Evolution of NGN Control Plane for Future Telecommunications Networks

Rashmi Yadav*, Rashmi Kamran†, Pranav Jha†, Shwetha Kiran †, Abhay Karandikar†§
Department of Electrical Engineering, Indian Institute of Technology Kanpur, India*
Department of Electrical Engineering, Indian Institute of Technology Bombay, India†
Secretary to the Government of India, Department of Science & Technology, New Delhi, India§
Email: rashmiy@iitk.ac.in*, rashmi.kamran@iitb.ac.in†, pranavjha@ee.iitb.ac.in†,
shwethak@iitb.ac.in†, karandi@ee.iitb.ac.in†

***Abstract*—The future telecommunications networks (IMT-2030 and beyond) are anticipated to capacitate a wide range of use cases with differing requirements, such as high-speed and latency-tolerant communication, or hyper-reliable and low-latency communication. It is therefore imperative that the future network architecture is scalable, and flexible to support the wide-ranging needs presented by these emerging use cases. To this end, the International Telecommunication Union (ITU) is engaged in evolving the architecture for future telecommunications networks through its Study Group 13 (SG13), "Future networks". In ITU terminology, an abstract architecture for an existing packet-based telecommunications network, such as, the 4th Generation (4G) network or fixed broadband network is known as Next Generation Network (NGN) and its future evolution beyond IMT-2020 has been christened as "NGNe". One of the key components of the NGN architecture is the "transport stratum". The transport stratum comprises user data transfer functions (known as user plane) along with functions to control them (known as control plane). In addition to controlling the user plane, the control plane is also responsible for signalling exchange with the end-user devices. Both these functionalities are tightly coupled within the control plane of the NGN transport stratum. However, we believe these functionalities are distinct and should be handled separately. In this article, we propose to move the signalling handling functionality out of the NGN control plane and treat it as payload (data), handled via service functions outside the control plane. Separating these two groups of functionalities leads to a scalable, flexible, and modular control plane for future telecommunications networks (NGNe). Information flows for procedures and network services like registration, authentication, and mobility are presented to validate the advantages of the proposed architecture. We also elucidate an ongoing standardization activity under ITU related to this work.**

***Index Terms*—Next Generation Networks, Software Defined Networking, Service-based Architecture, NGNe**

I. INTRODUCTION

THE telecommunications network in the future needs to accommodate diverse usage scenarios, including immersive communication, haptic communication, massive communication, extremely high-rate access, ubiquitous connectivity, and many more, as outlined in [1]. The diverse usage scenarios along with a potentially huge number of network users necessitate a flexible and scalable network architecture in future. A few years back the International Telecommunications Union (ITU) came up with an abstract architecture for extant packet-based telecommunications networks, such as, fixed broadband networks or the 4th Generation (4G) mobile networks. This abstract architecture is known as the Next Generation Network (NGN) [2]. One of the key elements of the NGN architecture is the presence of separate control and user planes with disparate roles within its transport stratum. The user plane (data plane) comprises user data transfer functions that perform data forwarding. The control plane functions, e.g., 'network attachment and control' and 'mobility management and control', are responsible for resource control functionality, i.e., establishing/modifying/deleting data paths over the user plane. In addition, the control plane also interacts with end-user devices for signalling message exchange. Both these functionalities are treated as integral parts of the NGN control plane and they are tightly coupled to each other. This leads to a monolithic, and bulky control plane, which may not be scalable and flexible enough to support future requirements, especially the huge signalling load that may be generated by a large number of users in future networks. Another issue with the NGN control plane architecture is that the internal network services, such as mobility services are not managed in a fashion similar to external services, such as Internet Protocol Television (IPTV) service. This results in a complex architecture with the coexistence of diverse service delivery mechanisms. In this article, we propose a new architecture for NGN evolution (NGNe) addressing both these issues. The proposed architecture has been submitted for consideration for NGNe standardization under the ITU's Study Group 13 (SG13), "Future networks". NGNe denotes the evolution of network architecture for beyond IMT-2020 networks in ITU parlance.

