This full text paper was peer reviewed at the direction of IEEE Communications Society subject matter experts for publication in the IEEE ICC 2010 proceedings

Next Mobile Network Architecture

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***Abstract*—This paper proposes a general architecture for the Next Mobile Network (NMN). NMN is composed of four planes: Advanced Mobile Access (AMA), Optical Mobile Network (OMN), Virtual Mobile Network (VMN), and Service Delivery Network (SDN). AMA, OMN, and VMN are revolutionary additions while SDN is an enhancement of that found in the All-IP network as SDP (Service Delivery Platform). NMN aims at offering sophisticated services along three service directions, "Multimedia", "Ubiquitous", and "Global". This paper describes the research being done on key NMN component technologies, e.g., advanced radio transmission, mobility management over the optical and virtual network, and ubiquitous service management.**

Keywords-Next Mobil Network; Advanced Mobile Access; Optical Mobile Network; Virtual Mobile Network; Service Delivery Network

I. INTRODUCTION

Today, 102 million users are enjoying 3G in Japan with 830 million users around the world. 3G radio has evolved from W-CDMA to 3.5G radio (i.e., HSPA). Now, it is approaching to the final stage, 3.9G radio (i.e., LTE (Long Term Evolution) [1]). The 3G core network has also evolved from the GSM circuit-switched network/GPRS to the IP-based soft switch network/GPRS+IMS (IP Multimedia Subsystem). Now, it is approaching the All-IP network (e.g., EPC (Evolved Packet Core) [2], [3]). In real commercial networks, the 3G network is being overlaid, not replaced, by LTE/EPC (Fig.1.). Several new services will be offered by SDP (Service Delivery Platform) over IMS.

On a related topic, ITU-R has assigned frequencies for 4G radio (i.e., IMT-A (International Mobile Telecommunications-Advanced)) in WRC07 [4]. 3GPP has started the standardization of LTE-A (LTE-Advanced) [5] as a promising candidate for IMT-A.

This paper proposes a general architecture for the NMN (Next Mobile Network) with Advanced Mobile Accesses such as further extensions of IMT-A or new advanced mobile radio access. The paper is organized as follows. Section 2 discusses the service directions that are to be realized by NMN. Section 3 describes the general NMN architecture needed to support the service directions. Section 4 presents the key basic technologies and outstanding research subjects for NMN. Section 5 concludes this paper with some consideration of NMN research and standardization activities.

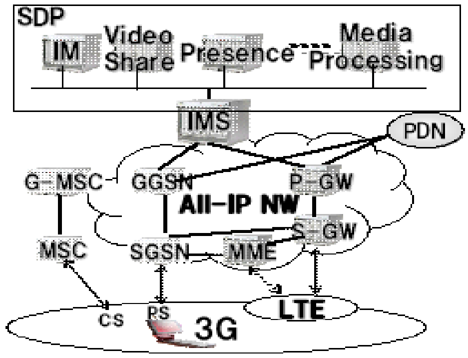

Figure 1. All-IP network with 3G and LTE Access

II. TARGET SERVICE DIRECTIONS

NMN is intended to advance three service directions: "Multimedia", "Ubiquitous", and "Global". Furthermore, NMN must take "Green" into consideration regardless of the service directions.

A. Multimedia service direction

As IMT-A is aimed at achieving 1Gbps throughput, NMN will offer a video service with the same quality as HD-TV. Given the negligible signaling delay over IMT-A access and the service intelligence offered by NMN, several sophisticated services will emerge. For example, the view from the front of the car is laid over a map (Fig.2). If the passengers talk about lunch, the heads-up display shows an attractive nearby restaurant. They can make a registration from the car. Sophisticated mobile services will be possible through the merger of the real world and the virtual world.

