IIJ's Further Challenges as a Full MVNO

—Road to commercial NSA/SA services through a unique path in local 5G environments

2.1 Introduction

IIJ launched its MVNO[*1] services for enterprises in 2008 and for consumers in 2012. It has since offered a whole range of MVNO services and solutions as a leader in the industry and, since 2018, as Japan's first full MVNO[*2]. In terms of wireless networks, it initially used NTT Docomo's 3G network; in 2012 it became Japan's first MVNO to support 4G LTE; and in 2014 it added support for the KDDI 4G LTE network. It has thus evolved to become a multicarrier MVNO capable of providing optimal solutions to customers seeking carrier redundancy. And it has continued to grow using the latest wireless networks operated by MNOs[*3], adding support for KDDI's 5G network in 2020, for example.

So IIJ has always been at the forefront of the MVNO space, but its ultimate aim in rolling out a HSS (Home Subscriber Server)[*4] as a full MVNO is to advertise its PLMN (Public Land Mobile Network)[*5]—440-03 (IIJ)—from base stations and thus make it possible to offer IIJ's own services on an end-to-end basis including user devices.

To achieve this, IIJ needs to have not only a HSS/P-GW (Packet Data Network Gateway)[*6] but also an MME (Mobility Management Entity)[*7] / S-GW (Serving Gateway)[*8] and base stations. But telecommunications operators[*9] like IIJ have so far not really had any opportunities for frequency allocations that would allow them to obtain a commercial station license (wireless).

Against this backdrop, the report of the Information and Communications Council's New-generation Mobile Communications System Subcommittee (June 18, 2019) laid out the technical requirements for the 28.2–28.3GHz range from among the candidate frequency bands, and the necessary systems were put in place in December 2019. In terms of local 5G, the systems necessary for 4G communications systems that use the regional Broadband Wireless Access system (BWA)[*10] frequency band (2575–2595MHz) were also developed with the role of an anchor using NSA (non-standalone)[*11] architecture.

With the systems in place, it became possible for IIJ to own local 5G base stations / BWA base stations, and we quickly commenced the technical studies necessary for transitioning to NSA.

Section 2.2 below discusses our technical studies related to NSA deployment, Section 2.3 goes over some NSA deployment case studies, Section 2.4 looks at the functionality necessary for deploying an SA system, and Section 2.5 discusses our efforts to make the full VMNO concept a reality.

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*1 Abbreviation of Mobile Virtual Network Operator.

*2 IIJ, "IIJ to Begin Offering 'IIJ Mobile Access Service Type I' as a Full MVNO" (https://www.iij.ad.jp/en/news/pressrelease/2018/0315-2.html).

*3 Abbreviation of Mobile Network Operator.

*4 A logical node that manages the subscriber information database for 3GPP mobile telecommunications networks. It manages authentication information and location information.

*5 In mobile telecommunication systems, a globally unique subscriber identification number called an IMSI (International Mobile Subscriber Identity) is issued to each device (internal SIM card). The IMSI is a combination of three identification numbers. The first three digits are the MCC (Mobile Country Number), which identifies the country/region, and the next two or three digits (depending on the country) are the MNC (Mobile Network Code), which identifies the operator. The remaining digits are the MSIN (Mobile Station Identification Number), which identifies the subscriber. The MCC and MNC combined are called the PLMN, which identifies the operator's network. MCCs are defined by the International Telecommunication Union (ITU-T), and Japan has been assigned two numbers: 440 and 441. MNCs are issued by the Ministry of Internal Affairs and Communications (MIC) based on applications from operators and consist of two digits in the range 00 to 99. The MIC has published guidelines for converting MNCs to three digits (https://www.soumu.go.jp/main_content/000663786.pdf, in Japanese).

*6 A logical gateway node and the transit link, the P-GW allocates device IP addresses, forwards S-GW packets, etc.

*7 A logical node that accommodates the LTE base station (eNodeB) and provides mobility control etc.

*8 A logical gateway node that accommodates the 3GPP access system.

*9 A telecommunications carrier that does not own transmission line equipment (previously known as a Type 2 Telecommunication Carrier).

