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Access and Mobility Policy Control at the Network Edge☆

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Abstract

The fifth generation (5G) system architecture is defined as service-based and the core network functions are described as sets of services accessible through application programming interfaces (API). One of the components of 5G is Multi-access Edge Computing (MEC) which provides the open access to radio network functions through API. Using the mobile edge API third party analytics applications may provide intelligence in the vicinity of end users which improves network performance and enhances user experience. In this paper, we propose new mobile edge API to access and control the mobility at the network edge. The application logic for provisioning access and mobility policies may be based on considerations like load level information per radio network slice instance, user location, accumulated usage, local policy, etc. We describe the basic API functionality by typical use cases and provide the respective data model, which represents the resource structure and data types. Some implementation aspects, related to modeling the resource states as seen by a mobile edge application and by the network, are discussed.

1 Introduction

The fifth generation (5G) comes with the promise to provide the unified connectivity, to bring huge enhancements to current mobile broadband service, and to enhance network functionality in support of diverse use cases [1–3]. As to [4], it will operate in a wide frequency range supporting Multi Radio Access Technologies (RAT) to satisfy the requirements for higher system capacity, reduced latency, higher data rates, massive device connectivity, and energy saving and cost reduction. 5G enhances some of the features defined for 4G including:

- More network flexibility by providing additional support for essential functions.
- More flexibility for mobility solutions by expanding form of multi RAT integration and management.
- Enhanced efficiency for short burst or small data communication by expanding content information known to the network.

In 4G, to achieve seamless interoperability between heterogeneous networks, Access Network Discovery and Selection Function (ANDSF) is defined by 3GPP as an attempt to resolve challenges associated with connectivity, authentication, session persistence and traffic management. ANDSF provides the standard

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interface and functionality for operators to set device-based policies for operator-preferred network connections. ANDSF enables dynamic evaluation of rules determining which network to select based on conditions and operator objectives [5]. Based on information provided by ANDSF, multi-mode mobile terminals to select and associate with the network point of attachment that minimizes the average overall power consumption at the mobile terminal and guarantees a minimum supported quality of service for its ongoing connections [6]. A network ANDSF may be extended to update the statically configured mobility and routing policies provided to the UE for access selection, which provides the best access network for data offloading [7, 8].

In 5G, this functionality is a part of Policy and Charging Control framework [9]. The 5G core network provides policy information to the User equipment (UE). Such information includes access network discovery and selection policy information, and UE route selection policy information.

In this paper, we propose an open access to UE access selection and packet data session selection related policy information in the radio access network, following the principle for service-based 5G system architecture. The open access may be implemented by Multi-access Edge Computing (MEC) technology. MEC introduces cloud intelligence at the network edge and it provides mobile edge application with information about current radio network conditions, UE location and access to user traffic routing functionality. It is envisaged to be a key component of 5G as it must provide low latency and optimal bandwidth utilization [10, 11]. We propose a new mobile edge service that enables third party applications to provide access and mobility related policy control information based on network level congestion, UE location, local policy, etc.

The rest of the paper is organized as follows. The next section outlines research motivation. Section 3 describes the service resources and the access to resources. Section 4 concerns some implementation issues related to modeling an application logic and mobile edge platform behavior. Conclusion summarizes the author contribution.

2 Research Motivation

The access and mobility policy control enables management of service area restrictions and the management of the RAT priority functionality. The open access to access and mobility policy control functionality enables third party applications to define policy containing RAT restrictions, forbidden areas, and service area restrictions. The application logic for mobility restrictions may be based on UE location, information about congestion in RAN, user preferences defined, or local policy.

The open access to access and mobility policy control, exposed at the network edge, enables extraction of mobility patterns and resource management functions. An analytic 3-rd party application may extract UE mobility patterns, based on statistics of UE mobility using historical data or estimating expected UE moving trajectory. The mobility pattern can be used by the application to optimize mobility support provided to the UE, e.g. registration area allocation. An intended application may provide index to RAT/Frequency Selection Priority (RFSP Index) to different radio access networks based on current radio conditions. The RFSP, which is UE specific, may be used for radio resource management (e.g. to decide on redirecting active mode UE to different frequency layers or RATs).

