5G best choice architecture

White Paper

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Executive summary

As LTE matures and Rel-15 standard freezes, mobile operators should start carefully considering available network upgrade paths. Unlike LTE, the primary goal of 5G will not only be about increasing data rates and network capacity. This time, 5G promises more opportunities and KPIs to address vertical industries and innovative applications for exploring new revenue sources. In the early life of 5G, operators will have the option to choose between two network deployment modes.

The choice to be made by operators is architectural in nature. Mobile operators will have to choose between deploying a full 5G standalone (SA) network that provides E2E 5G experience or deploying a 5G non-standalone (NSA) network to be complemented and supported by LTE network. While the former will take time to develop, the latter offers limited 5G benefits confined to the improvement in some network KPIs.

In addition, 5G NSA is expected to be less capital-intensive as compared to 5G SA architecture. However, as demonstrated by evidence presented in this white paper, that may not be the case. Therefore, the choice will be based on spectrum availability and use case requirements rather than budget.

The two 5G network architecture options can be compared by looking at four main perspectives: investment, spectrum availability, service offerings, and network KPIs.

Exhibit 1 5G SA versus NSA architectures

	Standalone (SA)	Non-standalone (NSA)
Investment needed		
Short-term	High	Low to medium
Long-term	N/A	High
Spectrum availability		
Sub-6GHz band	Best choice for good network coverage	Depends on LTE network for good coverage
mmWave band	Can work with SA by using hotspot-based network	Needed for hotspot-based network deployment
Service offerings	Covers all use cases including eMBB and those dependent on URLLC and mMTC.	Supports only eMBB use cases
Network KPIs		
Data rate (DL/UL)	20Gbps/10Gbps	20Gbps/10Gbps
Latency	1ms	4ms
Network density	1 mil devices per km^2	1 mil devices per km^2

Source: IHS Markit

As the comparison above shows, 5G SA architecture network deployment cost can seem capital intensive, but with the right deployment strategy operators can bring the cost down sharply. This strategy can be summarized as follows:

- Adopt selective 5G coverage to start in areas with highest demand for data.
- Co-site 4G and 5G whenever possible and consolidate RF equipment for lower costs.
- Deploy 5G Core in a data center relying on cloud and virtualization technologies.
- Start with fundamental 5G Core features only to lower investment.

Applying the above strategy, the 5G SA option becomes more economical and deployable as fast as NSA. Moreover, it allows operators to support all use cases of 5G and penetrate new verticals, as this paper will explain.

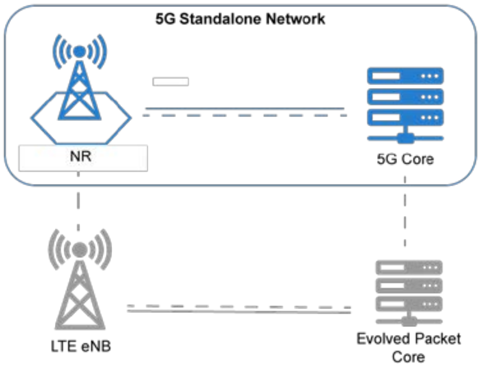
5G network architecture

The 5G race is underway, with many operators having already joined. Some are still in the planning phase, but many have announced their involvement in trials or pre-commercial pilot networks. GSMA reported that by November 2018, there were 192 operators actively involved in trials, testing, or being licensed for 5G. Band n87 (3300 to 3800 MHz), widely known as sub-6GHz band, was the most widely used in all these trials and pilots. Millimeter wave (mmWave) band n257 (26.5 to 29.5 GHz) was the second-most used spectrum band. However, with the trials taking place, most operators are still undecided about which deployment mode they should adopt.

Standalone (SA) network architecture

The first network deployment mode is referred to as standalone. SA refers to having an independent 5G network. It will have both the new 5G air interface, New Radio (NR), and 5G Core (5GC) in place. A standalone 5G network provides the user an end-to-end 5G experience. The SA network will still interoperate with the existing 4G/LTE network to provide service continuity between the two network generations.

Exhibit 2 5G SA network architecture



Source: IHS Markit © 2019 IHS Markit

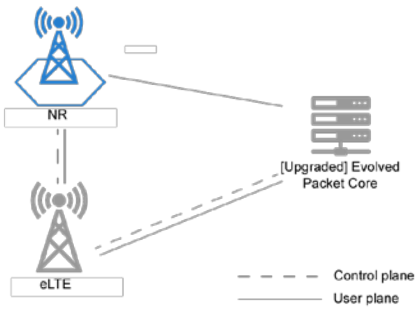
As shown in the above figure, the 5G network can operate independently. At the same time, interoperation with LTE network takes place in order to cover areas not yet covered by 5G and to connect 5G users with non-5G users.

