Deployment of Mobile Edge Location Service

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Abstract – **Multi-access Edge Computing (MEC) provides virtualized "cloud native" functionality into the radio access network. In this paper, we study the deployment of location service in MEC environment. The location service procedures are mapped onto positioning protocol functionality. Location service models are proposed, formally described and verified.**

Keywords – **Multi-access Edge Computing, Application Programming Interfaces, Finite state machines.**

I. Introduction

Multi-access Edge Computing (MEC) provides cloud and IT capabilities in a close vicinity to end users at the edge of the network. It offers customized mobile broadband experience by providing contextual and location information. MEC addresses challenges such as high latency, security vulnerability, low coverage, and lagged data transmission [1]. A number of security, safety and data analytics mobile edge applications may be deployed based on location information [2]. Location-based services are a promising way of exploiting the special possibilities created by ubiquitous mobile devices and wireless communication. Advanced location-based applications will require highly accurate information about the geographic location of mobile objects and functionality that goes beyond simply querying the user's position, for example determining all mobile objects inside a certain geographic area. Different aspects of location-based services related to positioning algorithms are studied in [3], [4]. Location-based services are beneficial for retailers, healthcare providers, airports, government organizations and many other enterprises around the world for multimedia broadcasting [5].

MEC is a novel paradigm and it is currently under standardization. In [6], the authors study how the capabilities of well established Parlay X Terminal Location Web Service may be used to provide location service in MEC environment. In this paper, we explore the way Mobile Edge Location Application Programming Interfaces (API) defined by ETSI may be implemented in the radio access network.

In the next sections, we describe the architecture for Mobile Edge Location Service, provide functional mapping of service API onto positioning protocol and model the location service state as seen by mobile edge application and by the network.

II. Architecture of Mobile Edge Location Service

The Mobile Edge Location service provides authorized applications with location-related information [7]. It exposes information to applications, such as:

- the location of specific UEs currently served by the radio node(s) associated with the mobile edge host;
- information about the location of all UEs currently served by the radio node(s) associated with the mobile edge host;
- optionally, information about the location of a certain category of UEs currently served by the radio node(s) associated with the mobile edge host;
- a list of UEs in a particular location;
- information about the location of all radio nodes currently associated with the mobile edge host;
- location in form of geolocation, Cell ID, etc.

The architecture for deployment of MEC Location service is shown in Fig.1. MEC platform exposes essential functionality required to run MEC applications on a particular virtualization infrastructure enabling them to provide and consume mobile edge services. The MEC platform is in the close vicinity of the eNodeB. The MEC platform may be integrated with Location server in order to provide Location service. The protocol between the target User equipment (UE) and the Location server is LTE Positioning Protocol (LPP) [8]. LPP is used to position the target UE using positioning-related measurements obtained by one or more reference sources or to transfer assistance data.

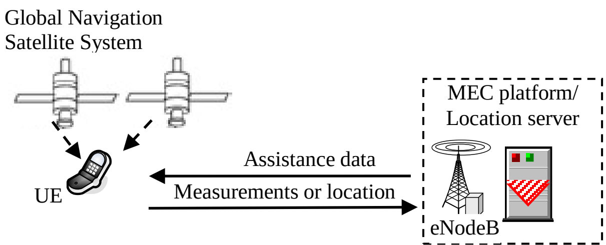

Fig.1 Architecture for Mobile Edge Location Service

The LPP procedures include the following:

- Transfer of positioning and protocol capabilities related to LPP and the positioning methods supported by LPP;
- Transfer of assistance data related to positioning;
- Transfer of location information where location information applies both to an actual position estimate and to values used in computing position (e.g., radio measurements or positioning measurements);
- Abort procedure used by one endpoint to notify the other endpoint to abort an ongoing procedure between the two endpoints.

III. Functional Mapping of Location Service API onto LLP

The UE Location Lookup is the procedure for applications acquiring the current location information of a specific UE or a group of UEs. In this procedure, the Location Service will

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report the lookup result once on each request. The Mobile edge application looks up an UE location by sending a request to the resource representing the UE location, which includes the UE(s) identifier, e.g. UE IP address. The MEC platform needs to determine which of the positioning methods has to be used in order to provide the requested accuracy. To do this, it starts an LPP dialogue with the target, as shown in Fig.2.

