increase in Korea comes from fast coverage expansion and Samsung has played a key role. Samsung MMU has a slim and compact design intended for efficient on site installation. It is among the smallest and lightest in the industry and can be easily installed in existing carriers' cellular sites. Carriers can reuse the infrastructure that is already installed on site with minimal changes necessary.

This ability to re-use existing sites has been key to enabling the Korean operators to deploy 5G network consisting of tens of thousands of radios within just a few months since the Dec 1st, 2018 launch. Also, site reuse is extremely critical when considering how difficult the site acquisition process is for carriers when deploying commercialized 5G with new equipment. More details on key success factors for early 5G launch are covered in the prior case study "5G in Korea version 1."[7]

Additional key drivers include the availability of new devices, like the latest 5G smartphones that include higher quality components, like high-resolution cameras and UHD quality displays. The availability of premium phones like the Samsung Galaxy S10 5G and Galaxy Note 10 5G continue to entice subscribers to upgrade to 5G.

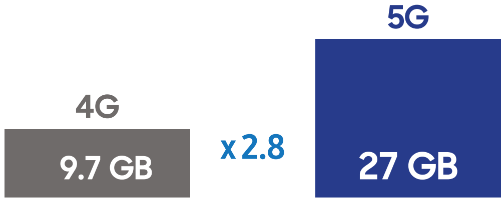
One of the challenges with 5G deployment is that the tariff for 5G is more expensive than that of 4G. Taking the fare into consideration, the competition amongst the carriers for 5G subscribers is fierce; with the higher tariff and the need for a new device, carriers are promoting applications unique to their networks while offering subsidies to attract subscribers to their networks.

5. http://news.kmib.co.kr/article/view.asp?arcid=0924111003&code=11151400&cp=nv
6. https://www.sktelecom.com/en/press/press_detail.do?idx=1420, https://www.sktelecom.com/en/press/press_detail.do?page.page=1&idx=1427&page.type=all&page.keyword=
7. "5G in Korea version 1," Samsung Case Study, 2019. 7

2.2 5G User Behavior

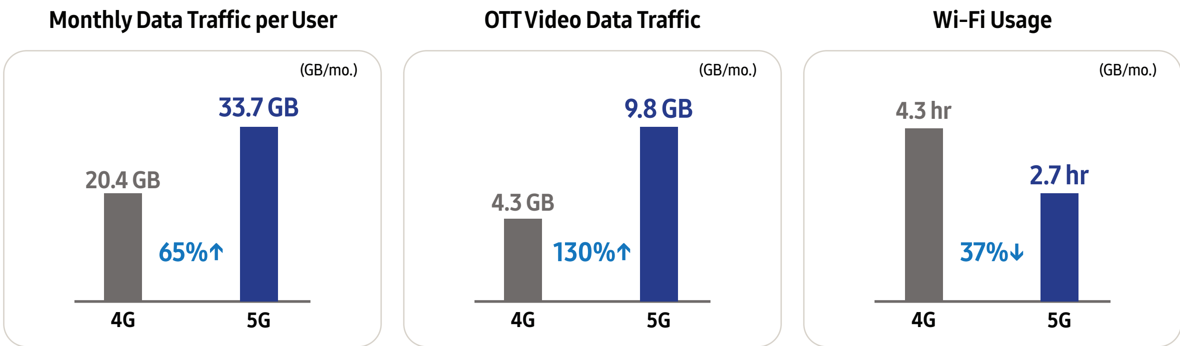
Despite the higher costs associated with tariffs and new devices, 5G is changing how the user accesses and consumes their information. With better user experiences, 5G-powered subscribers are using the commercial 5G network to consume their data and services more than the alternative network connections. Average data usage by 5G users is as high as 27GB, and average 4G users use 9.7GB in the same period, according to MSIT in October 2019. 5G data is nearly 3 times than that of 4G.