Non-standalone (NSA) network architecture

Non-standalone 5G network, on the other hand, refers to having only 5G NR cells in place with EPC as the core. Operators will deploy 5G cells and depend entirely on existing LTE network for all control functions and add-on services.

The 5G NSA architecture works in master-slave structure, where the 4G access node is the master and 5G access node is the slave. That is why this deployment option has several limitations that will be explained later.

Exhibit 3 5G NSA network architecture



Source: IHS Markit © 2019 IHS Markit

5G Core

We can infer from the two deployment modes described above that the main difference is having a 5GC in place or not. That said, it is important to examine the value behind 5GC and what differences it brings to the network.

The 5G Core or 5GC is truly a new generation of mobile core network. Designed to be cloud-native and heavily dependent on virtualization, 5GC is expected to bring the most value to the network. Most importantly, it will enable operators to extend service offerings beyond just enhanced mobile broadband (eMBB). New services such as ultra-reliable low latency communications (URLLC) and massive machine type communications (mMTC) are only possible with 5GC. These services will allow operators to cover more use cases and penetrate new markets.

Moreover, the inherited features that come with the 5GC enable a new level of service quality. The most notable of all these features is network slicing. Network slicing allows operators to apply and offer different QoS to different use cases. For instance, an operator may dedicate a network slice to vehicle-to-vehicle (V2V) communications. This network slice will make use of the URLLC to provide communications channels that are mission-critical and latency-sensitive.

5GC is not expected to be as costly as its predecessors. Thanks to cloud and virtualization technologies, operators can deploy 5GC of any size and capacity, and add instances of every 5GC function as needed. Moreover, if operators already have virtualized platform in their data center, the deployment cost of 5GC will be reduced sharply.

The 5GC system is expected to be in commercial availability in H1 2019. Therefore, operators with 5G deployment plans for H2 2019 should be ready to put their plans to reality.

5G architecture selection requirements

Choosing the right 5G architecture involves many deciding factors. Among these are desired service offerings, level of investment, and spectrum availability.

Service offerings:

There are many new services associated with the new 5G network. These services help operators diversify their revenue streams and improve their profitability from their network infrastructure. 5GC enables operators to offer these new types of services. There are three underlying factors that enable the new use cases, as follows:

- Higher data rates – 5G achieves data rates of over 100 Mbps on the DL and over 50 Mbps on the UL
- Lower latency – the round-trip latency realized by E2E 5G system is close to 1 millisecond.

These factors are in addition to better spectral efficiency and better overall network capacity.

These values achieved by 5G SA architecture allow the system to support new mission-critical use cases that previous mobile generations could not. Below is a list of some use cases that operators can offer using 5G SA network.

Exhibit 4 5G use cases realized by 5G SA architecture

eMBB	URLLC	mMTC
High quality content streaming	Factory automation	Smart city
AR/VR applications	Autonomous driving	Massive IoT
	Cloud VR game	
	Remote surgery	

Source: IHS Markit © 2019 IHS Markit

Investment

Capital expenditure is an important consideration for all operators. With decreasing ARPU, operators become more sensitive to network deployment costs. In general, the idea of deploying a complete new mobile network seems costly. However, the 5G network is expected to provide more cost efficiency. Below are the elements contributing to the lower cost of a 5G SA network:

- Co-site 5G and 4G radio reduces investment sharply. Co-siting involves consolidating RF equipment using multi-band, multi-port antennas and ultra-broadband, multi-mode AAU/RRUs.
- Use selective 5G NR coverage. This strategy accounts for the slow adoption of 5G technology and leverages LTE network for wide area coverage and service continuity.
- 5GC is built on cloud and virtualization technologies. That means that it can be deployed on a traditional data center, saving huge costs for operators. Moreover, 5GC is flexible in the sense that operators can choose which functions to deploy initially, apart from the fundamental functions.

Spectrum

To offer good 5G NR coverage, operators will need to have a spectrum band in the sub-6GHz range to make use of its propagation properties. If sub-6GHz band is not available, operators will have to depend on the LTE access network for wide coverage. In this case, operators might choose to deploy a hotspot-based 5G SA or NSA network using mmWave band. mmWave bands are not suitable for wide coverage due to weak propagation characteristics. But, it is a good option for hotspot and local 5G NR coverage, and offers large network capacity.

That said, although a sub-6GHz band is the best-case scenario for 5G network, the system can work using other spectrum band while altering the deployment strategy.

Operators' key concerns

In this section, we detail the main points that concern operators the most while deciding about the right 5G architecture. That includes the viability of the new technology, the cost of ownership, the use cases to be offered, and the overall user experience.