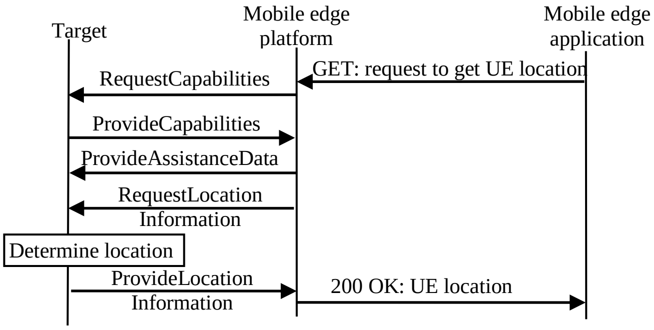

Fig.2 Flow of UE location lookup

The UE Information Lookup is the procedure for applications acquiring information of a list of UEs in a particular location. In this procedure, the Location Service reports the lookup result once on each request. First, the mobile edge application looks up UE information in a particular area by sending a request to the resource representing the UE Information, which includes location area information. The mobile edge platform identifies the base stations serving the cells in the location area. Next, each of the base stations identifies UE for which there is an established UE context. UE context is a block of information in a base station associated to an active UE. The block of information contains the necessary information required to maintain the radio access network services towards the active UE. At least UE state information, security information, UE capability information and the identities of the UE-associated logical S1-connection are included in the UE context. Having information about UE served by the base stations associated with the requested location area, the mobile edge platform queries the UEs about their capabilities and requests location information. The mobile edge platform may transfer additional assistance data to the target in one or more additional LPP messages. When the mobile edge platform receives information about UE(s) location it determines whether the respective UE is in the requested location area, and if so the UE is included in the UE list returned as a response to the mobile edge application. The flow for UE information lookup is shown in Fig.3.

The UE Location Subscribe is the procedure for applications acquiring up-to-date location information of a specific UE or a group of UEs in a period, which help the applications to track the UE(s). In this procedure, the Location Service will continue to report the subscribed information until the subscription is cancelled. Fig.4 illustrates a subscription to periodic UE location information reporting and periodic notifications.

The UE Information Subscribe is the procedure for applications to receive notifications of UE Information updates for the list of UEs in a particular location. The UE information can be used to update the status changes or periodic notifications of UE information. This procedure initiates similar action in the network as for UE Location Subscribe procedure.

