Design and Implementation of Network Data Analytics Function in 5G

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***Abstract*—For network automation empowered by advanced artificial intelligence (AI) and machine learning (ML) technologies, the third generation partnership project (3GPP) introduced a novel network function called network data analytics function (NWDAF), which collects network data and provides valuable analytics results. Based on the up-to-date NWDAF specification, we implement NWDAF including analytic logical function (AnLF) and model training logical function (MTLF). Our experimental study on analytics and ML model provisioning services demonstrates the feasibility of the NWDAF testbed.**

***Index Terms*—Network automation, Network data analytics function, AI/ML, Service based interface**

I. Introduction

As the demands for network automation increase, artificial intelligence (AI) for network has gained wide attention from industry to academic fields [1]. Especially 3rd generation partnership project (3GPP), the standardization group for the mobile network, has researched AI for mobile network services. They defined a new network function called network data analytic function (NWDAF) that analyzes the network data and provides the analytics results to other network functions (e.g., policy and charge function (PCF) and session management function (SMF)) [2]. In so doing, the other network functions can determine proper action with the analytic results (e.g., enabling redundant transmission for supporting high reliability [2], [3]).

Although the standardization and research efforts have been widely conducted, the network automation and development of NWDAF are still at the early stage in industry and open source. For example, even if the open source projects for 5G mobile core network (e.g., free5GC [4] and Open5GS [5]) exist, they do not implement NWDAF. To develop NWDAF in practical, it is important to support the service application programming interfaces (API) specified by 3GPP to interact with other network functions (e.g., PCF and SMF) [2]. There are several existing works that implemented NWDAF [6]–[8]. In [6] and [7], the authors implemented NWDAF based on open source projects but did not consider the service API for NWDAF specified by 3GPP. Meanwhile, the author of [8] implemented NWDAF with the service API to provide different analytics services. However, ML model provisioning service, which is essential for the complete operation of analysis, was not included.

In this paper, we present the implementation of NWDAF that supports the services (i.e., analytic service and model provisioning service) standardized in 3GPP [2], [9]. In addition, analytics logical function (AnLF) and model training logical function (MTLF) are deployed in NWDAF to provide each service. Then we design an NWDAF testbed to experimentally validate our implementation. The experimental results show that service consumers receive the appropriate responses from NWDAF for the analytics requests and ML model provision requests.

The remainder of this paper is organized as follows. Background knowledge on NWDAF is presented in Section II. The implementation results of NWDAF and the experimental results are described in Section III and IV, respectively. Finally, Section V concludes the paper.

II. Network data analytics function

3GPP defined NWDAF as one of the control plane functions in 5G core network to analyze network information with AI/ML technologies [2]. It provides analytic information to other network functions, application functions, and operation administration maintenance (OAM) to improve the performance of 5G networks. With the development of a network for AI, the use case of NWDAF have been gradually expanded including quality of services (QoS) sustainability analytics, network performance analytics, and user equipment (UE) related analytics.

In addition, 3GPP subdivides the functionality of NWDAF, allowing flexible deployment for efficient management [2]. For example, NWDAF can contain two separate functions (i.e., MTLF and AnLF). MTLF is a function that trains ML models and exposes new training services such as an ML model provisioning service. On the other hand, AnLF performs inference with ML models and provides the analytics results to service consumers (e.g., 5G network functions, application functions, and OAM).

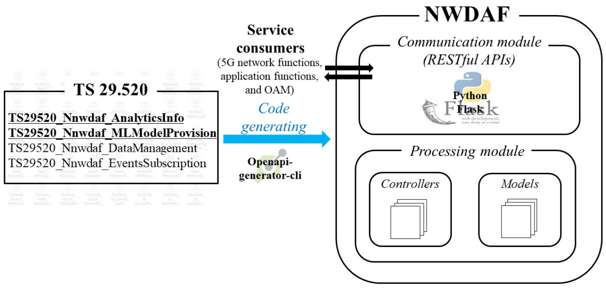

Fig. 1. Implementation of NWDAF.

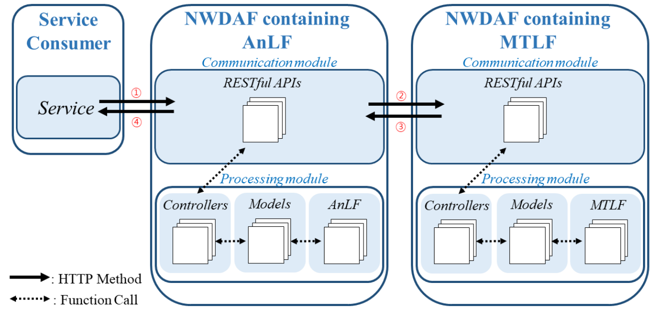

Fig. 2. NWDAF evaluation scenario.

In the current specification for NWDAF [9], four services of NWDAF are defined: 1) event subscriptions service, 2) analytic information service, 3) data management service, and 4) ML model provision service. Among those services, we focus on an analytic service and an ML model provisioning service. Because an analytic service is a key function of NWDAF and the choice of ML models is directly related to the performance of NWDAF.

Analytics service enables service consumers to request and get from NWDAF network data analytics. Substantial information (i.e., analytics results) that service consumers requested is contained in the service responses.

On the other hand, ML model provisioning service enables service consumers to receive information about ML models including the validity information and the addresses of ML models. The service consumer of ML model provisioning service is NWDAF containing AnLF [2]. Due to dynamically changing network environment, improper ML model selection can seriously degrade the performance of networks. So appropriate ML model provision would be an important issue.