[Monthly Data Traffic per User]



(Source : MSIT, October 2019)

[SK Telecom's 5G Subscriber Usage Analysis]



(Soucre : SK Telecom, August 2019)

According to SK Telecom's 5G subscriber usage analysis, the average monthly data traffic of customers who switched devices from 4G to 5G has increased 65% from 20.4 GB to 33.7 GB. In particular, monthly OTT video traffic rose about 130%, from 4.3 GB to 9.8 GB, with a corresponding drop in average Wi-Fi usage time per month of 37% from 4.3 hours to 2.7 hours. With unlimited data included in their 5G plans, subscribers prefer the improved 5G connectivity experience over the unmanaged Wi-Fi connections that cannot deliver similar high-quality experiences.

These data points support the premise that the high-speed, low latency 5G network is successfully changing how subscribers access and consume services and data. Not only are current entertainment and learning applications driving usage, but subscribers realize that it is worth the time and money to change to 5G, away from the slower and less flexible Wi-Fi enabled access.

SK Telecom also indicates that 5G subscribers consumed about 15 times more VR traffic than 4G subscribers. The number of 5G customers who enjoy the contents of the VR platform 'Jump VR' was nearly eight times that of 4G. The number of VR content also increased five times since the 5G commercialization.[8] Among KT's 5G services, AR/VR communication applications, like Real 360 (a see-what-I-see service), narle (an AR-based group video call application), and the e-sports live service are highly popular with those subscribers between the ages of 18 and 44.[9]

2.3 ARPU Turnaround

As would be expected from new technology, the operators are leveraging the latest technology to impose a bump in tariffs. Korean operators see a slight increase in per-subscriber revenue based on the higher 5G fees for service. The ARPU of all three telco increased from 0.4% to 0.8% (QoQ) at Q2 and 0.2% to 1.3% at Q3.[10] The numbers may not sound very impressive, but taking into account that Korean operators have been suffering from decreasing ARPUs for about 7 consecutive quarters before launching 5G services, even this slight bump in ARPU could mean a lot.

With the 5G networks launching at the same time, network operators needed effective campaigns to maintain or grow their total subscriber bases. They leveraged a three-step approach: (1) transition existing 4G users to 5G, (2) keep those 4G subscribers who did not upgrade to 5G, and (3) provide incentives to attract new subscribers to join their 5G network to offset any lost subscribers. Marketing between the operators became incredibly competitive.

In the process of securing and growing their 5G subscriber bases, mobile carriers relied on device discounts. But carriers expect that the increase in these marketing costs is only temporary and is setting up long-term profitability through the increased revenue from contract subscribers with plans of 24 months and longer.

8. http://www.koreaittimes.com/news/articleView.html?idxno=92517
9. https://www.asiae.co.kr/article/2019071009335036534
10. Carriers' Company IR, 2019. 11

3. Lessons Learned from Korea's 5G Deployment

Being the first in the world to deploy end-to-end 5G networks, Samsung and the partner carriers successfully navigated challenges during the launch and early days of operations. These challenges included increasing coverage areas of 5G, ensuring effective services between 4G and 5G, options to increase network throughput, and interoperations with other network equipment providers.

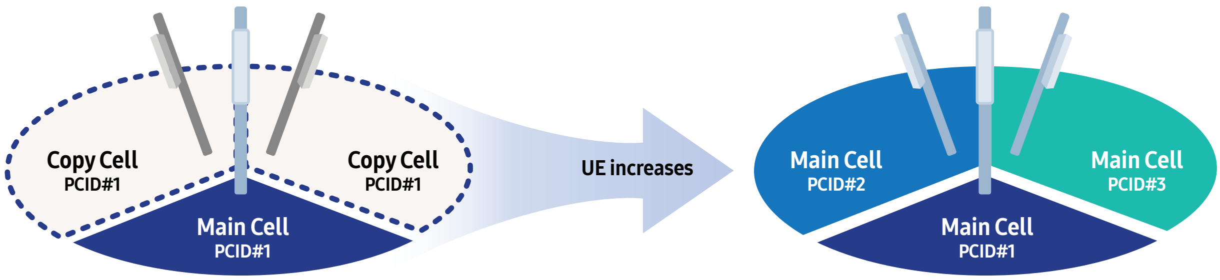
3.1 5G Coverage Expansion

The high growth for the subscriber base on 5G ensured a sharp focus on resolving these points to provide the quality of experience the users expected of the 5G network.