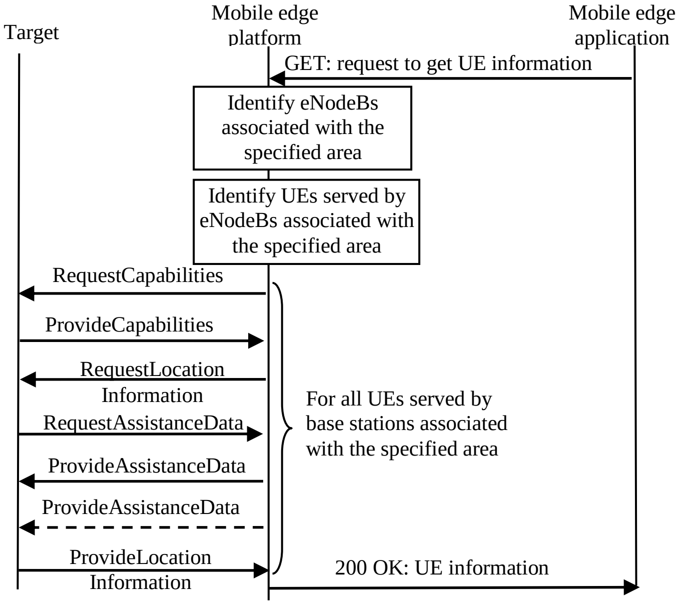

Fig.3 Flow for UE information lookup

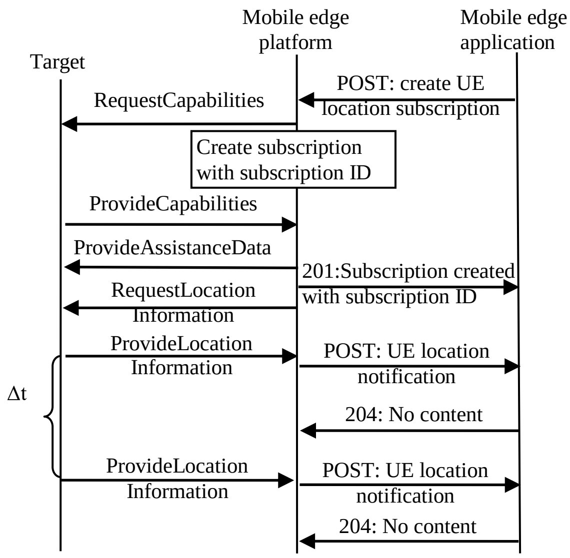

Fig.4 Flow of UE location information subscribe

The mobile edge application may at any time modify the subscription (e.g. the reporting period, or specified area) or to terminate the subscription. In order to modify existing subscription, mobile edge application updates the subscription resource by sending a PUT request to the resource containing all the subscriptions of the specific subscription type with the modified data structure specific to that subscription. Location service returns "200 OK" with the message body containing the accepted data structure specific to that subscription.

The Subscribe Cancellation is the procedure for applications to cancel the subscription, with which the Location Service must stop reporting the subscribed information to the application. Fig.5 shows the flow for subscription termination.

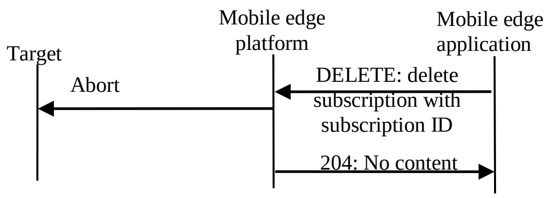

Fig.5 Flow of Location Subscribe Cancellation

IV. Location Service Models

The application and network views on location service status need to be synchronized during the process of UE(s) positioning. In this section, we propose models representing location service status as seen by a mobile edge application and the network view, and provide a method for its formal verification.

The application view on the location state is shown in Fig.6.

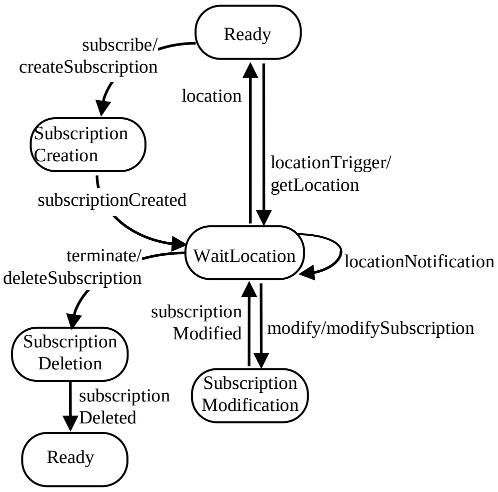

Fig. 6 Application view on the location service state

In Ready state, there is no particular event triggering location request or the location request has already been completed. In Ready state, when the application logic requests location information, it sends a query (getLocation) to the network. In Ready state, the mobile edge application may subscribe for location information notifications. Being in SubscriptionCreation state, the application waits for subscription acknowledgement. In WaitLocation state, the application waits for location information requests on demand or in the subscription frame. In WaitLocation state, when location information requested on demand is received, the location service moves to Ready state. In WaitLocation state, when location information notification is received, the location service remains in the same state. In WaitLocation state, the subscription for location information may be modified or terminated. In SubscriptionModification state, the application waits for subscription modification acknowledgement. In SubscriptionDeletion state, the application waits for subscription termination acknowledgement.

We use the mathematical formalism of Labeled Transition Systems (LTSs) to describe the location service state models. An LTS is defined as a quadruple of set of states, set of inputs, set of transitions, and an initial state.