Figure 2. Multimedia Service Example

B. Ubiquitous service direction

Several ubiquitous services have been or are being tested. The intention is to introduce some of them to form u-Japan in 2010 [6]. NMN targets innovative mobile-ubiquitous services by combining mobile objects. For example, a woman may carry only cosmetic items and an ornament (Fig.3). She does not need a handset because the ornament works as a mobile terminal. Each cosmetic item offers either mobile terminal functionality or has an RF-ID. In this example, her compact mirror is also a basic mobile terminal that provides visual display functionality. The lipstick has a wireless sensor to track the amount remaining. Such information is reported to NMN via the ornament. NMN will inform her of a brand new lipstick that suits her and the location of the nearest shop through the compact's mirror when she walks around the shopping center.

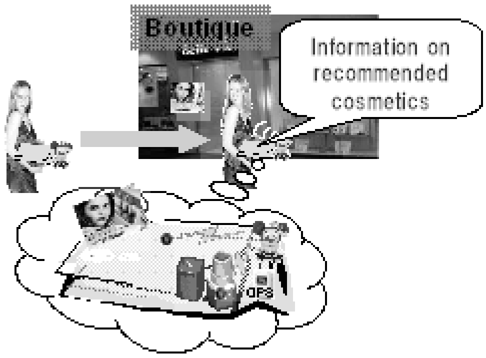

Figure 3. Ubiquitous Service Example

C. Global service direction

NMN is intended to offer the same services with same quality as offered by home network wherever users go around the world. For example, let's assume that a Japanese boy tries to talk with a Parisienne in Paris. The mobile terminal talks to the Parisienne on his behalf in real time by recognizing his Japanese, translating Japanese to French, and synthesizing the French equivalents. Note that his voice model has already been generated in advance.

Figure 4. Global Service Example

As NMN will support the essential capabilities for these three service directions, actual services will satisfy users from the viewpoint of "Multimedia", "Ubiquitous", and "Global" combination.

III. NMN GENERAL ARCHITECTURE

To realize sophisticated services along with the service directions mentioned, we propose the general architecture of NMN shown in Fig.5. NMN is composed of four planes: Advanced Mobile Access (AMA), Optical Mobile Network (OMN), Virtual Mobile Network (VMN), and Service Delivery Network (SDN).

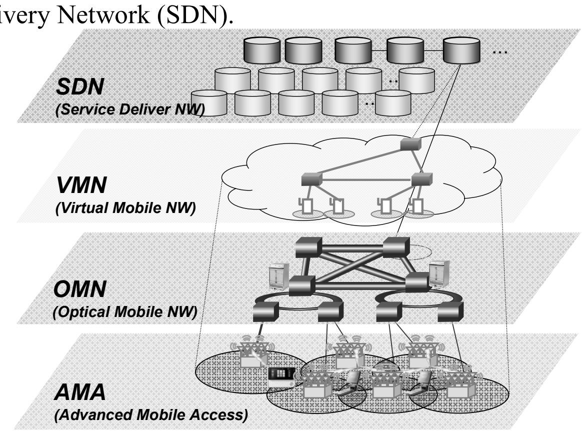

Figure 5. NMN general architecture

A. AMA

Figure 6 shows the evolution in mobile radio access system capabilities. The peak user data rate in IMT-A will be achieved to 1 Gbps maximum.

Furthermore, toward the next generation system, it may become possible to realize higher peak user data rate, e.g., 10 Gbps maximum. For the base station of AMA, we are first targeting 1 Gbps peak user data rate with wider service areas. By introducing Femto cells to the indoor environment to meet dense local traffic needs effectively, and also introducing Relay cell base stations for service area complementation, much more flexible area expansion can be realized at lower cost.

