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Araştırma Makalesi / Research Article

NWDAF Architecture to Support Mobility Analytics Subscription

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Abstract

With the standardization of 5G and unprecedented growth in the network traffic data, data processing becomes critical. Therefore, a network entity is needed that could generate analytics from this data to improve the entire operations in the network. Network Data Analytics Function (NWDAF) is a 5G Core Network Function (5GC NFs) which is standardized by Third Generation Partnership Project (3GPP) for creating either statistical or prediction-based analytics regarding different use cases. These analytics are obtained by other Network Functions (NFs) by subscribing to NWDAF or requesting from NWDAF. An NF consumer can obtain multiple analytics when it is subscribed to NWDAF with specifying the subscription details. So, this paper provides details of NWDAF focusing on the current phase of its specifications. Contrary to the existing specifications, this study evaluates a network scenario in which only a single NWDAF instance is present. With this, how the subscription mechanism of NWDAF can be used, by specifically focusing on the User Equipment (UE) Mobility use case, which is one of the standardized analytics, is also explained in this paper. Finally, possible developments that can be added to the created system are discussed in conclusion.

Keywords: 5G Core Network Function, Service-Based Architecture, Network Data Analytics Function, User Equipment Mobility.

Hareketlilik Analitiğine Aboneliği Destekleyen NWDAF Mimarisi

Öz

5G Sistemi'nin standartlaştırılması ile birlikte ağda olağandışı artması beklenen veri trafiği ile, bu verilerin işlenmesi kritik bir hale gelmektedir. Bu nedenle, bu verilerden analitikler üreterek ağdaki operasyonların tamamını iyileştirebilecek bir ağ varlığına ihtiyaç duyulmaktadır. Ağ Veri Analitiği Fonksiyonu (NWDAF), bir 5G Çekirdek Ağ Fonksiyonu (5GC NF) olup, Üçüncü Nesil İşbirliği Projesi (3GPP) tarafından farklı kullanım senaryoları için istatistiksel ve/veya tahmine dayalı analitik oluşturmak amacıyla standartlaştırılmıştır. Bu analitikler, diğer Ağ Fonksiyonları (NFs) tarafından NWDAF'a abone olunarak veya NWDAF'tan talep edilerek elde edilir. Bir NF tüketicisi, NWDAF'a abone olduğunda abonelik ayrıntılarını belirterek birden fazla analitik elde edebilir. Bu nedenle, bu makale NWDAF'ın spesifikasyonlarının mevcut aşamasına odaklanarak detaylarını sunar. Mevcut spesifikasyonlar aksine, bu çalışmada yalnızca bir NWDAF'ın bulunduğu ağ senaryosu değerlendirilmiştir. Bununla birlikte, NWDAF'ın abonelik mekanizmasının, özellikle standartlaştırılmış analitiklerden biri olan Kullanıcı Ekipman Hareketliliğine odaklanılarak, nasıl kullanılabileceği de bu makalede açıklanmıştır. Son olarak, oluşturulan sisteme eklenebilecek olası geliştirmeler de sonuç kısmında tartışılmıştır.

Anahtar Kelimeler: 5G Çekirdek Ağı Fonksiyonları, Servis-Temelli Mimari, Ağ Veri Analitiği Fonksiyonu, Kullanıcı Ekipman Hareketliliği.