Next we provide a comprehensive review of available literature focusing on the evolution of the control plane in NGN. The authors in [3] outline the implementation of a carrier ethernet (a set of services that carry data over long distances) control plane using Multiprotocol Label Switching (MPLS) within the NGN framework with a simulation illustrating the improvement of the carrier ethernet network with the NGN control plane. The article in [4] discusses the growing significance of emerging packet network architectures featuring detached service and transport planes while examining pertinent resource management considerations within these network frameworks. In [5], the standardization status of NGN and an enhancement to incorporate control plane-enabled transport networks are presented. In [6], the authors propose an adaptive service provisioning method for NGN, which can adapt to user, network and service environment. An NGN-enabled autonomous transportation system is proposed in [7] to support intelligent and independent mobility services. This article [8] addresses the problem of modelling call processing performance in a multidomain NGN architecture, including the IP (Internet Protocol) Multimedia Subsystem (IMS) elements in the service stratum and MPLS technology in the transport stratum.

To the best of our knowledge, there appears to be limited discourse regarding aspects of NGN control plane architecture, specifically in the direction of scalability, flexibility, Software Defined Networking (SDN) based enhancements and uniform handling of internal and external network services. To introduce further improvements to the next-generation network, particularly within the control plane, we propose to separate the end user-associated signalling exchange from the user plane control and treat the signalling exchange with end-user as a service. Separating these functionalities leads to a simpler (with a thin control plane), flexible, modular and scalable control plane architecture. To further elucidate the proposed idea, we present the information flows for some internal services, such as "Registration, Authentication and Authorization service" and "Mobility service". These services are referred to as "built-in services" in this paper.

The rest of the paper is organized as follows. In Section II, we provide an overview of the existing NGN architecture. The proposed architecture is described in Section III. Section IV presents the example information flows for some of the built-in services of the proposed architecture while conclusions are presented in Section V.

II. Existing NGN architecture and its limitations

Fig. 1 (a) shows the existing NGN architecture (based on Figure 7-1 of ITU recommendation [2]). To provide services like multimedia, conversational, content delivery and IPTV, the functions in NGN are distributed between the service and transport stratum [9] as shown in Fig. 1 (a). In the service stratum, the application support function, service support function, service control and content delivery functions facilitate service delivery to the end users. Data/IP connectivity to the end users is established via the transport functions (user plane) in the transport stratum with the help of transport control functions (control plane) like Network Attachment Control Function (NACF) (which provides access and authorization (registration) at the access level and also initialization of the end user device for accessing the NGN services), Resource and Admission Control Function (RACF) (responsible for resource and admission control in NGN) and Mobility Management and Control Function (MMCF) (handles mobility management and control in NGN).

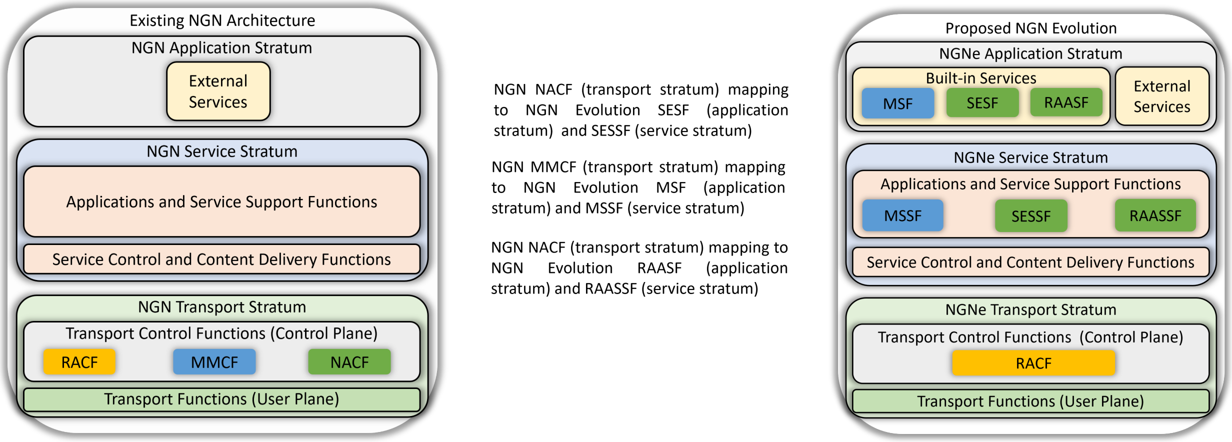
Let us understand how an external service is handled in the existing NGN by considering the example of IPTV services (as detailed in [10]). For delivery of service to an end-user (IPTV terminal), the IPTV application requests the establishment of a session from the (IPTV) service support function in the service stratum. The request is forwarded to the control plane (in the transport stratum) via the service control function. The control plane reserves the resources (for the session) at the user plane for eventual service delivery to IPTV users (terminals). The session is established via transport functions between the end-user and the IPTV application. The content delivery functions receive content from the IPTV application function and store, process and deliver the content to the end-users using the capabilities of the user plane. Further, content (data) and application level signalling (if needed) are exchanged between the end-user (IPTV terminal) and IPTV applications through the session established via the user plane.