Viability

The two-network architecture, SA and NSA, are 3GPP compliant. Both architectures were introduced in 3GPP release 15, just six months apart from each other. Their viability depends largely on external factors such as equipment readiness, user equipment availability, and deployment complexity.

Equipment readiness – All 5G trials and pre-commercial demonstrations suggest that vendors are on track to release commercial-ready systems in 2019. That includes New Radio base stations and complete 5G Core platform. Pre-commercial versions have achieved encouraging results. The last section of this paper presents a detailed example showcasing vendor readiness.

User equipment readiness – UE is still considered the bottleneck hindering any large-scale commercial deployment. Qualcomm, being the main vendor of UE chipsets, announced that it will release its first 5G-enabled commercial-ready chipsets in Q3 2019, which will support 5G SA. The same timeline applies for other vendors such as Intel and MediaTek. UE vendors, such as smartphones manufacturers, have all revealed their plans to integrate 5G in their newly released devices, including the Samsung Galaxy S10, Huawei P30, and OnePlus 7.

Ease of deployment – Each architecture has its own complexity. For instance, deploying a 5G SA network would require a long-term plan to provide nationwide coverage. However, operators can always start with selective coverage—covering only spots with potentially high demand for data and use 4G fallback for service continuity and voice service. Moreover, both cloud and virtualization (the fundamental technologies of 5GC) are considered relatively new technologies, requiring operators to build a new team for network operation and maintenance. On the other hand, NSA architecture will have other types of complexities. Primarily, operators who choose the NSA option will need to upgrade their LTE network including all eNBs and EPC nodes. The upgrade is needed to support the master-slave network structure needed by the NSA mode. This structure poses a high level of complexity when it comes to service enablement and network performance optimization.

Investment

In this section, we contrast the two 5G network architectures from acquisition cost perspective. It makes sense to assume that the final network state all operators will aim for is a SA 5G network. In other words, even if operators chose the NSA option as a starting point, operators will eventually migrate to a fully SA 5G network.

Exhibit 5 5G deployment options – total investment

	SA	NSA
Initial investment	Medium (selective 5G NR + 5GC)	Low (selective 5G NR)
LTE upgrade cost	Minor	Medium (LTE and EPC upgrade to support master-slave setup and dual connectivity)
Migration cost	None	High (migration from NSA to SA)

Source: IHS Markit © 2019 IHS Markit

*The comparison above is not based on actual costs. The values are relative. 'High' does not mean high in absolute term, but it's high compared to the other option.

In the short-term, it seems that NSA is more economical as operators will skip 5GC. In this mode, operators will only invest in selective 5G NR coverage in addition to LTE network-wide upgrade. On the other hand, SA architecture requires, in addition to 5G NR selective coverage, the deployment of 5GC from day one. However, according to the experience of 3G/4G, the core network only takes less than 20% of total network investment. For 5GC, it is expected to be even less costly, thanks to cloud and virtualization technologies, which make 5G deployable on operators' existing data centers.

In the long-term, operators, with NSA network architecture, will need to migrate their network to full 5G SA network. This means deploying 5GC and enabling both NSA and SA in the transition period, and finally migrate to SA-only architecture. Obviously, the complex migration procedure will introduce additional cost such as frequent EPC upgrade, multiple periods of network planning and optimization, additional site visits, RAN equipment upgrade, and reconfiguration of transport network, etc. The accumulated investment of two-step SA (from NSA to SA) could be higher than that of SA.

Overall, operators would be better off adopting the SA option in order to avoid the cost of upgrading the LTE network. In addition, operators will enable all sources of revenues other than just eMBB, not to mention that being a first-mover in the new verticals assumes a market leadership position.

Use cases

There are many use cases that depend on an end-to-end 5G experience. These use cases are made possible only by the 5G's URLLC. URLLC is designed to reduce network latency from LTE's four millisecond to only one millisecond or less. In addition, the overall system reliability would reach 99.999%. Delay-sensitive and mission-critical use cases, which were not possible using LTE, can now be implemented at large scale. Some of these use cases are as follows:

Industrial IoT – Industrial IoT includes process automation, machine-to-machine communication, and sensor-based motion control, to name a few. All these applications fall under mission-critical machine-type communication. They require very low latency. As of now, industries depend on wired communications to build these systems, as wired technology is more reliable than existing wireless counterparts. However, with 5G latency and reliability promises, these systems can be taken to a whole new level, reducing connectivity costs and increasing mobility for many industries.