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1. Introduction

Since the advent of 3G, the Third Generation Partnership Project (3GPP) has emerged as a prominent organization in shaping standards for mobile communication technologies. Despite the proliferation of organizations involved in standardization, the architecture of 5G continues to be developed by 3GPP (3GPP, 2024). A fundamental distinction of this architecture from previous generations lies in its emphasis on Network Function Virtualization (NFV) and Software-defined Networking (SDN) (Quadrini et al., 2023). The concept of virtualization, championed by the European Telecommunications Standards Institute (ETSI) along with leading firms in the mobile communication sector for over a decade, has permeated various disciplines (ETSI, 2012). In the context of 5G, this virtualization has facilitated the creation of the Service Based Architecture (SBA). Entities utilizing this architecture, termed as 5G Network Functions (NFs), classified as dedicated. In other words, each of these functions is only allowed to perform the operations they are designed for. For instance, the Network Repository Function (NRF) enables registered functions to discover each other. Moreover, NWDAF processes data collected from NFs based on requests from other 5G entities, disseminating analyzed insights to the requester (He et al., 2023). Additionally, by leveraging Machine Learning (ML) techniques, NWDAF is standardized to optimize network operations, which are crucial given the projected surge in mobile subscribers, estimated to reach 5.3 billion by 2029 (Ericsson, 2023). Particularly with emerging technologies like Autonomous Vehicles (AVs) network connectivity becomes pivotal, elevating the significance of NWDAF's impact on Handover (HO) operations. Also, when User Equipment (UE) (i.e., which denotes an equipment with a Subscriber Identity Module (Dolente et al., 2024), mobility which is one of the use cases standardized by 3GPP (3GPP, 2024) is considered, deploying an NWDAF instance could address possible problems (e.g., ping-pong effect) that may be occurred in future states. For this, an NWDAF instance is not only responsible for generating statistical results but also creates predictive analytics about future network conditions. With this, UEs using these analytics can perform more seamless HOs (Derehag et al., 2021). Therefore, this study aims to explore the potential benefits of NWDAF, specifically focusing on UE Mobility analytics. To this end, in this study, an NWDAF instance is implemented which can support receiving subscriptions regarding UE Mobility analytics.

Even though using intelligent models and strategies are not new in mobile telecommunications, especially SBA and NFV, 3GPP's NWDAF brings a paradigm shift to this technology. Therefore, this function paves the way for new studies. One of the studies aims to implement NWDAF into 5G Core (5GC) using open-source software like Open5GS and UERANSIM, (Chouman et al., 2022) analyze how NWDAF processes network data collected from other 5G Network Functions (i.e., Binding Support Function (BSF) and NRF) and create insights, as they conclude their paper by

indicating the NWDAF's capability on Management and Orchestration (MANO) with their case study. Also, since anomaly detection is one of the fundamental concerns when all mobile communication technologies are considered, in a study (Barriaga et al., 2022) authors focus on anomaly detection using NWDAF in 5G. When mobility of a single entity (i.e., UE) is considered, HO will be more complex in 5G due to the extreme number of connected devices and existence of macro and micro cell data exchange. For this reason, in another study, authors (Kao et al., 2023) investigate HO behaviors of UE groups in a real 5G network with data they collected from 5G commercial non-standalone (NSA) networks. They conclude their paper by indicating NWDAF's usability for predicting possible ping-pong occurrences in the sense of HO. Since 3GPP has described micro services for each NFs in 5GC, which can be used by other NFs to interact each other, main concern of a study was to both introduce and implement NWDAF's two micro services, namely Nnwdaf_AnalyticsInfo and Nnwdaf_MLModelTraining (Cha et al., 2022). Even though this study covers the interaction between multiple NWDAFs (one of them carrying Model Training Logical Function (MTLF) feature while the other is carrying Analytics Logical Function (AnLF) capability), authors only focused on request and response mechanisms. On the other hand, as 3GPP stated (3GPP, 2024), NWDAF also has another micro service, namely Nnwdaf_EventsSubscription, which allows consumers to subscribe to NWDAF to receive multiple analytics with a single request. Despite there is a significant number of studies which aim to introduce NWDAF usage on mobility solutions, to the authors' knowledge, how NWDAF responds to the consumers who were subscribed for UE Mobility analytics (i.e., one of the analytics standardized by 3GPP) using Service Based Interface (SBI) weren't focused. So, this study aims to contribute:

1) Creating the subscription mechanism between an NWDAF Consumer and NWDAF supporting UE Mobility Analytics,
2) Providing analytics results to NWDAF Consumer that is already subscribed when parameters in the subscription request are met.

2. Background

2.1. 5G Core

The architecture of 5G systems must accommodate diverse use cases, including Augmented Reality (AR), Virtual Reality (VR), as well as applications in smart farming, healthcare, transportation, and smart cities. Each of these areas demand different capabilities from the network. To meet these varied requirements, several new concepts have been integrated into the design of the 5GC. Additionally, the emphasis on scalability and protecting investments in equipment has led to a

greater focus on network virtualization. This virtualization can only be fulfilled when the following key functions are satisfied (T. E. Centre, 2021):

- **Network slicing** allows independent scalability, decoupled technical evolution, and flexible deployment and configuration of the network to meet the specific needs of various services.
- With **state-agnostic network functions**, computing resources are separated from the storage, a concept borrowed from cloud applications. This separation enables more efficient creation and utilization of network resources.
- Support for **cloud-native** applications represents an advancement beyond NFV, enhancing scalability and the efficient creation and consumption of network resources.