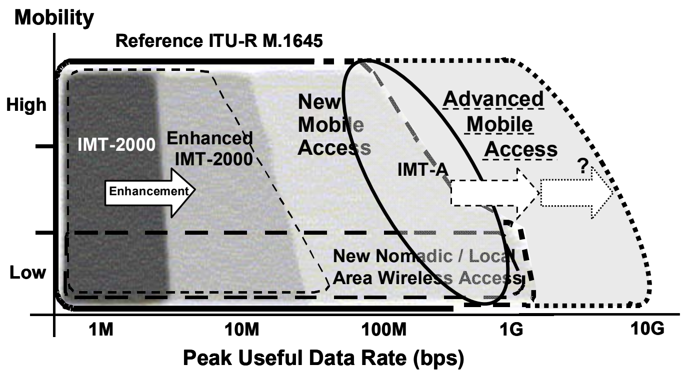

Figure 6. Expansion of mobile radio access system capabilities

B. OMN

Like trend in the fixed broad band access, mobile user will be able to enjoy more enriched broadband multimedia services through AMA. Then it may become the large bandwidth that some form of optical technology is needed to achieve practical levels of power consumption and minimal node footprint.

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Traffic in NMN includes both Internet traffic, to/from external networks, and peer to peer traffic, which stays in the mobile network. Peer to peer traffic is expected to increase with the emergence of new communication services such as IM or Video sharing. Therefore, the NMN transport network needs a combination of λ path switching for the aggregated traffic routing to external networks and optical packet switching for designating each packet's destination (optimized routing should be supported).

The candidate transport network consists of (1) a high speed PON, which can efficiently accommodate increasing numbers of base stations due to the high frequency band aggregation and installation of Femto cells, (2)an optical ring network with OADM(Optical Add Drop Multiplexer), and (3) a mesh network connecting access rings with OPS(Optical Packet Switching), see Fig.7.

OMN must accommodate not only IMT-A but also legacy 3G accesses, fixed wire line (i.e.,FTTH/ADSL).

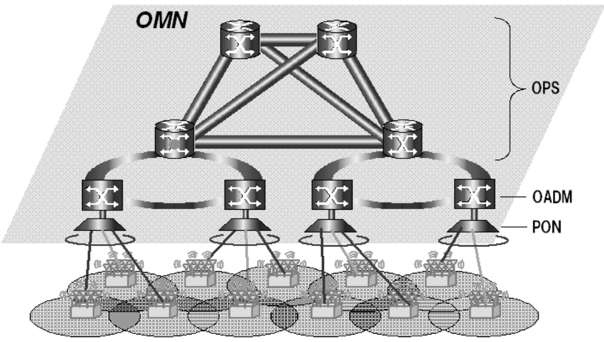


Figure 7. NMN transport network realized by optical technologies

C. SDN

The SDN in NMN will evolve to support further advanced network value added services (Fig.8). For example, Mobile Ubiquitous services enhanced by dynamic object management will make the most of cellular terminal mobility.

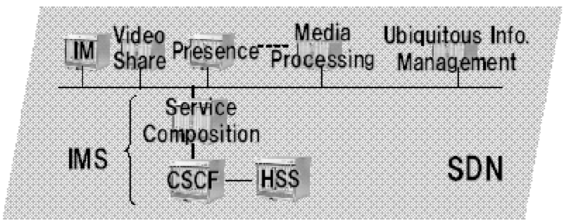


Figure 8. Network value added service composition in SDN

To realize object management, a RF-ID reader equipped with wireless communication and GPS, will acquire the RF-ID information around the user and send the information to the ubiquitous information management server in SDN. This RF-ID reader function could be placed in the user's carry bag as described in Section II.B.

NMN SDN also provides service program mobility to support global real time services that offer the same functionality and quality as those provided in the home network (Fig.9). For this global service realization, SDN contains a personal service program management function; it maintains service customization information for each user, and processes user profile information and device information. An up to date personalized service program is thus available to the optimum physical processing severs in OMN as indicated by the user's location under the control of VMN.