Autonomous vehicle – The use case of autonomous vehicles includes passenger vehicles, commercial trucks, railways, and others. These applications require extremely reliable channels and very low latency. Failure to offer these characteristics to the communication channels can result in serious casualties or even death. That is why with 5G's URLLC, network slicing, and high priority QoS, autonomous vehicle can become a reality.

Human-to-machine interaction – This includes many applications in healthcare, fitness, and any other applications that involve human interaction with machines. In addition to low latency and high availability, such applications require high capacity in the uplink as well as on the downlink.

There are many other 5G-enabled applications that have great market potential as well. For instance, applications like augmented reality (AR) and virtual reality (VR) will have huge demand for 5G-level throughput on both uplink and downlink.

User experience

At the end of the day, it is user experience that matters the most, and users are becoming more and more sensitive to delays and inconsistencies in communication services. This is especially true with the increasing popularity of video streaming, gaming, and AR/VR applications over smartphones.

To understand how user experience differs between SA and NSA, we have to again look at what 5GC brings and how it will affect end user experience. The URLLC features will enable a smoother overall experience. Online activities such as streaming are expected to perform much better under 5G. Users will be able to stream high-quality content and use their mobile devices to access AR- and VR-based applications.

Time-based network slicing is another advantage of 5GC that benefits users directly. This feature can be used by operators to improve user experience during events. During concerts, festivals, and other large events, operators can create a network slice and apply special QoS that take into consideration the increasing number of users and the peak upload activities, etc. Not to mention that using technologies such as massive MIMO and beam forming improve data rate at the cell edge.

Based on some field tests and simulation, chipsets vendor Qualcomm reported network performance values achieved by 5G SA architecture. These values show the great improvements that 5G SA can bring in latency, streaming, and other applications.

Exhibit 6 User Experience Under 5G SA Architecture

Latency	1-4 ms
Streaming quality	8K/120 FPS/10-bit
Browsing	333 Mbps
Downloading	131 Mbps

Source: IHS Markit

5G deployment strategies

In this section, we explain the deployment strategies of each of the network modes. When it comes to 5G deployment, it is important to have a clear strategy defining where to start and how to migrate from the starting point to a full 5G SA network. It is also important to highlight that nationwide adoption of new technology takes a long time, from initial selective deployment and new UEs adoption to nationwide continuous coverage and adoption of 5G-capable UEs by the majority of network subscribers.

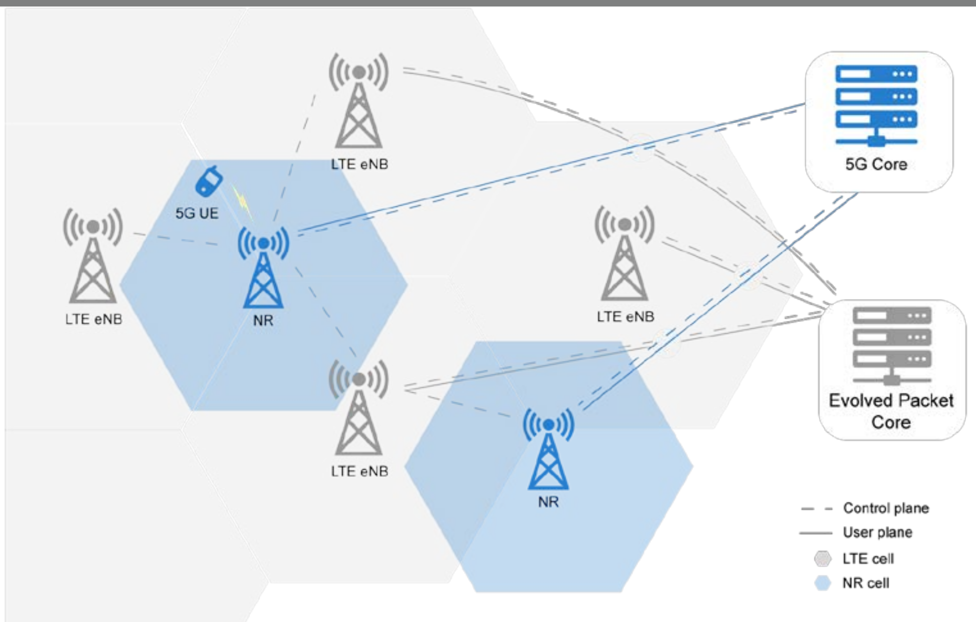
What that means for 5G is that 5G network will have to interoperate with LTE. In the case of 5G SA mode, interoperation is confined on session handover and service continuity. However, in the case of 5G NSA architecture, the case is more complex and involves heavy integration between 4G and 5G radio. This section details the necessary actions and precautions that operators need to be aware of while formulating their 5G deployment strategy.