In [12], it is proposed a new mobile edge service that enables authorized mobile edge applications to monitor the overall amount of resources that are consumed by a user and to control usage independently from charging mechanisms. Based on this functionality, it is possible for mobile edge application to make dynamic decisions on access and mobility policy instructions taking into consideration e.g. accumulated usage, load level information per network slice instance etc.

An example use case might be a multi-team, multi-player role game with augmented/virtual reality components and live video streams. The requirements put by such application are high level of mobility, high data speeds and low latency. To cope with these requirements the access and mobility policy control at the network edge could help especially in cases of heterogeneous access environment.

Figure 1 shows a use case illustrating the open access to access and mobility policy control at the network edge. The proposed new mobile edge Access and Mobility Policy Service (AMPS) provides access to access control and mobility management related services to Access and Mobility Management Function (AMF). AMF is a 5G core function which performs basically registration management, connection management, reachability management, mobility management, access related security functions, and sending of UE policy towards the served UE [13]. Mobile edge Location service provides information about UE location [14].

As a precondition, the mobile edge application needs to have an active subscription for policy associations.

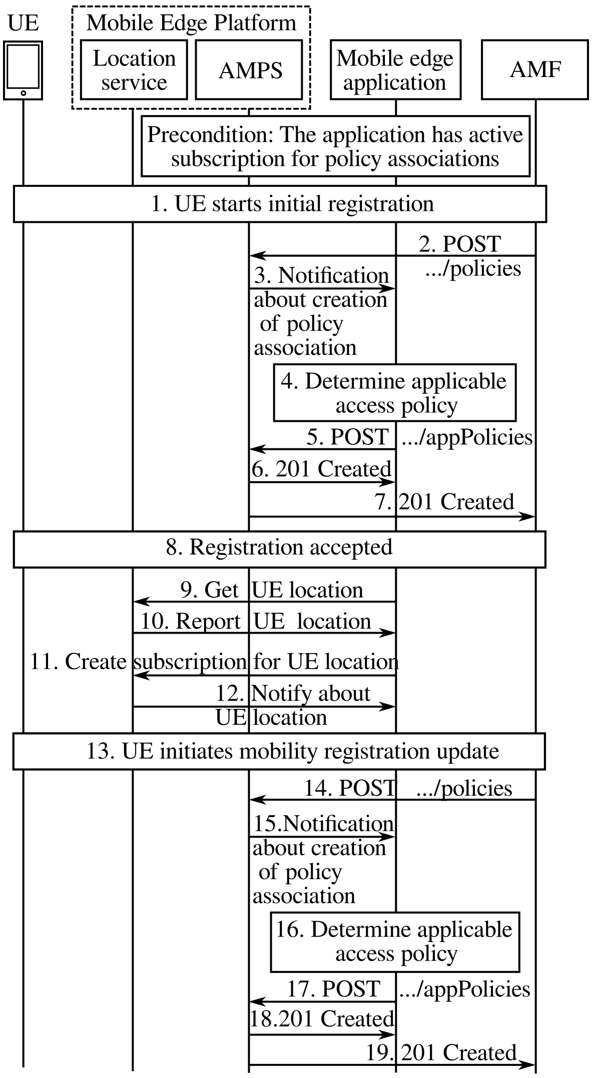

Figure 1. Use case of third party access and mobility policy control

1. When the UE starts initial registration the AMF retrieves subscription permanent data and initiates UE authentication.

2. The AMF creates an access and mobility policy association as to [15].

3. The AMPS notifies the mobile application about the request for creation of access and mobility policy association.

4-6. The application determines the applicable policy taking into consideration load level of the network and other information and sends an access policy.

7. The policy association creation is accepted.

8. The UE registration is accepted.

9-10. The application retrieves UE location data from the mobile edge Location service.

11. The application subscribes with the Location service to receive notifications about UE location changes.

12. The mobile edge application receives notifications about UE location and predicts the UE trajectory based on UE mobility pattern.