It should be noted that the application-level signalling is also treated as data (payload) between external services (the IPTV application) and the end-user. However, signalling exchange with end users in case of built-in services is not handled in the same manner and is tightly coupled with resource control functionality, which brings additional complexity to the NGN control plane. Hence, an evolved and simplified architecture is needed.

III. Proposed NGN control plane architecture

We propose an evolved NGN control plane architecture to decouple end-user signalling handling and the user plane control functionality in the transport stratum. Fig. 1 (b) provides an overview of the proposed architecture and its mapping with the existing NGN architecture. Signalling handling (i.e., control functions responsible for exchanging signalling messages with end user devices) and resource allocation (i.e., control functions responsible for controlling network resources for data path establishment) are tightly coupled in the existing NGN architecture. Following the decoupling, the control plane (transport control function) is now only responsible for resource and admission control (similar to the SDN controller) to set up the data path through the user plane, as shown in Fig. 1. The functionality, that currently constitutes MMCF and NACF in NGN, is moved out of the transport control plane and transposed to the application and service stratum as shown in Fig. 1(b). For example, MMCF functionality in NGN is transposed to MSF in the NGNe application stratum and MSSF in the NGNe service stratum.

The proposed architecture has improved alignment with SDN principles as standardized in [11] by treating 'signalling handling' similar to an external application service. By doing this, all user-associated signalling for built-in services (like session establishment, registration, authentication and authorization, and mobility) and external services (like IPTV, media streaming, and IP multimedia services) are handled in a uniform manner. Corresponding to each built-in service, such as session establishment, registration, authentication & authorization and mobility support, there is an application function in the application stratum, and a support function in service stratum similar to external services like IPTV.



(a) (b)

Fig. 1. (a) Existing NGN Architecture (b) Proposed Architecture for NGN Evolution

The proposed architecture offers following advantages over the next-generation networks:

- Since the signalling handling and service handling is moved out of the control plane, the control plane in the proposed architecture becomes very thin as compared to the NGN control plane. The design change facilitates a more modular, flexible and scalable architecture well-suited for future networks.
- Better aligned with the SDN control plane definition as described in [11].
- Enables dynamic deployment of built-in service functions.
- Ensures uniform treatment of built-in and external services, simplifying procedures and architecture.
- Enables slice-specific/use-case-specific signalling exchange.

IV. Information Flows for Proposed Architecture

This section presents information flows for initial registration, authentication, authorization and mobility by considering these as built-in services (as shown in the proposed architecture) using respective service functions (Session Establishment Service Function (SESF), Registration Authentication and Authorization Service Function (RAASF), Mobility Service Function (MSF)) and service support functions (Session Establishment Service Support Function (SESSF), (Registration Authentication and Authorization Service Support Function (RAASSF), Mobility Service Support Function (MSSF)).

A. Registration, Authentication and Authorization (RAA) as a Service

The end user devices initiate the registration procedure to avail the network services. As a result, after successful authentication and authorization, the context of end user devices is created in the network for providing allowed services. Registration, authentication, and authorization are executed by a dedicated service function RAASF with the help of a service support function, RAASSF in the proposed architecture.