5G SA architecture deployment strategy

5G SA architecture works better with sub-6GHz spectrum band. Whether operators will start with selective coverage or continuous nationwide coverage, sub-6GHz spectrum band is the best choice to achieve that desired coverage.

The 5GC system is flexible. Thanks to its foundations, the whole system can be deployed in an operator's data center. Moreover, operators can start with the most fundamental network functions only. This will not only cut CAPEX, but also will reduce the deployment time.

Exhibit 7 5G SA network architecture – selective 5G NR coverage



Source: IHS Markit © 2019 IHS Markit

When it comes to 5G NR, co-site strategy is recommended because 5G NR can achieve equivalent coverage as LTE for most of the urban scenarios. Using multi-band, multi-port antennas and ultra-broadband, multi-mode AAU/RRUs to consolidate the RF equipment on a tower and empty space for 5G AAU, operators can sharply lower cost and maximize the utilization of LTE infrastructure.

Selective 5G NR coverage would help operators introduce 5G services to early adopters first and to those who are more likely to buy an early version of a 5G-capable UE. At the same time, this strategy would give operators the time to optimize network performance and get ready for wide-scale deployment. Moreover, operators can still leverage their LTE network by using its infrastructure for service continuity.

The network should then transition to nationwide continuous 5G coverage. The continuous coverage would enable operators to offer other services that depend on 5G continuous coverage such as connected cars and fleet monitoring.

5G NSA architecture deployment

NSA depends entirely on LTE infrastructure for service continuity and continuous coverage, and, before that, core network. The deployment strategy of NSA architecture is divided into two phases:

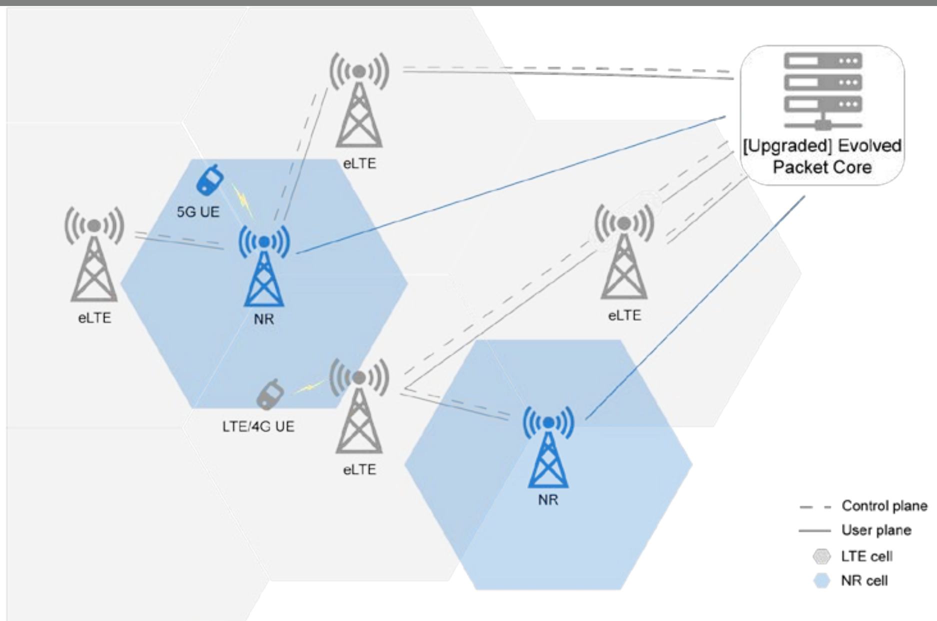
Phase I:

Phase I aims at providing 5G services by leveraging the existing LTE network. The deployment strategy involves two major deployment/upgrade steps:

1. Upgrade both access and core network infrastructure of the LTE network. The upgrade enables the LTE network interwork with 5G NR.
2. Deploy 5G NR selectively in areas with expectedly high demand for data services.

The 5G NR acts as a secondary access node controlled by an upgraded eNB as a master access node. This setup allows operators to offer eMBB services to end users. Yet it introduces some complexities into network operations and service optimization, as it requires close interoperation between 4G and 5G networks. In addition, operators may need to upgrade the EPC capacity.