2.2. Network Data Analytics Function

NWDAF is an NF in the Control Plane (CP) within SBA. Standardization of this function is also delivered by 3GPP like the 5G System itself (3GPP, 2024). Essentially, NWDAF generates analytics using intelligent models (i.e., Artificial Intelligence (AI) and ML) upon requests it receives. Therefore, as can be seen in Figure 1, there is bidirectional communication between NWDAF and NFs enabling any NF to request analytics from NWDAF and NWDAF to collect required data for creating requested analytics (Sevgican et al., 2020).

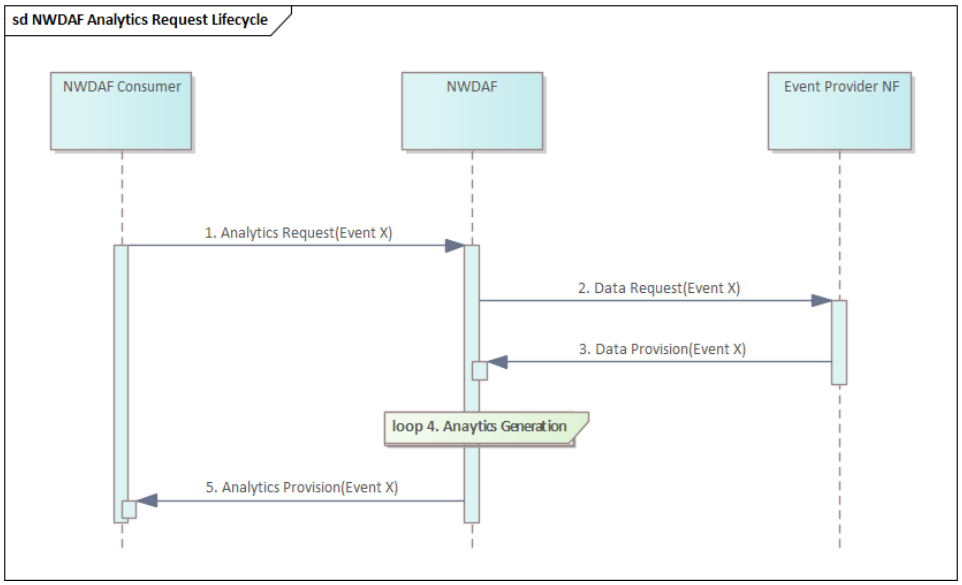

Figure 1. Analytics Request and Provision

NWDAF has its own microservices and service operations like all NFs in the 5GC have. In the current specification, there are eight services NWDAF supports: (1) Analytics subscription service, (2) Analytics info service, (3) Data management service, (4) ML Model Provision service, (5) ML Model training service, (6) ML Model monitor service, (7) Roaming data service and (8) Roaming analytics service. Here, while the first five services don't require additional NFs, remaining services require either additional NFs (e.g., data management entities or repositories) or multiple NWDAF instances.

Instead of using multiple NWDAF instances, this paper assumes there is only one NWDAF deployed. So, interaction between multiple NWDAF instances, like analytics context transfer or data management etc. are outside of the scope. Also, the focus of this paper is the analytics subscription (i.e., Nnwdaf_EventsSubscription) service.

Within this service, an NWDAF Consumer can subscribe to NWDAF with using its Application Programming Interface (API) and an HTTP POST request. In this request, there are required and optional parameters that are sent by an NWDAF Consumer. Since this consumer request to subscribe to NWDAF to receive analytics, the type of analytics (i.e., analyticsId) shall be indicated in the first place. Here, since this study mainly focuses on UE Mobility analytics, the selected analyticsId is UE Mobility. Parameters which specify the scope of the analytics are also sent by NWDAF Consumer.

Upon the subscription request, NWDAF creates a new subscription, assigns an event subscriptionId and stores the subscription. After this, since subscription of an NWDAF Consumer is created for UE Mobility, the next step is to collect data from the NF (i.e., AMF in this case), if NWDAF doesn't include necessary data in advance. Once data is collected, creation of analytics using both data and trained models can be performed. Analytics subscription lifecycle operation can be seen from Figure 2.