13. UE initiates mobility registration update (possibly entering in a new tracking area).

14. The AMF modifies the access and mobility policy association.

15. The mobile application is notified about the request for creation of access and mobility policy association.

16-18. The application determines the applicable policy taking into consideration load level of the network and UE mobility and sends a mobility policy to the AMPS.

19. The policy association modification is accepted.

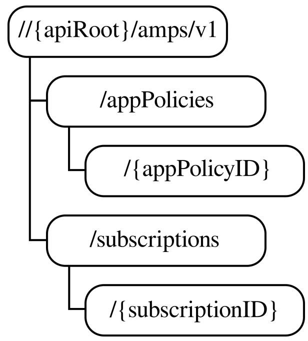

Figure 2. Structure of resources supported by AMPS

The proposed mobile edge service provides access and mobility policies and offers the following functionalities:

- Notification of the mobile edge application about request for policy association;
- Sending an access and mobility policy, which is provided by a mobile edge application.

3 Service Resources and Resource Access

The service resource definition and resource manipulation follow the Representational State Transfer (REST). The request URI (Uniform Resource Identifier) in HTTP request from the mobile edge application towards the AMPS has the following structure:

```
apiRoot/amps/apiVersion/
```

The resource structure is shown in Figure 2.

The **appPolicies** resource contains a list of all access and mobility policies. The applicable HTTP methods are GET (retrieves all policies) and POST (creates a new policy).

The **appPolicyID** resource represents existing policy. The applicable HTTP methods are GET (reads the individual policy resource), PUT (updates existing policy), DELETE (terminates the individual policy resource).

To receive notification about creation of policy association, the mobile edge application creates a subscription with the AMPS.

The **subscriptions** resource presents all subscriptions for policy association creation. The applicable HTTP methods are GET (retrieves all subscriptions to policy association creation) and POST (creates a new policy association creation). The **subscriptionID** resource represents existing subscription. The applicable HTTP methods are GET and DELETE.

The **SubscriptionData** defines data structure for subscriptions. It consists of the following attributes: **timeStamp**, **callbackuserID**, and **filterCriteria**.

The **callback_ref** is URI at which the mobile edge application wants to receive notifications. The **filterCreteria** defines the criteria for notifications about policy association creation. It is a structure of **userID**, **ueLocationInfo**, **servingNetwork**, **ratType**, **serviceAreaRestrictions**, **rfspIndex**, and **policyRequestTrigger**. The **ueLocationInfo** provides information about UE location. The **userID** is subscriber permanent identifier. The **servingNetwork** identifies the serving mobile network. The **ratType** attribute identifies the RAT. The **serviceAreaRestrictions** define the restriction for allowed and forbidden service areas. The AMF derives from user profile this data and sends them in the request for policy association creation. The **rfspIndex** presents the RFSP index. The **policyRequestTrigger** defines the reason for requesting policy association creation. The request triggers may be UE location change, UE presence area change, serving area change, or RFSP change. These data types are defined in [16].

The **PolicyAssociationData** defines data structure for notifications. It consists of the following attributes: **timeStamp**, **userID**, **ueLocationInfo**, **servingNetwork**, **ratType**, **serviceAreaRestrictions**, **rfspIndex** (as defined above) and **associateID** - identifier to associate the event for a specific UE.

4 Implementation Issues

Implementation of the mobile edge service API requires modelling of the UE mobility management state as seen by the mobile edge application and by the network. Both models have to be synchronized, i.e. they have to expose equivalent behaviour.

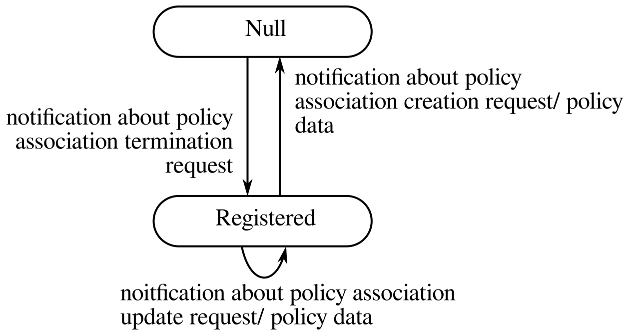

Figure 3. The UE mobility management model, supported by a mobile edge application

Figure 3 shows a simplified model of the logic of mobile edge application which is authorized to provide access and mobility policies.