Exhibit 8 5G NSA network architecture – Phase I: Selective 5G NR coverage + LTE upgrade



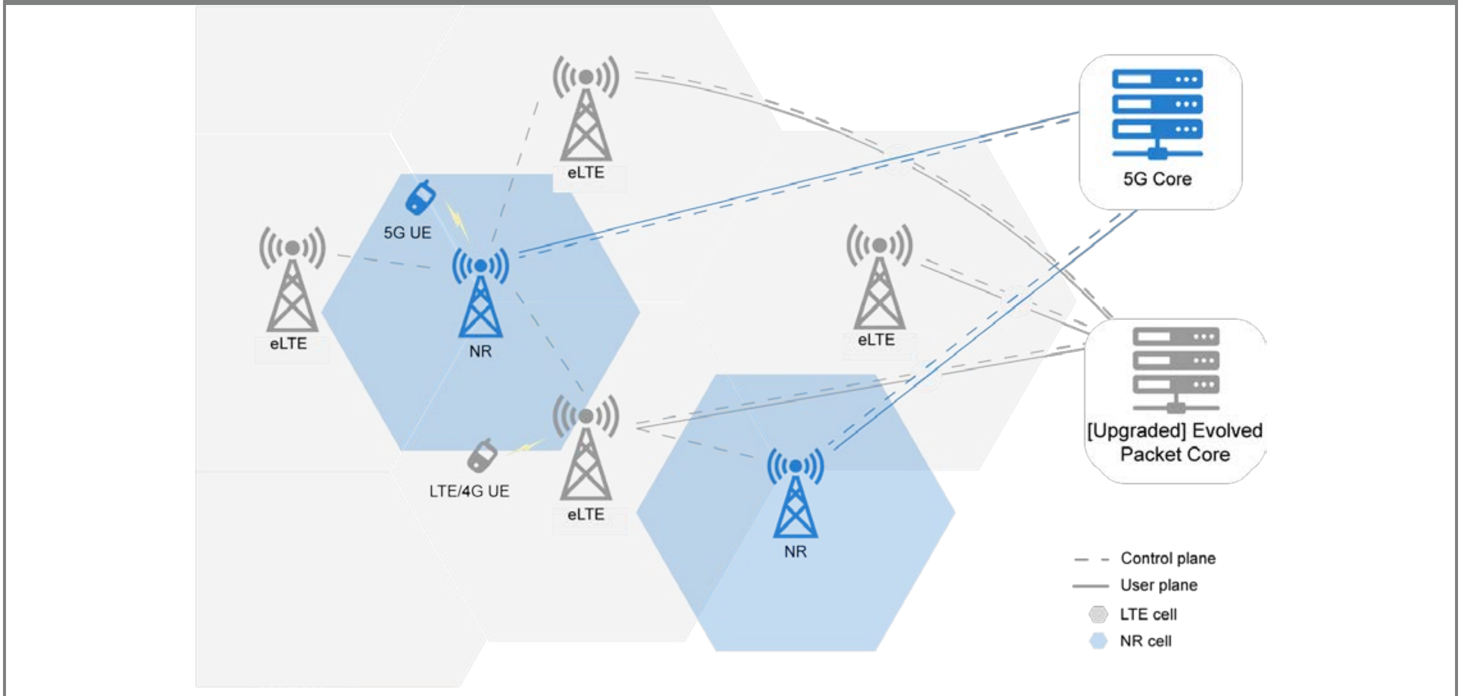
Source: IHS Markit

Phase II:

Phase II of NSA deployment strategy involves the introduction of 5GC into the network and increasing the 5G NR coverage area. In this case, the 5G network would be less dependent on the LTE infrastructure. LTE network can still be used for service continuity.

EPC and 5GC will coexist for a long time; operators need not replace their EPC with 5GC unless they know that 5G adoption among their subscribers is 100%. In other words, operators with only 5GC will not be able to service subscribers with 4G-only UE, or early UE that supports only NSA and needs EPC to connect to the network.

Exhibit 9 Migration to 5G SA network architecture – Phase II: 5GC deployment



Source: IHS Markit

After phase II is realized, operators will be able to offer all 5GC-dependent use cases. The deployment of 5GC and ability to perform E2E network slicing will allow operators to serve new verticals.

Which deployment strategy is better?

Both deployment strategies have an end goal which is the deployment of an independent 5G network. One of them moves directly to the end goal, optimizing investment and claiming a market leadership position in new verticals. The other is keener to leverage the current infrastructure to maximize its ROI, risking losing a significant market share in new markets. The common ground between both options is the fact that they must maintain the LTE network for a period of time. How much time exactly depends on the following factors:

- The availability of sub-6GHz spectrum band
- User adoption of 5G technology
- Operators ability to deploy nationwide 5G coverage

Vendor readiness: ZTE as an example

There are several vendors competing to offer the first 5G deployment. ZTE is the most active vendor that advocates and fully supports 5G, especially on standalone architecture. The company provides end-to-end 5G products and solutions and partnered with many operators and performed many field trials in commercial setups to verify the performance and maturity of 5G SA network architecture.