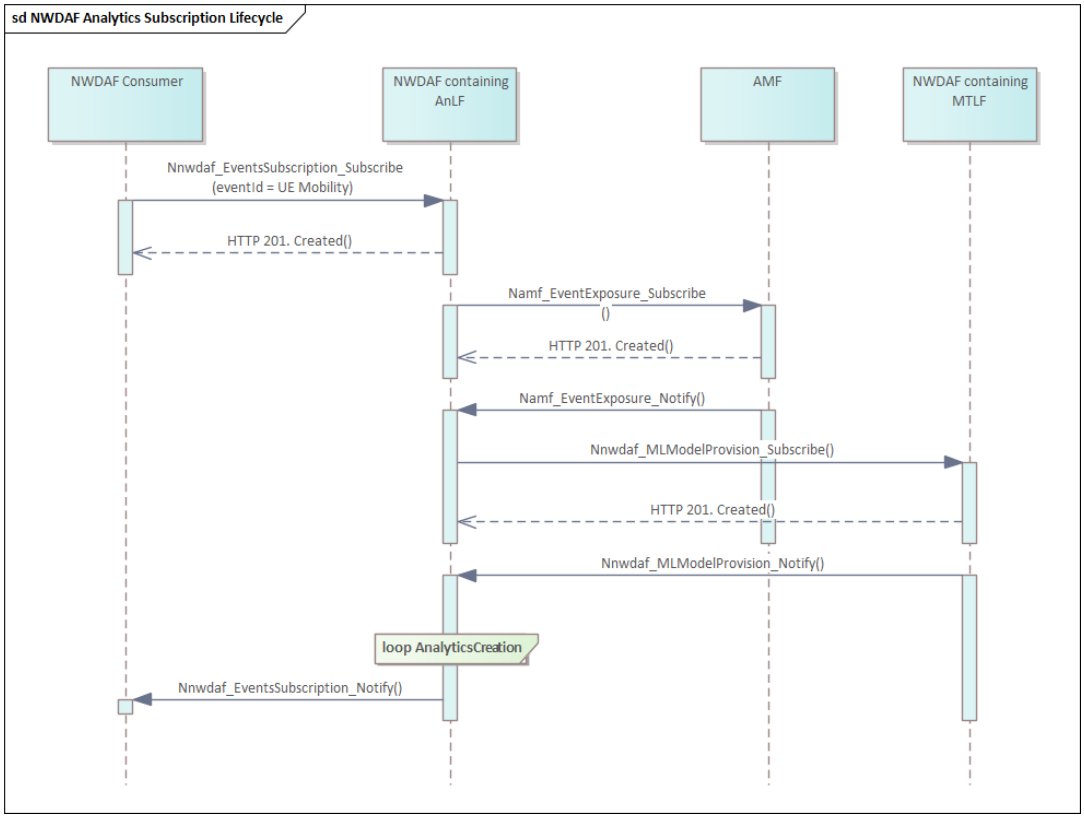

Figure 2. Analytics Subscription Lifecycle

2.3. Handover in 5G System

Mobility management is one of the essential functions in mobile networks (Kim et al., 2024). When connected devices which move fast (e.g., AV) are considered, mobility management becomes crucial. For this, connection of such devices shall be provided continuously. Therefore, 3GPP provides a standard which also includes Key Performance Indicator (KPI)s regarding HO below the topic of Mobility KPI (3GPP, 2024). When 5G is considered, various NFs are responsible for fulfilling the HO operation for a UE or a UE Group. In an HO operation, while AMF tracks and manages the location-based data of a UE, Session Management Function (SMF) updates the sessions belonging to the cells that are determined by AMF. With this, using NWDAF to create location-based predictions brings opportunities to utilize resources of each NF for a HO before it occurs.

3. Method

3.1. Architecture to Support Subscription to NWDAF

In the system architecture of this study, an NWDAF Consumer (i.e., Analytics Consumer) initiates the process by subscribing to NWDAF. This is achieved through an HTTP POST request

directed to NWDAF's service API, with the necessary parameters. Upon sending the subscription request, the Analytics Consumer is also required to provide a notification method along with the analyticsId. An analyticsId represents an event that will be reported either with predictions or statistics based, while the notification method determines the type of event reporting employed by the NWDAF.