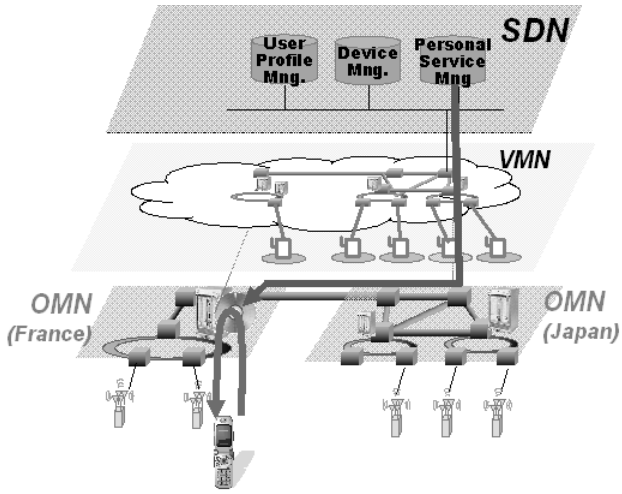


Figure 9. Service Program Mobility

D. VMN

VMN must be flexible in terms of dynamic configuration/ reconfiguration to utilize the limited resources efficiently while satisfying the service requests. Moreover, VMN needs to be capable of utilizing the physical networks of multiple OMNs across the world to realize global services. Successful implementation will trigger a business paradigm shift. For example, in Figure 10, VMN1 is providing home services in Japan while VMN2 is providing the same sets of the home services to a specific area of France in response to the user's request. This minimizes the need to keep full sets of physical resources in areas that users are not visiting while ensuring that the guaranteed services are available wherever the user is visiting.

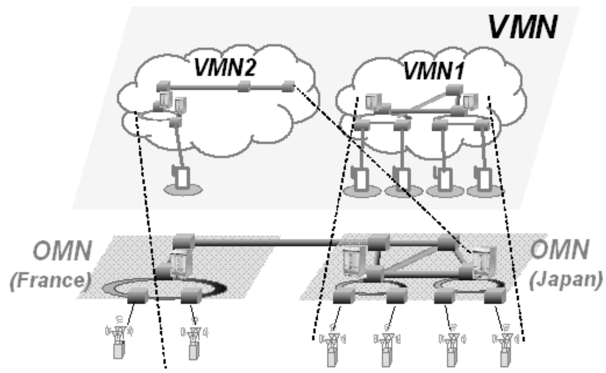


Figure 10. Service provisioning with VMN

Considering the importance of service continuity to users, SDN should be smoothly evolved from the existing IMS/SDP. On the other hand, the current functionalities in EPC must be reassigned to OMN and/or VMN, resulting in mobile business paradigm shift.

IV. MAJOR TECHNOLOGIES IN NMN

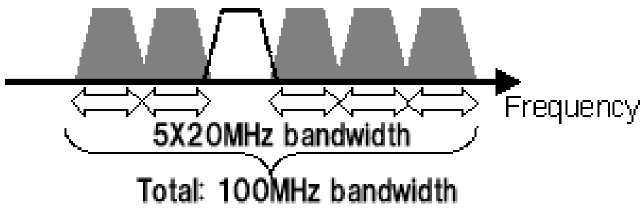
A. *Technologies in AMA*

To realize peak user data rate 1 Gbps or over in a wide variety of user environments in AMA, it is indispensable to employ advanced radio transmission techniques, for example, frequency band expansion technique to ensure radio transmission in a wider frequency bandwidth, high order MIMO techniques to raise space transmission efficiency and advanced radio resource management techniques to achieve very high efficiency of radio frequency use.

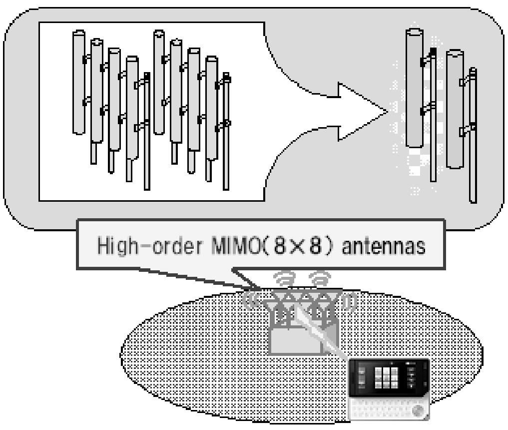
A promising radio frequency band expansion technique, carrier aggregation (Fig.11 (a)) can group multiple separate frequency bands into one single wide frequency band to ensure wide band radio transmission of 100 MHz maximum. To realize this technique, wide band RF devices and high speed signal processing methods must be researched.