*10 Wireless systems for telecommunications services that use the 2.5GHz band, created with the objective of improving the public welfare across regions by, for example, improving public services and closing the digital divide (gap faced by areas disadvantaged by poorer access to modern ICT).

*11 Architecture defined in 3GPP Release 15; the industry mainstream is Option 3x, whereby LTE is used for control signalling and 5G is used to send data signals. For the core system, the LTE MME/S-GW/P-GW are used.

2.2 Technical Studies for the Shift to NSA (Non-Standalone)

The equipment required for transitioning to NSA is: HSS, MME, S-GW, P-GW, 4G anchor (BWA) base stations, and local 5G base stations. Having become a full MVNO, IIJ already has its own HSS, so we have already done the HSS development work needed for transitioning to NSA. We have also developed the HSS functionality shown in Figure 1 to prevent users on BWA-only contracts from using 5G.

The provisioning interface between the BSS (Business Support System)[*12] and HSS also needs to be changed, but we were able to deal with this via a minor expansion to the existing full MVNO interface. As an MVNO with LTE support, we already had a P-GW. We had the option of only setting up a new MME/S-GW, but sharing the P-GW among existing IIJ mobile services and NSA services would complicate the P-GW resource design and make it difficult to isolate when faults occur, so we decided to set up the MME/S-GW/P-GW anew.

We also looked at whether it would be possible to make use of IIJ's existing equipment for the Radius / PCRF (Policy and Charging Rules Function)[*13] / OCS (Online Charging System)[*14] / OFCS (Offline Charging System)[*15], which control the S-GW/P-GW. In light of the impact on IIJ's mobile services, we decided to develop a new system, as with the P-GW. We used a little ingenuity in designing the Radius. Giving the PCC (Policy and Charging Control) rules managed by the PCRF to the Radius means the PCRF is no longer needed. Since the PCRF is no longer required, neither is the OCS for on-line processing. So we only needed to develop the Radius/OFCS, which greatly reduced the cost and number of steps. But there is a disadvantage with this. Because we can't do real-time processing, speed limits and the like are processed in batches, so there is a one-day lag when imposing them.

In terms of services, we are now able to provide unlimited-capacity services in both BWA and 5G. Unlike IIJ mobile services, the services do not use carrier equipment, so in effect they move us toward the ultimate aim for IIJ as an MVNO, which, as mentioned in Section 2.1, is to make it possible to provide IIJ's own services on an end-to-end basis. We also developed dual connectivity[*16] (downlink only) for BWA and local 5G and thus provide services that aggregate BWA speeds and local 5G speeds.

We also need to lay the backhaul line from the base stations to the MME/S-GW. Mixing the C-Plane, U-Plane, and M-Plane[*17] all into a single line can result in the crucial

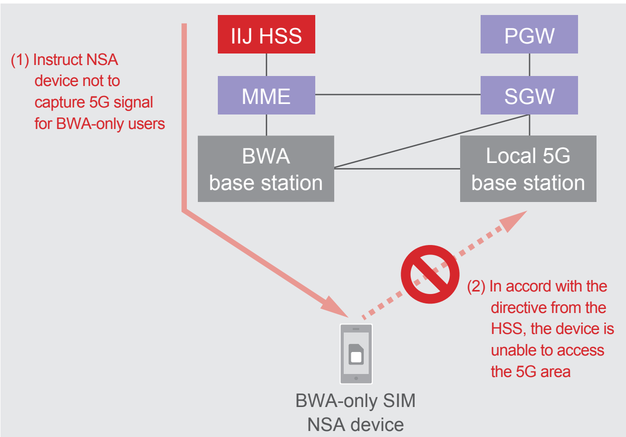

Figure 1: Mechanism for Preventing BWA Customers from Using 5G Services

*12 General term for business support systems for telecommunications carriers. Manages customer information and charging (billing) information, and supports business processes such as applications for services, commencement of service, billing, and inquiries.

*13 Logical node that controls QoS and billing for user data transfers.

*14 Online Charging System.

*15 Offline Charging System.