3GPP defined three types of notification methods, and these are one-time or periodic notifications or notifications upon event occurrence. In this study, periodic notifications are exclusively focused on. Given that the notification method is assumed to be periodic, the repetition period (e.g., once per hour) must also be specified by the Analytics Consumer.

Following this, a designated module within the system parses the parameters included in the request to identify and segregate those that are necessary for tracking the subscription. Subscription data must be stored in a database or repository to facilitate NWDAF in sending notifications to the Analytics Consumer. Once all subscription data is stored, the NWDAF will notify the Analytics Consumer with an analytics report in accordance with the specified repetition period. The overall architecture supporting this mechanism is illustrated in Figure 3.

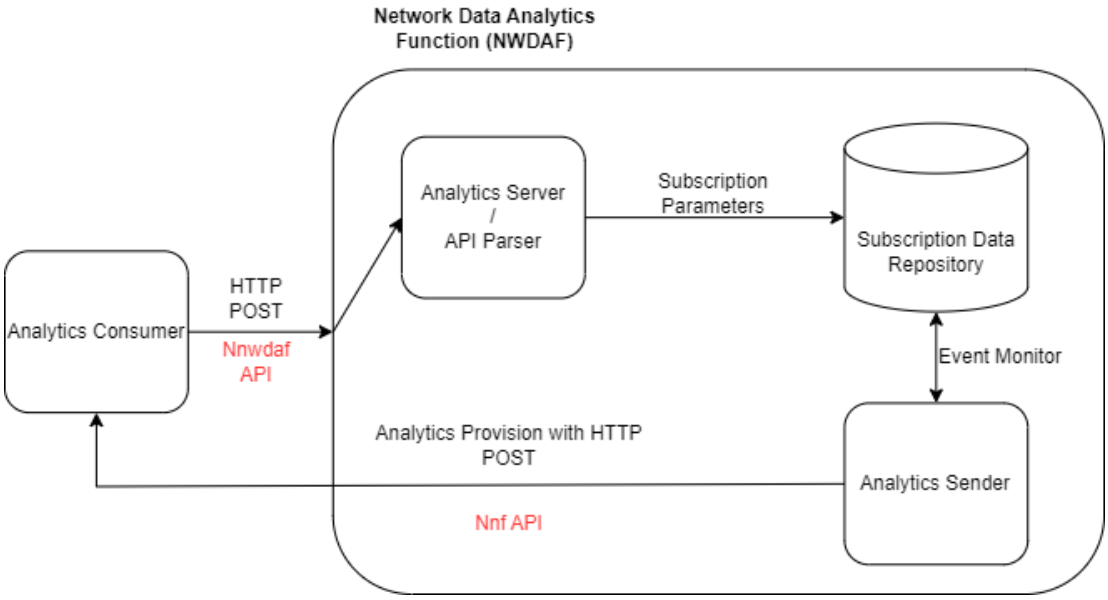

Figure 3. Interaction Architecture for Subscription

3.2. Application

To handle subscription requests from an NWDAF Consumer, it is required to create an endpoint which can get HTTP POST request. This entity is called Application Server (or API Parser) in this system. Then, since the subscription is accepted, each parameter of this subscription shall be stored within a database to monitor whether an analytics event occurred. Here, a Subscription Correlation

ID is created by NWDAF and shared with NWDAF Consumer within the HTTP POST response. This unique ID is mandatory for future requests (e.g., HTTP PUT for subscription update). A sample subscription request and response are designed in this study as in Figure 4 below.