In Null state, the UE is in idle state and the mobile edge application has not provided any access and mobility policy. The transition from Null to Registered state occurs when the mobile edge application is notified about policy association creation request. In response to the notification, the mobile edge application returns access and mobility policy. In Registered state, the UE is registered to allowed network as to policy sent by the application. The mobile edge application may be notified about update of policy association and it sends the respective applicable policy. The transition from Registered to Null state occurs when the mobile edge application is notified about request for policy association termination.

Figure 4 shows a simplified AMF behavior in case of UE registration. The model is based on Registration procedure and Deregistration procedure [15]. In order to register the UE, the AMF requests user permanent identity and initiates authentication and authorization. Before sending a policy association creation request to the mobile edge platform, the AMF retrieves the user data. On receiving the access and mobility policy provided by the mobile edge application the AMF acknowledges the registration. Deregistration procedure may be initiated by the user or by the network. The procedure includes termination of policy association.

In order to formally prove that both models expose equivalent behavior, we use a formal model representation by the notion of Labeled Transition Systems.

A Labeled Transition System (LTS) is represented as quadruple of a set of states, a set of actions, a set of transitions and a set of initial states.

The definition of an LTS, representing the model of UE registration state as seen by the application is given by

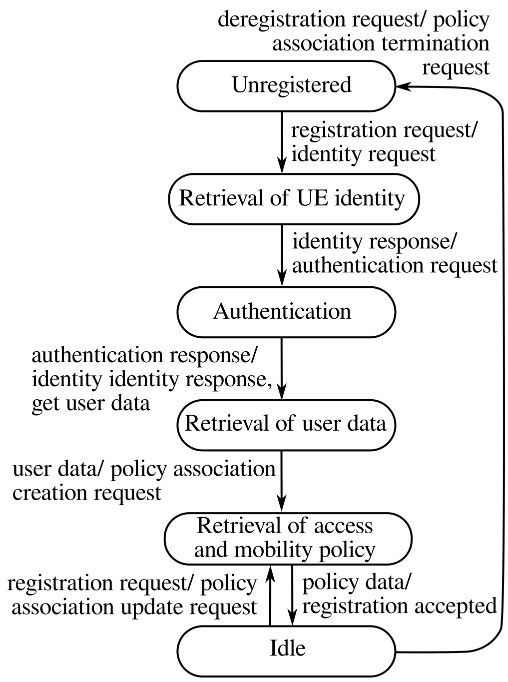

Figure 4. A simplified model of UE registration states, supported by the network

$$T_{App} = \left(S_{App}, Act_{App}, \rightarrow_{App}, s_0^{App}\right)$$

In T_{App} the set of states is

$$S_{App} = \{Null\ [s_1^A]\ , Registered\ [s_2^A]\}$$

and the set of actions is

$$Act_{App} = \{policyAssocCreateNot\ [t_1^A]\ , policyAssocUpdNot\ [t_2^A]\ , policyAssocTermNot\ [t_3^A]\}$$

Then, the transitions might be presented as

$$\rightarrow_{App} = \{(s_1^A, t_1^A, s_2^A)\ , (s_2^A, t_2^A, s_2^A)\ , (s_2^A, t_3^A, s_1^A)\}$$

and the set of initial states as

$$s_0^{App} = \{s_1^A\}$$

For brevity sake, short notations for states and actions are given in brackets.