*16 A technology for improving speeds on wireless network sections by bundling multiple component carriers between separate base stations.

*17 Control Plane (C-Plane) / User Plane (U-Plane) / Management Plane (M-Plane).

C-Plane packets being discarded, so we decided to separate them with a VLAN and assign priority based on the DSCP (Differentiated Services Code Point) value.

As for the SIMs (Subscriber Identity Modules)[*18], we arranged two types: one that can only use the BWA base station area, and one that can use the Docomo LTE network area and the BWA base station area. Japan's Guidelines for Local 5G Implementation say that while it is not possible to link local 5G networks to complement nationwide MNO services, it is possible to use nationwide MNO services for the purpose of supplementing local 5G services. While this can be interpreted to mean that it is possible to link together local 5G areas and nationwide MNO 5G areas, we determined that this would necessitate coordinating with the MNOs, so we only arranged SIMs capable of using local 5G areas.

For BWA base stations, we developed an adaptive modulation method that switches among QPSK, 16QAM, 64QAM, and 256QAM[*19] depending on radio quality, with our requirement being to achieve radio speeds above those of BWA base stations provided by other operators. Developing this made it possible to achieve up to 295Mbps (256QAM) wireless downlink throughput and up to 17Mbps (64QAM) wireless uplink throughput under MU-MIMO (Multi-User MIMO)[*20] 4x4 conditions. As for local 5G base stations, only 100MHz of bandwidth in the 2GHz band was available for licensing, but we were able to achieve up to 484Mbps (64QAM) wireless downlink throughput and up to 125Mbps (64QAM) wireless uplink throughput under MU-MIMO 2x2 conditions. Based on the above technical investigations, we were able to complete IIJ's NSA architecture (Figure 2).

2.3 NSA Implementation Case Studies

■ (1) Shiroi Wireless Campus

IIJ's mobile technology testbed, Shiroi Wireless Campus in Shiroi-shi, Chiba Prefecture, went into full operation in November 2020. More than just a showcase for the latest mobile technology, Shiroi Wireless Campus will also be made available as an environment for testing interoperability between user devices and network equipment as well as between different pieces of network equipment, and as an environment for proof-of-concept testing in collaboration with customers in the aim of making use of the latest mobile technology.

A highlight of Shiroi Wireless Campus is local 5G, for which a commercial station license was obtained in March 2021. As explained in Section 2.2, we have already built the NSA core housing the local 5G base station / BWA base station based on NSA architecture design concepts for IIJ. We

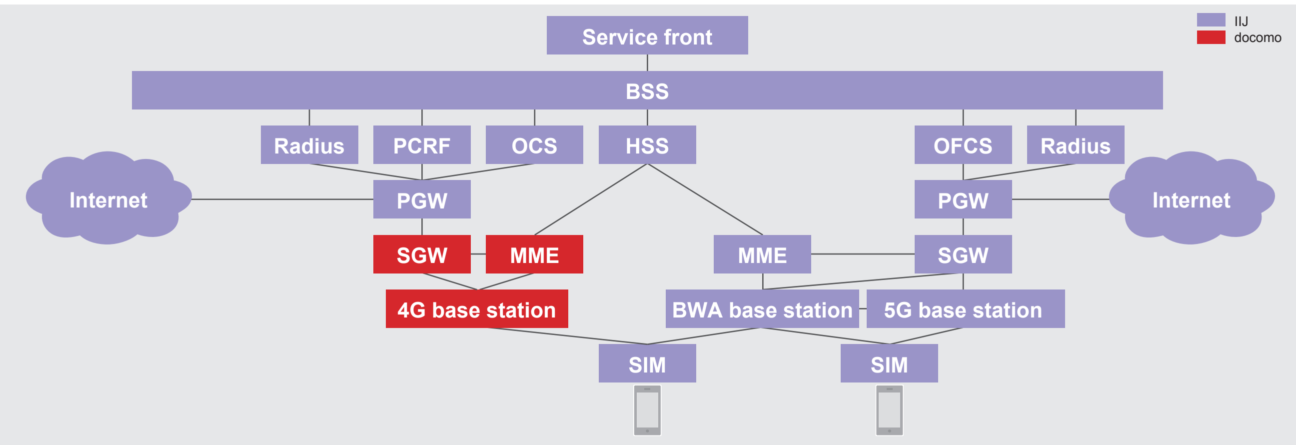

Figure 2: IIJ's NSA Architecture

*18 Officially called a UIM (User Identity Module Card) or USIM (Universal Subscriber Identity Module Card) but generally referred to as a SIM card.