3.1.1 Fast Coverage Expansion Using Copy Cell

In the early stages of 5G commercialization, operators would choose 5G coverage to gain a competitive advantage in the race to attract customers. The speed of deployment to expand 5G service coverage area became a significant part of the competition. However, deploying the sufficient volume of digital units (DUs) and radio units (RUs) to ensure the service coverage during rollout was a challenge since there would be only a few 5G users.

To expedite deployment of new cells, Samsung implemented "copy cell" that, in the early stage of commercialization, facilitates increasing the 5G service area at a relatively low cost. Copy Cell is a specialized cell deployment that operates several RUs with one Physical Cell Identifier (PCID). In this deployment, the DU transmits the replicated downlink (DL) signals to multiple RUs and processes the combined uplink (UL) signals received from the RUs. The carrier creates a larger coverage area using fewer DUs, which reduces the cost of network installation.



The technique of using this deployment option is suitable for sites with a small number of users because multiple RUs share the wireless resources and the DU processing power of one cell. As the number of 5G users in the area increases, carriers will be able to plan for and invest in the requisite additional DU deployment with reduced urgency. Carriers activate the new DUs and easily convert the copy cells into independent standard cells, which have their unique PCID.

3.1.2 Optimizing Cell Coverage Near MMU with Tilt Adjustment

In general, the design of the cell-specific beam of an MMU for transmitting signals to user equipment (UEs) has a wide horizontal beamwidth and a narrow vertical beamwidth. The horizontal component allows the antenna to cover an angle range suitable for the target sector, and the vertical component increases the beam gain to enable the signal to have a more extended reach. General cell planning mainly focuses on adjusting the direction of the cell-specific beam. This approach can cause a signal level degradation for in-cell UEs that are not within the pattern of the main lobe of antenna coverage. This challenge occurs because null angles are formed that point near the base station (BS). Even the cell-specific beam with high gain can cause Reference Signal Receive Power (RSRP) degradation of the UEs near the base station.

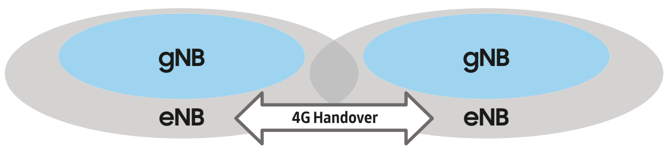
To mitigate the RSRP degradation for in-cell UEs, Samsung introduced a technique that uses mechanical downtilt and electrical uptilt to optimize cell coverage. This technique results in increased UE RSRP near the base station, while also providing the ability to adjust the main lobe direction. Based on array theory, sidelobes grow in the opposite direction of main lobe. For example, using an electrical up tilt creates large sidelobe levels in down side and vice versa. Then, by over-applying mechanical downtilt and adjusting electrical uptilt for the desired direction, both main and sidelobes can better cover in-cell UEs and increase overall RSRP.