A prime candidate for high order MIMO is 8x8（8-stream）maximum MIMO transmission (Fig.11(b)). This demands extensive miniaturization to offset the high number of antenna elements and high speed signal processing for transmission pre-coding based on quality information fed back from the receiver.

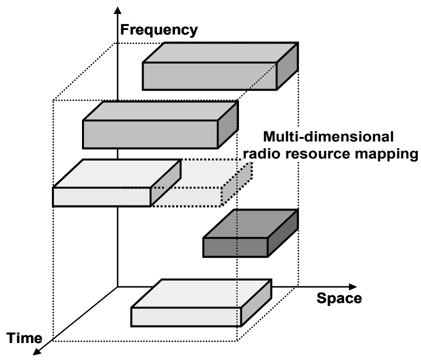
An advanced radio resource management technique adapting multi-dimensional radio resource mapping (Fig. 11 (c)) can enable efficient radio frequency use in various user environments.



(a) Frequency band expansion technique (Carrier aggregation)



(b) High order MIMO transmission technique



(c) Advanced radio resource management technique

Figure 11. Examples of radio transmission technologies in AMA

B. *Technologies in OMN*

Mobility management is essential in the mobile network. Unfortunately, current optical packet switching techniques cannot realize practical photonic memories or sophisticated packet routing processing. For these reasons, OMN nodes may be hybrids, they will use the best-of-breeds from among optical and electric component techniques. Ideally, all-optical packet switching, which enables optical label processing and optical memory, could drastically reduce the switching delay and power consumption. Figure 12 shows the interaction between mobility control and label swapping in the optical switch. When an optical packet with label “L1” is received by the line card, the label swapper rewrites the label as instructed by mobility control to “L3”, which corresponds to the destination node determined by the receiving user’s location. Label swapping is currently based on electric processing, however, using passive optical devices to realize this function will yield ultra low delay packet transmission.

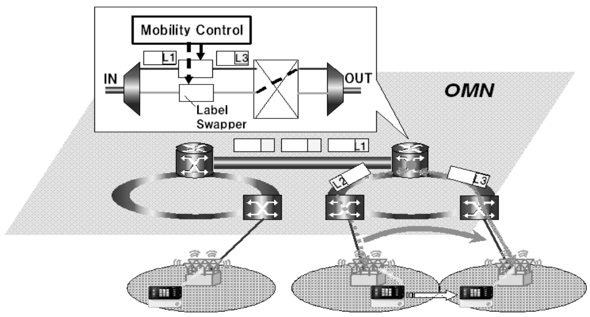


Figure 12. Mobility control in OMN

C. *Technologies in SDN*

As described in Section III.C, object management for mobile ubiquitous service provisioning is realized by the collaboration of the RF-ID reader in the carry bag at the user’s side and the ubiquitous information management server in the network.

The ubiquitous information management server maintains user’s requested service setting in its service management table (e.g. recommendation of desired cosmetic item (Fig.13)).

RF-ID reader sends object information (ex. lipstick) and its parameters (e.g. percentage remaining) when the reader finds a new object or detects a parameter change. Upon receiving this information from the user's RF-ID reader, the mobile ubiquitous information server updates the object management tree and their parameters. When the state of this object management tree and user's GPS location information match the user's service setting, the service (information delivery) is invoked. The delivery information will be sent to the terminal device best able to display the information (ex. the compact's mirror).

To realize this service, information management formats and information exchange protocols need to be specified.