*19 Wireless modulation methods.

*20 A method of increasing the amount of data that can be transmitted simultaneously using spatial multiplexing technology, whereby multiple antennas transmit data at the same time and multiple antennas receive the data. With MU-MIMO, multiple users can transmit at the same time. In contrast, only a single user can transmit with SU-MIMO (single-user MIMO).

developed the base stations / MME so that each of the base stations could advertise multiple PLMNs (see Figure 3). The local 5G base station and BWA base station are now in operation and emitting radio waves (see Figure 4).

Alongside local 5G / BWA, we are also building a heterogeneous wireless environment at Shiroi Wireless Campus. We have already connected the sXGP (band41) base station to the MME/S-GW, and we also intend to build Passpoint*21-compatible Wi-Fi access points into the HSS. To facilitate seamless communications between different wireless areas, we incorporated SIM design knowhow gained through proof-of-concept work*22 with the University of Tokyo's NakaoLab into IIJ SIMs. As for the SA (standalone)*23 system, we plan to obtain a Sub-6*24 base station / SA core and build them at Shiroi Wireless Campus.

(2) Grape One

To launch local 5G services, we established a new company, Grape One Co., Ltd.*25, in association with Sumitomo Corporation and CATV companies. The knowhow gleaned from the NSA technical studies described in Section 2.2 is also being used in Grape One's NSA core.

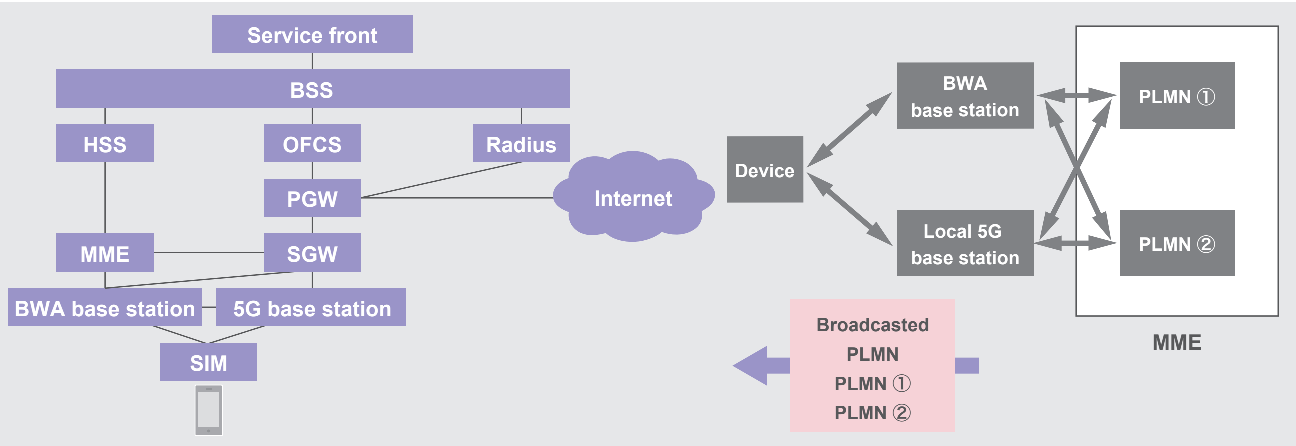

Figure 3: Overview of NSA Network Structure and Multiple-PLMN at Shiroi Wireless Campus

Figure 4: Local 5G Base Station and Device Speed Test at Shiroi Wireless Campus

*21 Communication standard certified by the Wi-Fi Alliance, which manages wireless LAN standards. Formerly called HotSpot 2.0. Normal Wi-Fi requires an SSID and password, but with support for this standard enabled, a device will automatically connect upon entering a Wi-Fi spot.