3.2 Stable Network Operations with EN-DC Mobility

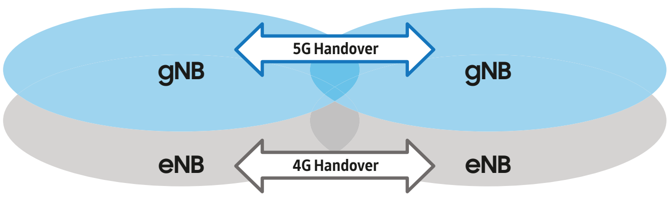
The launch of the 5G network into a highly populated 4G network required that the deployment support both 4G and 5G. The 5G RAN network uses the 4G core network to achieve coexistence with 4G, which means that the 5G RAN is operating in the non-standalone (NSA) architecture. It is also known as 'E-UTRAN New Radio Dual Connectivity (EN-DC)' based on the 3GPP 5G New Radio (NR) standard. In the initial deployment stage when 5G coverage is limited, EN-DC enables UE mobility between cells, a big hurdle that needs resolution to ensure acceptable service.

Samsung takes into account various scenarios of EN-DC mobility and supports them as part of the transition to 5G coverage. At the beginning of EN-DC system deployment, the inter-eNB handover occurs with gNB release. Then the gNB addition occurs in the target eNB, as below. This approach is more feasible in initial deployment and should follow a two-step process:

- Step 1 : Inter-4G eNB handover
- Step 2 : 5G gNB addition



As the 5G NR coverage gets extended and EN-DC mobility gets stabilized, Samsung eNB/gNB supports independent and concurrent 4G/5G NR handover. Thus, handover can be handled by Samsung's eNB/gNB without additional latency.



3.3 Throughput Improvement

To deliver a significant technological leap from 4G, 5G needs a significant increase in both downlink and uplink throughput. To achieve the best balance of the throughput, the network needs to optimize the split bearer path (where user traffic arrives at the UE over both 4G and 5G) for higher downlink throughput and facilitate MRC beamforming for higher uplink throughput.

3.3.1 Downlink Throughput Enhancement with Split Bearer Optimization

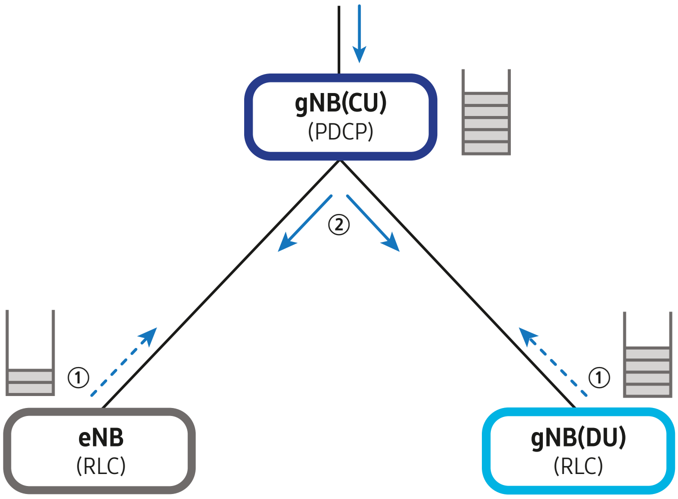
Current 5G networks are tightly linked to 4G, and EN-DC allows operators to improve throughputs to the UE by sending data destined for the UE over both 4G and 5G NR RANs.

The split bearer UE receives packets from two links both over 4G and 5G. Non-sequential packets received from two links are transmitted to the upper layer through a reordering operation in the PDCP (Packet Data Convergence Protocol) layer. If the UE receives an out of order packet, it waits for a specific period of time to ensure reception of all packets. Called the reordering time, several factors, including the UE buffer size, PDCP reordering timer, and TCP retransmission timeout affect the duration of the reordering time. When the reordering time exceeds the limits from these attributes, throughput degradation occurs due to packet loss or retransmission.

Therefore, the base station needs to efficiently distribute packets over the two networks to minimize the reordering time. To achieve this distribution, Samsung developed the new "split" algorithm which takes 2 steps depicted in the figure below. In this way, the algorithm minimizes reordering time to achieve target throughput.