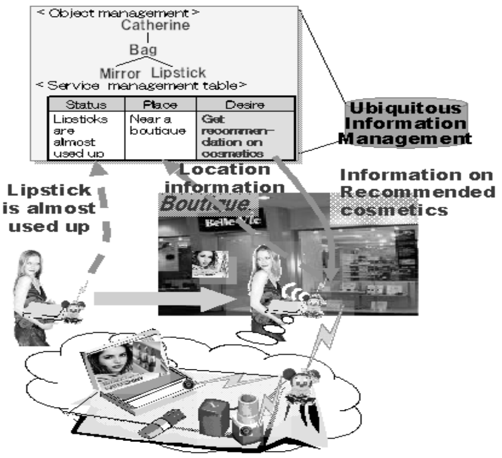


Figure 13. Ubiquitous Mobile Service

Also in SDN, a customized service program is created for each user, so service provisioning is possible in whatever network is being visited. For program provisioning, VMN first requests and reserves the required resources in the visited OMN. The customized program is then transferred to the reserved resources in the OMN. The service program is executed locally in ensure real time service quality in accordance with the user's service request.

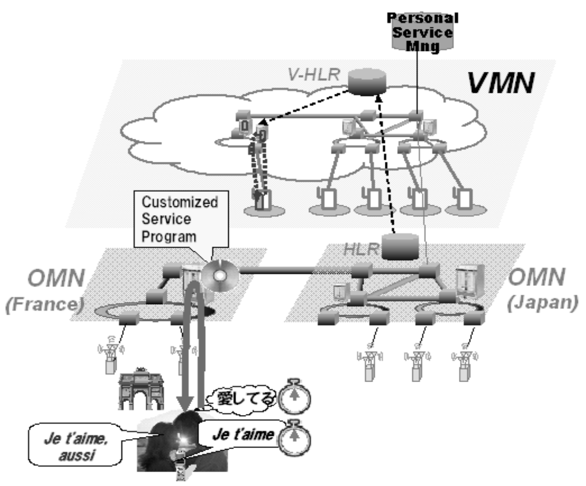


Figure 14. Customized service program provisioning

D. Technologies in VMN

VMN manages only abstract object information; the actual physical network topology or hardware of the OMN is hidden.

When a VMN receives a service request from SDN, VMN determines the resource types required, reserves the resources needed, and the service provisioning area, then negotiates with the OMNs involved.

The first step is to study the virtualization of mobility. This includes determining the level of location information that should be reported and managed as abstract information in the VMN (i.e. Virtual HLR). Mobility management in the VMN should trace and follow the user's movement for resource reconfiguration in the OMNs. Furthermore, even though one VMN can support several OMNs, it is impractical to force it to support connection to all OMNs in the world as even today there are hundreds of roaming partners. This indicates the need to establish interconnections among regional VMNs.

V. CONCLUSION

This paper proposed a general architecture for NMN; it combines AMA, OMN, VMN, and SDN. NMN aims at offering sophisticated services while meeting the trends of multimedia, ubiquitous, and global service. This paper described major research subjects on the key components such as advanced radio transmission, optical mobility management, virtual mobile networks, and ubiquitous service management in NMN.

Currently, both mobile and fixed networks are evolving toward the All-IP network. Nevertheless, since their research and standardization activities have been conducted separately, the result is that we have similar, but different, All-IP network standards, that is Next Generation Network (NGN) and EPC (Evolved Packet Core). Philosophically, the mobile network encompasses the fixed network. Therefore, it is important to proceed with research on and standardization of a single NMN.

REFERENCES

[1] 3GPP TS36.300: "Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2", June, 2009.

[2] 3GPP TS23.401: "General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access"

[3] 3GPP TS23.402: "Architecture enhancements for non-3GPP accesses"

[4] ITU-R, Report M.2135, "Requirements related to technical performance for IMT-Advanced radio interfaces", Nov, 2008.

[5] 3GPP, TR36.913, "Requirements for Evolved UTRA (E-UTRA) and Evolved UTRAN (E-UTRAN)", March, 2009

[6] u-Japan website:
http://www.soumu.go.jp/menu_seisaku/ict/u-japan_en/index.html

[7] GENI website: http://www.gen