A Study on Simplified Test Bench Evaluation Model of Application Layer Protocols for Pre-5G Service

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***Abstract*—This paper introduces a 5G network simulator capable of conducting a performance test and analysis on new technological methods, industry requirements, and products. This is necessary for the creation of a 5G K-Test bench for developing new network architectures and service provision methods that are required for 5G mobile communication to achieve industry convergence. Based on ongoing 5G technical documents, the network simulator developed earlier determines the key technologies and requirements that should be further defined and designs the structure. In addition, by defining the I/O required for each interlocking function module and designing the interface between modules, the interlocking function module studies the reliable network simulator interlocking function, including the functions given in the standard.**

Keywords—5G systems; Network Simulator; quality of service; quality of experience; business network applications

I. INTRODUCTION

The new 5G technology may revolutionize all service sectors, including agriculture, automotive, construction, energy, finance, health, factory, media, retail, and logistics. The mobility, low-power consumption, cloud services, distributed structure, and end-to-end computing that 5G offers provide new business opportunities and enables the creation of new services. The importance of industry convergence will become more emphasized and the mobility offered by mobile communication will play a key role in this process [1]. 5G network is expected to provide not only the unique infrastructure for the 4th-generation mobile communications, ubut also the foundational infrastructure necessary for future industry convergence at large. To achieve this, international standard organizations such as ITU, ETSI, and 3GPP are focusing their effort on creating a standard technology that covers 5G wired/wireless networks, and also on creating standard solutions that can allow future vertical industries to operate at low cost and high-efficiency. In addition, from the telecommunication companies' perspective, 5G networks' network function virtualization (NFV) and software-defined networking (SDN) technologies are being considered as standard technologies that would enable the conversion of the currently hardware-focused network equipment market into a software-focused one, especially in light of the importance of such a conversion [4] [5]. In this paper, we will examine the characteristics of 5G technology based on the 5G network standards completed by the 3rd-generation Partnership Project (3GPP). In addition, a 5G network simulator that can be interconnected with the application services of vertical industries was developed that can be used to evaluate the performance

II. STRUCTURAL CHARACTERISTICS OF 5G NETWORKS

A. Service-Based Architecture (SBA)

The Service-based architecture (SBA) model is a new concept that did not exist in LTE, and was introduced to strengthen the architecture's flexibility and scalability through "modularization of network functions (NFs) and interaction between NFs" [6][7]. The basic concept of this model is to enable free designs for the addition, change, and reuse of NFs by operating the interaction between two NFs based on the provider-consumer relationship. In one of the earlier stages of the 5G network architecture called technical report (TR), companies such as Cisco, Huawei, Nokia, and Deutsch Telekom suggested potential solutions, and a final product was developed after several discussions and integration efforts. The operational logic of the model is as follows: first, the functions of the 5G core network (CN) are modularized into appropriately-sized NFs, and the inter-NF interactions are defined. Afterwards, related NFs sets are interconnected through standardized interfaces (Nxxx) according to service chaining scenarios required for specific service applications. Finally, the NFs are operated based on the provider-consumer relationship. This model is applied only to NFs in the control plane (CP) and not to those in the user plane (UP).

The HTTP/2 protocol was selected to support the majority of the service-based interfaces. This structure and protocol are already being widely used in existing IT systems and cloud environments. The introduction of service-based architectures and interfaces has a great significance, given that it not only improved the interface efficiency between NFs, but also provided the foundation for enabling implementation and evolution based on the technological experience in the existing IT system environment.

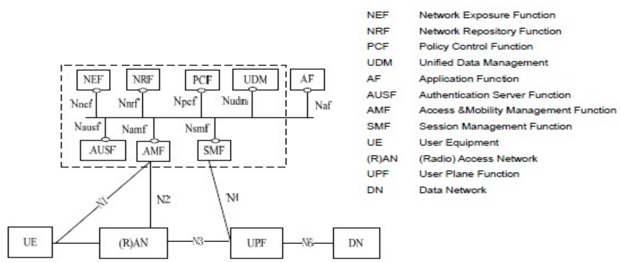

Fig. 1. Reference model for service-based 5G system structure

B. Data Storage Architecture

Elements that allow the separation of computing and storage that support the implementation of cloud environments and virtualization technologies have also been reflected in the structure and functions. For storing nonstandard data formats that are defined by manufacturers and businesses, a new standard NF called unstructured data storage function (UDSF) has been defined. It allows parts that are responsible for computing and data storage, including the computing results, to be defined separately even within the standard structure. Furthermore, to support environments in which the modules in a virtual cloud environment that are responsible for computing for certain base stations or UE can change dynamically, a technology that more loosely defines the connection between access and mobility management function (AMF) and base stations has been added to the standard. This technology minimizes the effect of changing core network computing modules on running services and thus allows continued provision of said services. Unified data repository (UDR), the storage of the respective information, has been defined separately from the NF responsible for signaling. This makes the standard more useful in cloud environments where computing and storage are separated.