*22 IIJ, "First in Japan! University of Tokyo and IIJ start proof-of-concept tests on integration of public LTE and private LTE" (https://www.iij.ad.jp/news/pressrelease/2019/0605.html, in Japanese).

*23 Architecture in which 5G base stations operate on a dedicated 5G core network independent of the LTE core network (HSS/MME/S-GW/P-GW). 5G SA Option 2 is the industry mainstream option.

*24 Frequency bands below 6GHz.

*25 IIJ, "Pursuing the Wireless Platform Business Using Local 5G" (https://www.iij.ad.jp/en/news/pressrelease/2019/1224.html).

2.4 Functionality Necessary for Implementing SA (Standalone)

As mentioned in Section 2.3, we have already started commercial services with the NSA core and local 5G base stations / BWA base stations. The next necessary step is to look at how to incorporate SA into IIJ services. We therefore investigated what functionality would be needed to implement SA.

(1) NEF (Network Exposure Function)[*26] to control SA core from applications

3GPP R16 provides quite a bit more clarity than R15 on the functionality required of the NEF (see Figure 5). 3GPP TS 23.502 contains an updated list of NEF APIs, and while it is based on the LTE SCEF (Service Capability Exposure Function)[*27], it also features APIs not present in SCEF, such as Nnef_TrafficInfluence/Nnef_ AnalyticsExposure. IIJ has a bevy of cloud applications, such as an IoT platform called the IIJ IoT Service, so it will be possible to provide some interesting SA services using the NEF.

(2) Centralization of subscriber profiles provides single point for queries

With NSA, subscriber profile data was distributed across different equipment (UDR/MME/S-GW/P-GW), so subscriber profiles had to be queried at multiple points and processing this data was complicated. So 3GPP TS 23.501 "4.2.5 Data storage architectures" defines the Nudr interface for centralized storage and retrieval of previously distributed data on a UDR (Unified Data Repository) / UDSF (Unstructured Data Storage Function) (see Figure 6). This enables cloud-based centralized data management and provides a unified point (UDR/UDSF) for querying subscriber profiles, making data processing more efficient.

(3) Local breakout (MEC[*28])

NSA does not have a local breakout function, so the S-GW/P-GW had to be distributed around the area. So with SA, we physically separated the logical functions within the S-GW/P-GW. That is, we newly defined and physically divided the SMF (Session Management Function), which controls the session function, the PCF (Policy Control function), which controls the PCC rule function, and the UPF (User Plane Function), which controls packet processing.

Consolidating the SMF in the cloud means it has a major role in maintaining sessions from old UPFs to new UPFs, making breakout easier. If the SMFs were distributed, session information data would have to be synchronized across each of them, so there would have been no point in physically separating the system components. Consolidating the PCF in the cloud is a significant move for the same reason as with the SMF.

Also, using the NEF API Nnef_TrafficInfluence, as mentioned in (1) above, enables local breakout via application-based control.

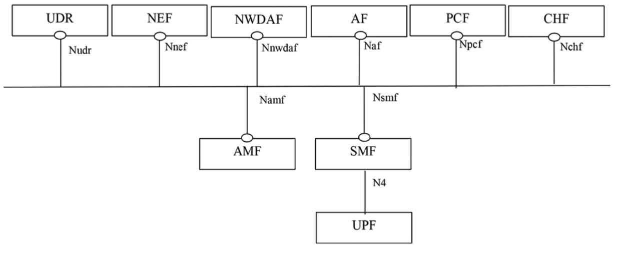

Figure 5: SA Core Architecture Including NEF (excerpt from 3GPP TS23.503)

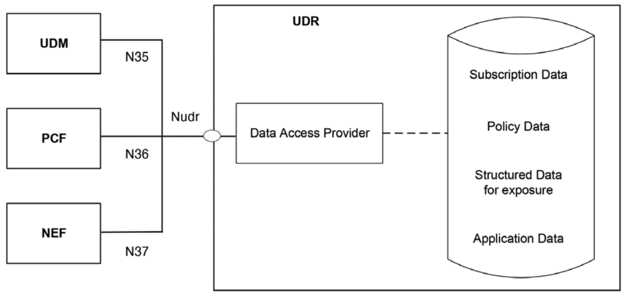

Figure 6: Data Storage Architectures (excerpt from 3GPP TS 23.501)

*26 Logical node that provides an API (application programming interface) to external applications for controlling the logical network nodes (Network Functions: NFs) that make up the 5GC (5th Generation Core network). In addition to being able to see subscriber information and network state changes in detail on the application side, it is also possible to control NFs via applications.