- **Step 1 : Periodic request of desired buffer size**
  → Decide 'target buffer size' proportional to air throughput
  → Periodically send a request of desired buffer size
  (i.e., 'target buffer size' – current buffer size)

- **Step 2 : Determine the path for each packet**
  → Estimate the packet delay on each path (4G, 5G)
  → Select a path with the expected smaller packet delay



3.3.2 Uplink Throughput Enhancement with MRC Beamforming

With the introduction of the MMU, Samsung is both enhancing coverage and increasing throughput. For the uplink traffic, array gain and diversity order theoretically increase with the number of receiving antennas. Given received signals in multiple antennas, the carrier can maximize Signal to Noise Ratio (SNR) for receivers through a technique known as Maximal Ratio Combining (MRC) beamforming. This technique, however, requires significant signaling link capacity between the MMU and the DU primarily so the uplink modem in the DU can send a high volume of antenna signals. While reducing the spatial dimensions of received signals at the MMU can lessen the impact on the signaling link, there are corresponding losses of array gain and diversity gain, as the DU performs MRC with reduced dimension data.

To mitigate the reduced data, Samsung proposed the MMU-DU structure below to resolve MRC gain loss problem.

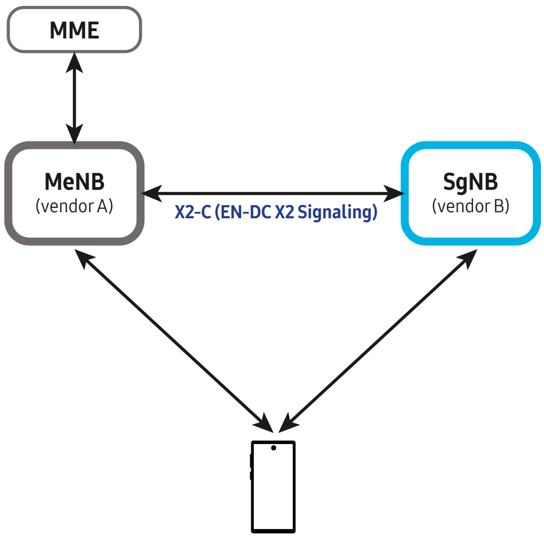
- To reduce the impact of dimension reduction, the MMU also performs MRC using uplink channel information estimated based on Sounding Reference Signal (SRS).
- The effectiveness of the MRC gain depends on channel estimation accuracy. Since there is a time delay between the SRS and the received Physical Uplink Shared Channel (PUSCH), the gain from MRC at this time is not accurate as the channel estimate occurred at a different time. To improve the accuracy, the DU performs MRC again using channel information based on demodulated reference signal (DMRS) of the PUSCH with reduced dimension.

3.4 Multi-vendor Interoperability

As mentioned earlier, the current commercial 5G networks in Korea use the NSA architecture, which allows the UE to connect to 4G eNB as a master node (MeNB) and a 5G gNB as a secondary node (SgNB). When the EN-DC network consists of eNBs and gNBs from different vendors, the interoperability of the EN-DC X2 interface is essential for the performance and stability of users as they move between sites in the network. Though 3GPP specifies the EN-DC procedures between MeNB and SgNB, the actual operations of the interface need to be discussed and adapted between the eNB and gNB of the different vendors.
Through the commercialization of 5G in Korea, Samsung has fully experienced multi-vendor interoperability testing.

3.4.1 X2 Control Plan (X2-C)

During validation of the network, Samsung, along with the other equipment providers, found that implementations of the EN-DC X2 procedures, while compliant to 3GPP procedures, required additional work to enable successful operations between the eNB and gNB of the different vendors.



The collaborative work below created alignment on the support schedule for the procedures as well as adapting the operation algorithm. The coordination is necessary to prevent conflict (or ping-pong) between the procedures which both eNB and gNB can initiate. Also, 5G NR measurement configuration information should be coordinated between the vendors because it can be handled by both eNB and gNB and the data is closely related to the EN-DC mobility procedures.