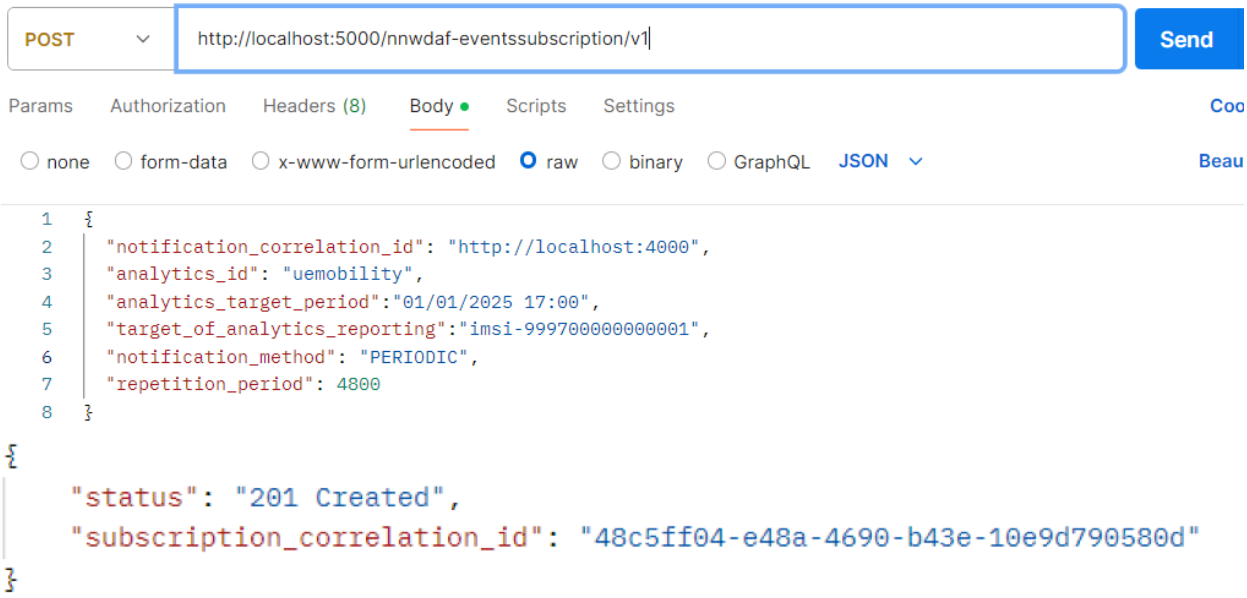

Figure 4. Subscription Request and Response

Here, parameters that are provided within the HTTP POST requests are required ones. Definition of each parameter is as follows:

- *Notification Correlation ID*: This unique ID represents the endpoint of an NWDAF Consumer. So, when an analytics report will be sent to the NWDAF Consumer, this id is used as an address.
- *Analytics ID*: As it was explained before, NWDAF may support different types of analytics (i.e., use cases) which are either 3GPP's standard analytics or custom analytics.
- *Analytics Target Period*: This parameter is sent by the consumer to indicate until when analytics are needed. If the current time exceeds this parameter, subscription is automatically deleted and no further request (e.g., HTTP PUT) for this subscription is accepted.
- *Target of Analytics Reporting*: Since the focus of this article is UE Mobility Analytics, which UE or UE group will be included is specified within this parameter.
- *Notification Method*: As it was described in the earlier section, there are three possible reporting ways that a consumer can choose, these are either one-time report, report when an event occurred and periodic reports. So, this parameter is used by a consumer to indicate which one is chosen.

- *Repetition Period*: This parameter is only required when the notification method is chosen as periodic and indicates the exact time interval between two reports.

Upon creating a subscription for an NWDAF Consumer, NWDAF shall collect data from the appropriate NF to generate either statistics or prediction-based analytics. Data collection from other NFs requires subscribing to them. In other words, the request and response methods (i.e., HTTP GET) are not used in this operation.

With this subscription, NWDAF can send periodic reports about the UE indicated in the Target of Analytics Reporting parameter. Therefore, either potential handover(s) or handover statistics of this UE will both be extracted and sent to the subscriber. This sending was done creating a cron to send HTTP POST requests to the subscriber once in 4800 seconds. In other words, in every 4800 seconds, a report is sent to the endpoint of the subscriber which was indicated within HTPP POST with Notification Correlation ID parameter.

Finally, HTTP POST response includes a status code and Subscription Correlation ID. Status code indicates no other than HTTP status codes and Subscription Correlation ID is generated by NWDAF for each subscription for the subscriber to update its subscription.

4. Conclusion

In this paper, the subscription life cycle of an NWDAF instance based on 3GPP's current specifications was explained and created. This creation is limited to answer how NWDAF handles subscription coming from an NWDAF Consumer about UE Mobility analytics. Since, to fulfill the operation and evaluate the contribution of NWDAF to these analytics, it is required to have an AMF to collect real 5G data. Thus, future works will be in this perspective covering both data collection mechanism and appropriate ML model usage of NWDAF.

Authors' Contributions

Bahadır Yalın: Concept, Methodology, Theoretical Background, Writing.
Tarık Veli Mumcu: Methodology, Edit, Supervision.

Statement of Conflicts of Interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

The author declares that this study complies with Research and Publication Ethics.

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