*27 3GPP TS 29.122-compliant logical node that provides an API to external applications for controlling LTE core network components such as HSS/MME.

*28 Abbreviation of Multi-access Edge Computing.

(4) Network slicing

NSA already has technology for network slicing between devices and the core network with multiple PDP Contexts[*29] and dedicated bearers[*30], but with SA it becomes possible to specify detailed SLAs (Service Level Agreements) for each network slice. While RAN (Radio Access Network) network slicing is still under development, support on the RAN side is essential in order to enable network slicing between devices and the UPF.

(5) 5G-AKA

LTE had incomplete IMSI encryption, so 5G-AKA introduces a mechanism for encrypting the MSIN (Mobile Station Identification Number) of the 5G subscriber ID (SUPL) that is equivalent to IMSI. IIJ has also succeeded in getting 5G-AKA-compatible eSIMs to work on the SA core[*31]. For details on 5G-AKA, see 3GPP TS 33.501 V17.1.0 (2021-03).

Looking ahead, we plan to procure Sub-6 / SA core products that meet the functional requirements described in (1) to (5) above and build the systems at Shiroi Wireless Campus.

2.5 The Path to Full VMNOs

With nationwide 5G areas, MVNOs will no doubt have to connect to nationwide MNO base stations, as is the case with full MVNOs, because only MNOs can obtain frequency licenses.

IIJ is advocating the concept of the full VMNO[*32] and envisions RAN sharing[*33] for nationwide MNO 5G base stations. With RAN sharing, operator PLMNs are distributed as keys, so MVNOs also need to have an SA core.

Local 5G bases stations, meanwhile, are owned by the individual operators, so there is a wider range of options, including setting up your own SA core or connecting to a VMNO's SA core.

As explained in Section 2.4, we plan to procure an SA core and Sub-6 base stations for Shiroi Wireless Campus so that we can test them and identify any issues as part of our efforts to make VMNOs a reality.

2.6 Conclusion

COVID-19 has accelerated moves toward remote work and other DX (digital transformation) initiatives. Before the pandemic, people expected the rollout of local 5G to happen after the Tokyo Olympics and to take several years, but it now looks to be moving ahead earlier than that.

Having installed BWA base stations, local 5G base stations, and an NSA core, IIJ is now also in a position to develop its own wireless and core system knowhow.

With an eye to rolling out an SA system ahead, we will continue to coordinate our efforts not only with mobile services but IIJ's other services as well so that we can continue to provide the types of services not available from other providers.

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Since joining IIJ in 2017, Mr. Kakishima has worked on the development of corporate mobile services. When IIJ launched its full MVNO operations, he worked on specifications development, construction, and operations design for the core equipment, including the HSS. He is also involved in specifications development, construction, and operations design for local 5G services and NSA/SA, and in planning the introduction of SoftSIM/eSIMs.

*29 Providing multiple PDP (Packet Domain Protocol) contexts to a single user (device). See 3GPP TS 23.976.

*30 Setting up multiple bearers for a single PDP (Packet Domain Protocol). See 3GPP TS 23.401.

*31 IIJ, "Establishing the essential technologies needed for full MVNO and local 5G services, beyond the 5G core networks technologies" (https://www.iij.ad.jp/en/news/pressrelease/2020/1102.html).

*32 Internet Infrastructure Review (IIR) Vol.48, Focused Research (1), "MVNOs in the 5G Era: Advocating the VMNO Concept" (https://www.iij.ad.jp/en/dev/iir/048.html).

*33 Multiple operators' core networks sharing a single radio access network (RAN).