For example, ZTE, in cooperation with China Mobile and Qualcomm, built an E2E 5G network on the 3.5GHz band. This trial put 3GPP release 15 standard into actual context. The trial verified many advanced 5G technologies, including the scalable OFDM numerology, new advanced channel coding and modulation schemes, and the low-latency self-contained slot structure.

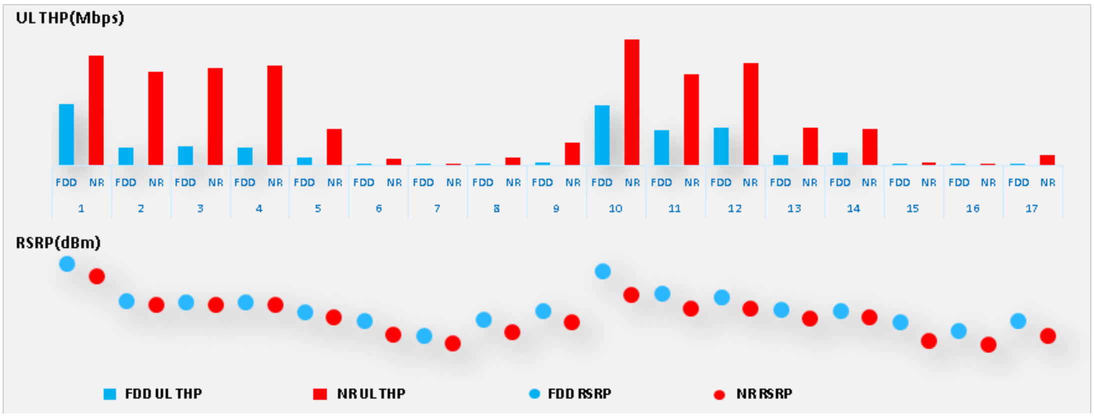
ZTE also partnered with Orange to test the E2E 5G SA network and demonstrate the validity of E2E network slicing and low latency.

Results achieved by ZTE and its partners in field trials includes two network setup scenarios: “network setup one” and “network setup two”, both of which are detailed below.

- Network setup one: Co-sited 1.8GHz FDD LTE and 3.5GHz 5G NR.

The test involved 17 test points on two floors in the test building, including good, medium, and bad points of coverage. The comparison results show that the 3.5GHz NR uplink rate of all 17 test points is better than 1.8GHz LTE, and the 3.5GHz NR uplink rate of 16 test points has more than 100% performance gain compared to 1.8GHz FDD LTE.

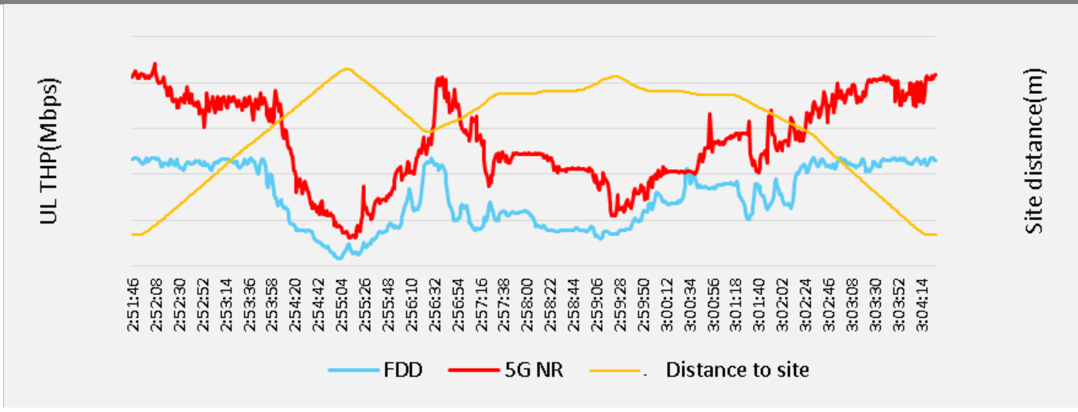
Exhibit 10 Field comparison between 1.8GHz FDD LTE and 3.5GHz 5G NR – uplink coverage



Source: IHS Markit

In the outdoor long-range driving test for the normal test route, 99.7% of the test points of 3.5GHz uplink resulted in better throughput, and most test points have a gain of more than 100%. In the extreme long-range test route, the 3.5GHz NR upstream throughput of the 97.3% test point is better than the 1.8GHz FDD.