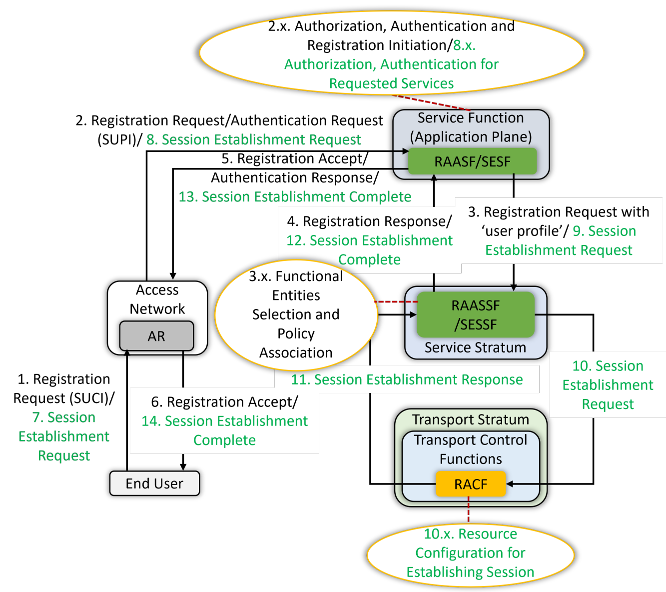


Fig. 2. Information flow for RAA and Session Establishment procedures

RAASF is a service function for registration, authentication and authorization of built-in services and is similar to IPTV application function. It communicates with end users through a data path established between the RAASF and the user device. The data path between the RAASF and the user device is established with the help of the RAASSF before providing a registration service. RAASSF is similar to the IPTV Service Support Function.

Fig. 2 shows the information flow for the registration, authentication and authorization procedure, while the session establishment procedure (from steps 7 to 14) is also included in continuation, as illustrated in Fig. 2. In step 1, a registration request carrying an end-user id (for the authentication and authorization of the user) is initiated by the end user device and sent to Access Relay (AR), as shown in Fig. 2, for requesting services. AR is a part of the user plane of the NGN and acts as the network attachment point (performed by base station in case of wireless networks) for the user device. The user device sends these service requests through the pre-configured data path (e.g., random access channel in wireless networks) to communicate with AR initially. One or more additional data paths may be set up for further signalling exchange between the end user and the service function (RAASF). AR forwards the step 1 request to RAASF, which performs the authentication and authorization of the end user (step 2). After the successful completion of the authentication procedure, the user registration procedure is initiated and RAASF forwards the request to the service support function (RAASSF) (step 3). RAASSF performs the selection of the corresponding functional entity and associates them with the end user. Completing these steps, RAASSF sends a registration response to the RAASF (step 4) and finally, the registration acceptance message is sent to the end user (steps 5 and 6).

Please be informed that for an end user to transfer data via NGN, it may be necessary to complete the registration, authentication, and authorization process. Subsequently, the user can request the establishment of a data session. The session establishment procedure is for creating a data path within NGN to facilitate the delivery of services to end users. Upon completing the registration process, the user sends a request to AR for session establishment service (step 7). AR sends this request to SESF where SESF performs the authentication and authorization process for the requested services (steps 8 and 8.x) while SESF initiates session establishment request to SESSF and SESSF forwards this request to RACF (steps 9 and 10) for resource configuration. The RACF performs resource configuration and then sends a session establishment response to the SESSF (steps 10.x and 11). Subsequently, SESSF sends a session establishment complete message to SESF (step 12). SESF forwards this message to AR (step 13) and AR forwards to the end user (step 14).

In the case of user mobility, the end-user initiates the mobility location binding update to the MSF (step 1) as shown in Fig. 3. The MSF updates the mobility binding information and initiates the path establishment procedure for the new path via the service support function (MSSF), which further triggers it via the control plane (RACF). MSF responds to the end user once the new path is established (step 9). MSF also triggers the release of the old path via MSSF. Please note that the steps highlighted in black colour are common to both host-based and network-based mobility; those in red colour are specific to host-based mobility, while the steps in green colour are for network-based mobility.

V. Conclusion

In this paper, we present a research proposal for an evolved architecture for the NGN control plane that segregates user-associated signalling functionality (control signalling) from the user plane control functionality. Our proposal treats user-associated signalling exchange as a type of payload (data) facilitated via a service function situated outside the control plane. This advancement in the control plane architecture inherently simplifies the network design and its procedures.