Data storage function (DSF) has been introduced to allow the data of individual NFs to be treated like a cloud DB in a network virtualization environment. Following this, the private data for each NF has been separated into DSF and UDSF on the CP. For the UDSF, a NF can store its private data into a UDSF DB, and can share or completely own the closest UDSF. For the DSF, certain NFs (UDM, PCF, NEF) can store their private data in a structured format into a UDR DB. UDR has been set to include subscriber data, policy data, and application data. NEF can search and request for specific application services using application data and locational data of devices.

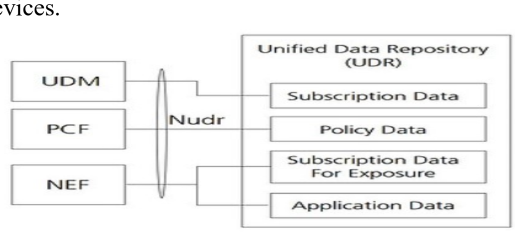

Fig. 2. Storage architecture for structured data

Besides those mentioned above, the main structural characteristics of 5G core network include independent management and scaling, enabled by clear separation between control plane NFs and UPFs that carry out user plane operations, and a clear functional separation between AMF that is in charge of mobility/access management, and session management function (SMF) that controls session management-related functions.

C. Mobility & Session Management

Several new functions related to access and mobility have been designed for 5G networks, compared to LTE systems, such as mobility on demand, RRC inactive status, policy control on device mobility management, and so on. LTE systems provide equal level of mobility and session continuity to all user devices, but 5G systems provide mobility only to devices that require it via a concept called mobility on demand.

III. Network Simulator Design for 5G Vertical Application Services Simulation

This study aims to develop and analyze a 5G network simulator, "5G K-SimNet" based on a network simulator called ns-3 that is widely used with high confidence for the application of two of the 3GPP SBA functions, NEF and NRF. The 5G K-SimNet and 5G vertical application services are interconnected to enable us assess the business value, technical aspects, operability, and so on of the application services of vertical industries at an early stage [8].

We design and study a server platform for smart factory environmental status measurements based on application service's scenario models and a module that can assess performance by designing the 5G CN Application Interface Layer that is extended by the 5G K-SimNet[9].

A. IoT Platform Structure for 5G Standard Application

The Internet-of-Things platform designed for 5G standard applications is capable of interconnecting with various sensor devices and collecting data from them, possesses data management functions, and is implemented in a dashboard format [10]. The IoT shield communicates with the Arduino and transfers the received data to the IoT platform. Commands sent by the IoT platform are relayed through the IoT shield to the Arduino.

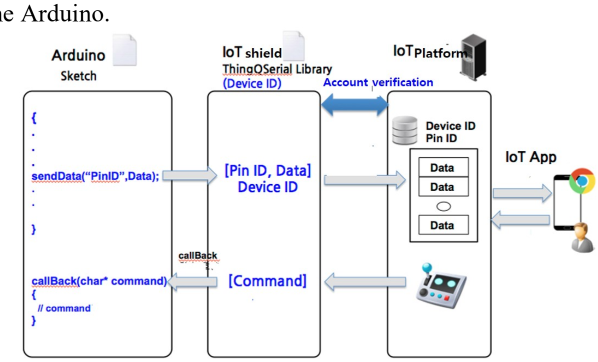

Fig. 3. IoT platform structure for 5G standard application

B. Service adaptation layer Design

The service adaptation layer is designed in the 5G K-SimNet for interfacing between the NFs of the SBA and the application services of a smart factory. Through this, we will design and study the NEF and NRF functions that fulfill the 5G service requirements.

We define the interface standards among the NEF, NRF, AMF, SMF, and UPF that are required for the smart factory application service simulation, and develop simulations to evaluate the compatibility between the said functions and the K-SimNet under development.

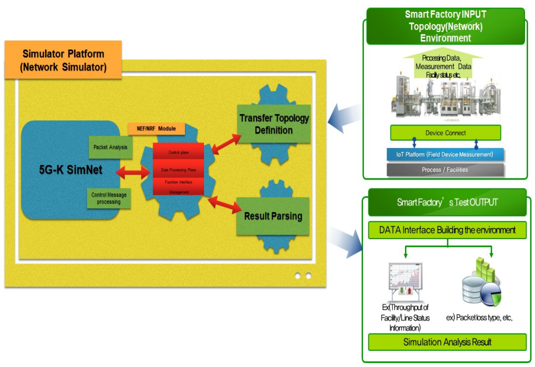

Fig. 4. Service adaptation layer structure (proposed)

Additional modules or layers developed will maintain compatibility with existing simulations under development for interfacing with the 5G K-SimNet. Also, if 3GPP SBA NFs are required instead of NEF, NRF, AMF, SMF, and UPF, they will be designed with only the minimum functions.