- EN-DC X2 setup procedure (both eNB and gNB can initiate)
- EN-DC configuration update procedure (both eNB and gNB can initiate)
- SgNB addition procedure
- SgNB modification procedure (both eNB and gNB can initiate)
- SgNB change procedure
- SgNB release procedure (both eNB and gNB can initiate)

3.4.2 X2 User Plane (X2-U)

In EN-DC with split bearers, both the eNB and the gNB use the NR-UP (New Radio-User Plane) to provide downlink traffic control over the X2-U interface. Although inter-working between multi-vendors' equipment may not be an issue due to the standardized NR-UP procedures, the experience in Korea pointed to several operational behaviors that required coordination between the participating vendors for successful operation.

In the NR-UP, the two vital components that maximize the available link bandwidth while preventing under-utilization of the link are DDDS (Downlink Data Delivery Status) feedback from the eNB and traffic distribution from the gNB. Computation of the desired buffer size in the DDDS and its reporting period can have significant impact on application performance since the gNB relies on estimation of network conditions through the DDDS. Sufficient and timely information about the network paths is crucial for efficient traffic distribution over the 4G and 5G NR paths.

The traffic distribution mechanism also needs to consider in-order delivery of packets that the majority of Internet applications require. The technique could be optimized such that the multi-path transmission of single session packets would not cause excessive delay due to re-ordering thereof in the cellular system

4. The Road Ahead

Network providers see good things with their 5G network deployments and are continuing to expand coverage to prepare for the rollout of more advanced technologies like edge computing and massive IoT connectivity services to set a path for their long-term growth.

The growth and density of the users in 5G will continue to grow, and as new services arrive, network providers will need more coverage. Especially with the use of the mmWave spectrum, carriers are expecting that 80% of 5G data traffic will need to reach from inside buildings.[11]The three Korean network operators are already focusing on 5G in-building solutions to provide coverage in crowded areas like shopping malls and subway stations and to increase coverage in traditionally challenging areas like underground parking lots.

The success of 5G is quickly filling the available capacity on the current network, and with the need for more capacity, industry experts forecast that the three Korean network operators will likely begin using their 28 GHz band in the next year. By utilizing both 3.5 GHz and 28 GHz spectrum, Korean operators will be able to deliver higher 5G capacity and better network performance.

Samsung Electronics announced on Oct. 23 that it is delivering the industry's first integrated 28 GHz 5G base station, which supports data transmission at 10 Gbps, the fastest speed among commercial 5G base stations. Samsung's 28 GHz 5G Access Unit integrates the radio, antenna, and digital unit into one compact box, making it the industry's first integrated radio for mmWave spectrum that is compliant to the 3GPP 5G NR standard. The small size and low weight of the new base station allow network operators to install it in a variety of locations, including streetlamp posts and building walls. Samsung powers the 5G 28GHz base stations with Samsung's new 5G NR system-on-a-chip (SoC) modem, the S9100.[12]

5G is not only multiplying the speed of wireless connectivity, but it is expanding the number of connected devices by several folds and leveraging edge computing technologies to optimize user traffic delivery. Today's networks support the evolution from 4G to 5G, but, the system must evolve to 5G Standalone, or 5G SA, to reach the full potential of 5G. Samsung announced the successful completion of an interoperability assessment between a Samsung 5G Standalone Core and one of Korean operators' commercial network systems.[13] Once 5G SA commences commercial service, operators believe that users will see a three-fold improvement in data processing efficiency, which is needed to support the expected massive increase in data traffic. It also creates opportunities for tailored vertical market solutions, like autonomous driving, smart factories, smart farms, and AR/VR services.

11 "5G-Oriented Indoor Digitalization Solution White Paper,"GSA White Paper, 2017. 11.

12. "Samsung Unveils New 5G NR Integrated Radio Supporting 28GHz at MWC LA 2019", Samsung Press Release, 2019. 10.

13. "Samsung and SK Telecom Advance in Bringing Korea Closer to 5G Standalone Commercialization", Samsung Press Release, 2019. 7.

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