III. NWDAF Testbed

A. Overview

As depicted in Figure 1, we implemented NWDAF based on TS 29.520 [9] with Openapi-generator. Openapi-generator allows the generation of API client libraries, server stubs, documentation, and configuration automatically with an openapi specification [10]. The implemented NWDAF consists of a *Communication module* and a *Processing module*.

Communication module, which is created with Python Flask, is responsible for exchanging hyper text transfer protocol (HTTP) messages with service consumers. In *Processing module*, *Controllers* identify the uniform resource identifier (URI) of HTTP requests and *Models* have several functions that can make a decision of what information should be returned.

To confirm the operation of the implemented NWDAF, we designed NWDAF testbed with the evaluation scenario as depicted in Figure 2. The design of NWDAF testbed and the workflow of the evaluation scenario are described in Section III-B and Section III-C, respectively.

B. Design of NWDAF Testbed

Our NWDAF testbed is mainly composed of three parts. There are a service consumer, an NWDAF containing AnLF, and an NWDAF containing MTLF in the testbed. First, the service consumer requests analytics events to NWDAF containing AnLF. Second, the NWDAF containing AnLF provides analytics services. It performs inference to handle the analytics requests and returns the results to the service consumer. Lastly, NWDAF containing MTLF, which provides ML model provisioning service, receives ML model provision requests from NWDAF containing AnLF. It provides proper ML models to perform the service upon receipt of this request. All of those three parts exchange messages with each other using HTTP method. We deployed a logic in each NWDAF to return an output that satisfies the service requirements.

C. Workflow of NWDAF Evaluation Scenario

The service consumer sends an HTTP GET request to NWDAF containing AnLF to retrieve the NWDAF analytics (see ① in Figure 2). To request analytics information, the service consumer should include an event-id to identify which services to be analyzed. In this scenario, we set the event-id to "DATA_ANALYTIC_REQUEST" to see how it works. When NWDAF containing AnLF receives the analytics request through *Communication module*, *Controllers* find proper functions to serve the request in *Models*. NWDAF containing AnLF may need ML models to process the analytics services listed in the event-id. If AnLF has a proper ML model to perform inference, it immediately handles the request and returns the analytics results. However, if the proper ML model does not exist in AnLF, NWDAF containing AnLF sends an ML model provision request to NWDAF containing MTLF.

To request ML model provision, the service consumer (i.e., NWDAF containing AnLF) sends an HTTP PUT request to subscribed NWDAF containing MTLF (see ② in Figure 2). When receiving the request, NWDAF containing MTLF responds with uniform resource locator (URL) or fully qualified domain name (FQDN) which indicates the address of the ML model file (see ③ in Figure 2). This process is the same as that of NWDAF containing AnLF. After this procedure, NWDAF

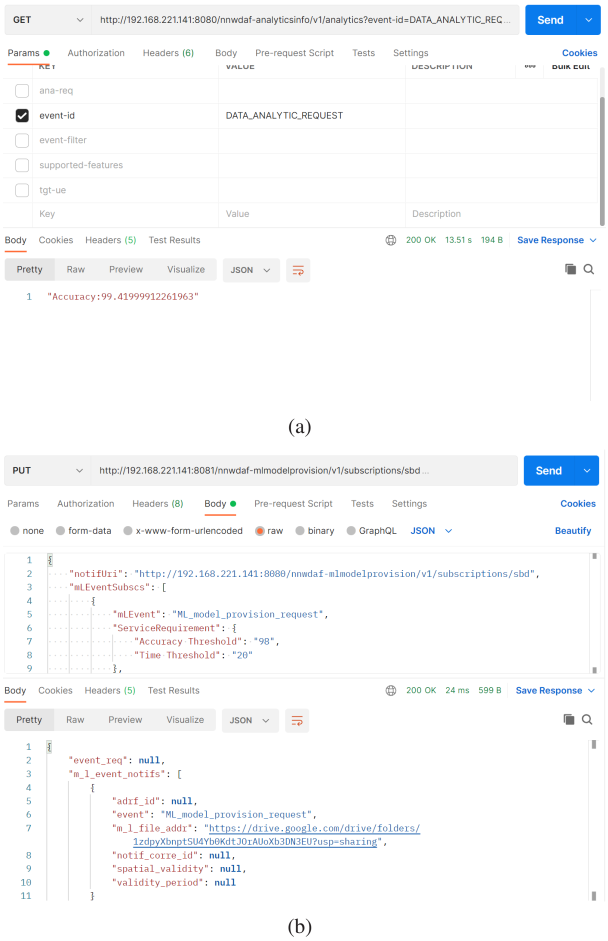

Fig. 3. Experimental results. (a) Analytics service. (b) ML model provisioning service.

containing AnLF downloads the ML model file in the given URL and performs inference with the model and then returns the analytics results to the initial service consumer (see ④ in Figure 2).

IV. Experimental Results

We confirmed that the implemented NWDAF provides analytics and ML model provisioning services through the NWDAF testbed. Figure 3(a) shows that the service consumer received the analytics results that match the requested event-id . When NWDAF containing AnLF is requested by service consumers with the event-id for the first time, it can not return the analytics results immediately. This is because AnLF can not create ML models itself. So it does not have any ML model to process the analytics requests at first.

Figure 3(b) shows that NWDAF containing AnLF requests ML model provision to NWDAF containing MTLF. Right after receiving the ML model file address, AnLF downloads the ML model and performs inference with them. Meanwhile, when the service consumers send the same analytics request next time, NWDAF containing AnLF performs inference with the ML model that it already had.

V. Conclusion

In this paper, we implemented NWDAF based on the current specification document and presented the experimental results through an NWDAF testbed. In addition, the evaluation scenario with the NWDAF testbed showed that the implemented NWDAF works properly for requested services. In our future work, we will conduct more extensive evaluations in various use cases and propose a novel ML model provisioning algorithm.

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