Each interface implements Nnef and Nnrf to invoke and return functions to minimize the impact of existing network simulators, and all data generated based on each data flow is generated, communicated, processed, and returned in a structured form.

Based on the IoT platform that has been designed for 5G standards, we model virtual nodes for the smart factory so that the results (throughput, packet loss rate) obtained by interfacing the application services with the 5G K-SimNet can be analyzed.

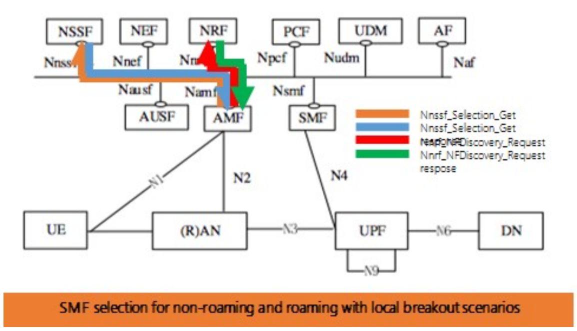

Fig. 5. Application service synchronization method research and design (proposed)

The interface design linking NEF and NRF functions to operate the simulator while maintaining organically compatible with the different functions. In the case of an interface, it is designed based on the data flow presented in the existing specification, adding each function to the simulation and implementing the module for each service. Based on this service, each operation was classified and designed as a sub-module.

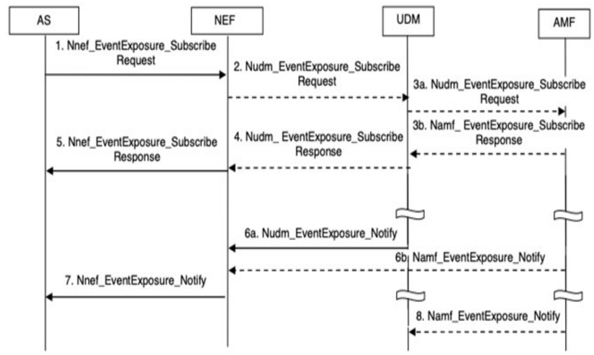

Fig. 6. Inter-module interface design

Each interface implements Nnef and Nnrf to invoke and return functions to minimize the impact of existing network simulators, and all data generated based on each data flow is generated, communicated, processed, and returned in a structured form.

- Nnef_EventExposure_Subscribe_operation will be updated if the subscriber subscribes to receive the event or if the event is already defined in the NEF.
- Nnef_EventExposure_Unsubscribe_service_operation deletes the event if NF Consumer is already defined in NEF.
- Nnef_EventExposition_Notify_service_operation reports the event to a customer previously agreed by the NEF.

The network simulator supports end-to-end IP connectivity simulation in LTE-EPC to see realistic end-to-end performance. Develop network functions that are compliant with 3GPP's 5G system architecture in a previously developed simulator. This added simulator is a simulator for the function implementation of NEF and NRF, and Nnrf interfaces are designed and implemented based on the analysis of data input/output according to 3G service-based interfaces.

IV. Conclusion

In the 4^{th}-generation of mobile communication systems, the change into an all-IP-based flat architecture brought many changes to business environments and services. The network architecture for the 5^{th}-generation of mobile communication systems entails changes to the business environment and services brought about by industry convergence. The extensive scope of the changes covers software-based virtualization, hierarchical separation, and changes to management and control methods throughout the core networks, access networks, and transport networks. The ultimate change in the network architecture is the evolution to unified mobile communication to effectively respond to changes occurring in industry services and environments. During this process, management technologies will evolve, and the demand for network automation will significantly increase.

This paper analyzed the main issues and detailed requirements for 5G core network technology, and examined methods for analyzing the capabilities of 3GPP's 5G system architecture as well as its application services. There is need for more active response and research on 5G mobile communication network systems that can effectively respond to various devices, services, and business areas.

This network simulator design aims to implement current 5G standard technologies based on LTE-A (Pre-5G) technology design. Each of these technologies is developed into functional blocks, a set of modules, to provide users with a free simulation environment.

The recently identified standard issues will be shared with businesses that develop relevant network equipment within the country. Through the help of small and medium-sized businesses that are currently conducting research and development, the implementation of 5G technology and development of devices using the technology will be supported to ensure their smooth utilization. The 5G K-Sim network simulator is expected to be used in many different areas, both academic and industry, for research and development purposes.

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