Exhibit 11 Field comparison between 1.8GHz FDD LTE and 3.5GHz 5G NR – uplink throughput

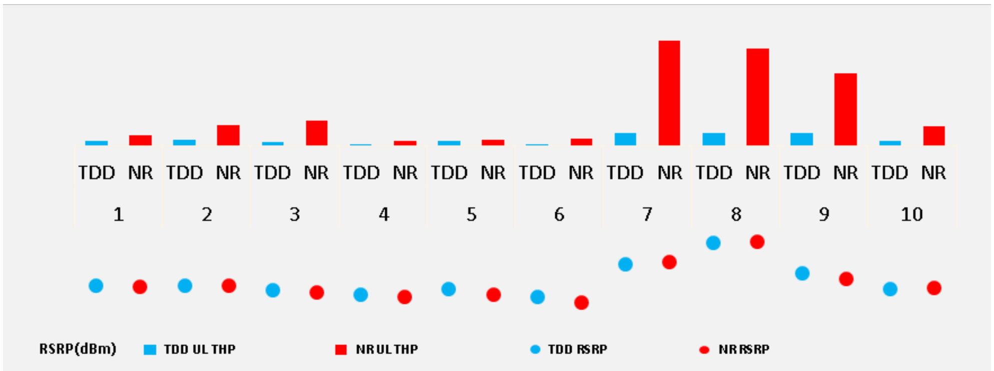


Source: IHS Markit

- Network setup two: 2.6GHz TDD LTE and 3.5GHz 5G NR with Massive MIMO

The indoor and outdoor drive test data shows that the 3.5GHz NR coverage is generally better than the 2.6GHz LTE, and the center-far field position has a significant gain. 5G Massive MIMO can also fully utilize its advantages in outdoor NLOS scenarios, verifying the networking capabilities of 3.5GHz NR.

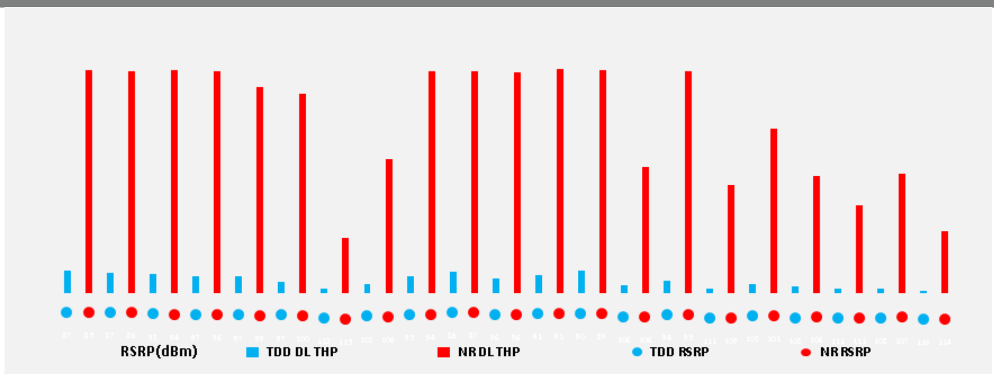
Exhibit 12 Field comparison between 2.6GHz TDD LTE and 3.5GHz 5G NR – uplink coverage



Source: IHS Markit

In the synchronous broadcast channel coverage enhancement test, the 5G base station is deployed on a 45-meter landscape tower. Within a radial distance of 1.2 km, the coverage route covers the traversal normal level in the cell +-30°, using a wide beam configuration and narrow beam configuration for test comparison. The results show that 5G can fully utilize the beamforming advantages of Massive MIMO.

Exhibit 13 Field comparison between 2.6GHz TDD LTE and 3.5GHz 5G NR – DL THP with Massive MIMO



Source: IHS Markit

Conclusion

The analysis presented in this white paper of 5G SA versus NSA considered all important comparison aspects including investment, spectrum, and KPI requirements.

From the investment perspective, operators are better off spending their money on 5G SA network. But looking at the wider picture, we find that SA deployment mode also achieves many other economic benefits such as increased sources of revenues and can enable an operator to capture significant market share in the new verticals.

As for spectrum availability, operators will need, sooner or later, to acquire a spectrum band in the sub-6GHz range. Investing in other spectrum bands will only mean more delays for the eventual 5G SA setup. That is because operators will need to make sure its ROI is reached before putting new investment in the network.

Finally, better network KPIs ensure that users receive a significant upgrade in the overall experience. To make this upgrade significant, operators must aim at improving not only data rates, but also network latency, capacity, and support for advanced data applications. All this is achieved by deploying an E2E 5G network.

The best way for operators to adopt the right decision and make the network upgrade smooth is by performing rigorous testing and field trials for all 5G network components as well as newly introduced features such as E2E network slicing, beam forming, URLLC, and more.

This report, which offers an independent assessment of 5G deployment methods, was produced as custom research at the request of ZTE. IHS Markit is exclusively responsible for this report and all the analysis and content contained herein. The analysis and metrics developed during this research represent the independent views of IHS Markit.

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