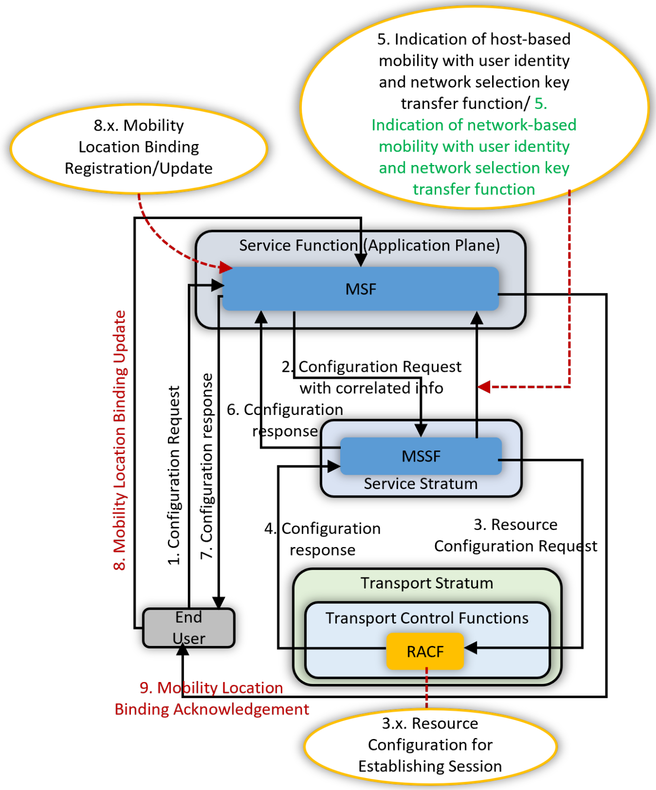


Fig. 3. Information flow for host-based/network-based mobility service

Besides, the control plane in the proposed architecture is quite thin vis-a-vis the existing NGN architecture, thereby improving its scalability and flexibility, and also rendering it highly compatible with the demands of future networks. The proposal has been submitted for consideration under ITU-T's standardization activity on the evolution of future networks.

Acknowledgment

We acknowledge the Ministry of Electronics and Information Technology (MeitY), India, for supporting the project.

References

[1] ITU-R M.[IMT.FRAMEWORK FOR 2030 AND BEYOND], "Framework and overall objectives of the future development of IMT for 2030 and beyond," *Draft new recommendation*, 2023.

[2] ITU-T Y.2012, "Functional requirements and architecture of next-generation networks," *Recommendation*, 2010.

[3] R. Fu, Y. Wang, and M. S. Berger, "Carrier Ethernet Network Control Plane based on the Next Generation Network," in *2008 First ITU-T Kaleidoscope Academic Conference - Innovations in NGN: Future Network and Services*, 2008, pp. 293–298.

[4] I. Widjaja, "Next-Generation Packet Network Architectures with Decoupled Service Plane and Transport Plane," in *2006 3rd International Conference on Broadband Communications, Networks and Systems*, 2006, pp. 1–10.

[5] F. Baroncelli, B. Martini, V. Martini, and P. Castoldi, "Supporting Control Plane-enabled Transport Networks within ITU-T Next Generation Network (NGN) architecture," in *IEEE Network Operations and Management Symposium*, 2008, pp. 271–278.

[6] P. Rongqun, M. Zhengkun, and W. Lingjiao, "A New Adaptive Service Provisioning Architecture for NGN," in *International Conference on E-Business and E-Government*, 2010, pp. 1990–1993.

[7] Y. Linlin, H. Junshu, W. Wei, and C. Ming, "Autonomous Transportation Systems and Services Enabled by the Next-Generation Network,," 2022, pp. 66–72.
[8] K. Sylwester, S. Maciej, and C. Michal, "Analytical Traffic Model for a Multidomain IMS/NGN Network Including Service and Transport Stratum," in *International Conference on Software, Telecommunications and Computer Networks (SoftCOM)*, 2022, pp. 1–6.
[9] ITU-T Y.2011, "General principles and general reference model for Next Generation Networks," *Recommendation*, 2004.
[10] ITU-T Y.1910, "IPTV functional architecture," *Recommendation*, 2008.
[11] ITU-T Y.3300, "Framework of software-defined networking," *Recommendation*, 2014.