By

$$T_N = (S_N, Act_N, \rightarrow_N, s_0^N)$$

it is denoted an LTS, representing the model for UE registration state in the network, where the set of the states i.e. S_N is

$$S_N = \{Unregistered\ [s_1^N]\ , RetrievalOfUeIdentity\ [s_2^N]\ , AuthenticationSecurity\ [s_3^N]\ , RetrievalOfUserData\ [s_4^N]\ , RetrievalOfAccessMobilityPolicy\ [s_5^N]\ , Idle\ [s_6^N]\}$$

The set of actions Act_N is as follows

$$Act_N = \{registrationReq\ [t_1^N]\ , identityRes\ [t_2^N]\ , authenticationRes\ [t_3^N]\ , userData\ [t_4^N]\ , policyData\ [t_5^N]\ , deregistrationReq\ [t_6^N]\}$$

The transitions i.e. $\rightarrow_N$, are

$$\rightarrow_N = \{(s_1^N, t_1^N, s_2^N), (s_2^N, t_2^N, s_3^N), (s_3^N, t_3^N, s_4^N), (s_4^N, t_4^N, s_5^N), (s_5^N, t_5^N, s_6^N), (s_6^N, t_1^N, s_5^N), (s_6^N, t_6^N, s_1^N)\}$$

and the set initial states for T_N is

$$s_0^N = \{s_1^N\}$$

The synchronized behavior of both models is formally proved by using the concept of weak bisimilarity. Intuitively, in terms of observed behavior, two LTSs are equivalent, i.e. they are bisimilar, if one LTS displays a final result and the other LTS displays the same result [17]. In practice, strong bisimilarity puts strong conditions for equivalence which are not always necessary. In weak bisimilarity, internal transitions can be ignored.

Proposition 4.1. The labeled transition systems T_{App} and T_N are weakly bisimilar, i.e.

$$T_{App} \underline{\leftrightarrow} T_N$$

Proof. As to definition of weak bisimulation, it is necessary to identify a relation between the states of both LTSs, such as for any transition from a state in one LTS there are respective transitions from states in the other LTS.

By U_{AppN} it is denoted a relation between the states of T_{App} and T_N, where

$$U_{AppN} = \{(s_1^A, s_1^N), (s_2^A, s_6^N)\}$$

Then the following transitions for the states in U_{AppN} are identified:

1. The UE starts an initial registration procedure, and the mobile edge application is asked for access and mobility policy data. For

$$\left(s_1^N, t_1^N, s_2^N\right), \left(s_2^N, t_2^N, s_3^N\right), \left(s_3^N, t_3^N, s_4^N\right), \left(s_4^N, t_4^N, s_5^N\right), \left(s_5^N, t_5^N, s_6^N\right) \exists \left(s_1^A, t_1^A, s_2^A\right)$$

2. The UE initiates registration update procedure, and the mobile edge application is asked for access and mobility policy data. For

$$\left(s_6^N, t_1^N, s_5^N\right), \left(s_5^N, t_5^N, s_6^N\right) \exists \left(s_2^A, t_2^A, s_2^A\right)$$

3. The UE, or the network, initiates deregistration procedure and the policy association is terminated. For

$$\left(s_6^N, t_6^N, s_1^N\right) \exists \left(s_2^A, t_3^A, s_1^A\right)$$

Therefore the labeled transition systems T_{App} and T_N are weakly bisimilar, i.e. they expose equivalent behavior. □

5 Conclusion

The 5G architecture is defined as service-based, where the core network functions are defined as a set of related services which are accessible by application programming interfaces. Network Function Virtualization and Multi-access Edge Computing are recognized as key 5G technologies.

In this paper we propose a new mobile edge service, which exposes core network functionality for access and mobility policy control at the network edge. Using the service interfaces an intended mobile edge application may provide access and mobility policies based on radio network load level, accumulated usage of network resources, etc., and thus it may dynamically control procedures related to registration and mobility management.

The proposed mobile edge service is described by typical use case, which illustrates the service functionality, by data model, which enables applications to access and store data uniquely, and by interface definition. Some implementation issues are considered related to modeling the behavior of the network during registration procedures and the mobile application view on UE registration status, which have to be synchronized.

Distribution of core functions at the edge of the network and exposing them for third party applications enables more flexible control, as not only the network operator and the subscriber may provide access and mobility restrictions, but also intended applications. The vicinity to the end user enables more dynamic reaction to changing radio conditions.

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