By $L_{App} = (S_{App}, Inp_{App}, \rightarrow_{App}, s_0^{App})$ it is denoted a Labeled Transition System (LTS) representing the Application's view on location service state where:

S_{App} = { Ready [s_1^A], SubscriptionCreation [s_2^A], WaitLocation [s_3^A], SubscriptionModification [s_4^A], SubscriptionDeletion [s_5^A]};

Inp_{App} = {locationTrigger[t_1^A], subscribe[t_2^A], subscriptionCreated[t_3^A], location [t_4^A], locationNotification [t_5^A], modify [t_6^A], subscriptionModified[t_7^A], delete[t_8^A], subscriptionDeleted[t_9^A]};

$\rightarrow_{App} = \{ (s_1^A\ t_1^A\ s_3^A), (s_1^A\ t_2^A\ s_2^A), (s_2^A\ t_3^A\ s_3^A), (s_3^A\ t_5^A\ s_1^A), (s_3^A\ t_6^A\ s_4^A), (s_4^A\ t_7^A\ s_3^A), (s_3^A\ t_8^A\ s_5^A), (s_5^A\ t_9^A\ s_1^A)\}$.

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

Short notations are given in brackets.

Fig.7 shows the network view on the location service state.

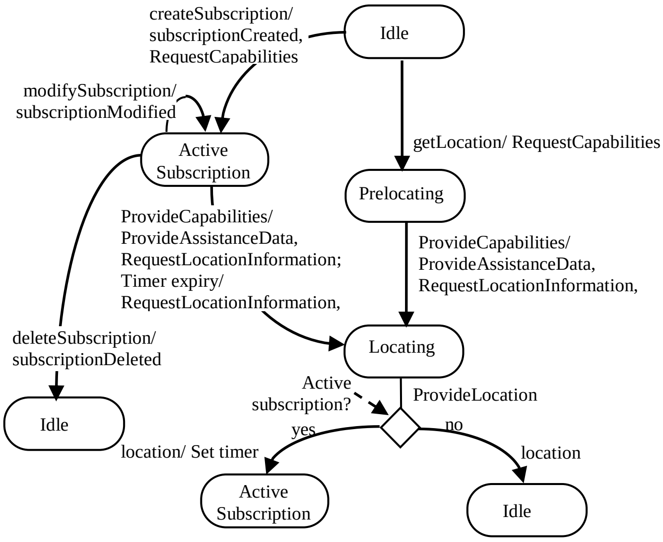

Fig. 7 Network view on the location service state

In Idle state, there is no location request or the location request is completed. Being in this state, the location service moves to ActiveSubscription state, if a request for subscription to location information is received. The location service moves to PreLocating state when a request for location information is received. In Prelocating state, positioning capabilities and assistance data are transferred. The location service queries the UE(s) about device capabilities and provides assistance data. In Locating state, the target UE(s) is being located. The transition from Locating to Idle state occurs when location information is provided. In case of active subscription, the timer for periodic location notifications is set and the location services moves to ActiveSubscription state. In ActiveSubscription state, the subscription may be modified or terminated.

By $L_{MEC} = (S_{MEC}, Inp_{MEC}, \rightarrow_{MEC}, s_0^{MEC})$ it is denoted an LTS representing the network view on location service state where:

S_{MEC}={ Idle[s_1^M], ActiveSubscription[s_2^M], Prelocating[s_3^M], Locating[s_4^M], };

Inp_{MEC} = { createSubscription[t_1^M], getLocation[t_2^M], ProvideCapabilities[t_3^M], TimerExpiry [t_4^M], ProvideLocation[t_5^M], modifySubscription[t_6^M], deleteSubscription[t_7^M]};

$\rightarrow_{MEC}$ = { (s_1^M t_1^M s_2^M), (s_1^M t_2^M s_3^M), (s_2^M t_3^M s_4^M), (s_3^M t_3^M s_4^M), (s_2^M t_4^M s_4^M), (s_4^M t_5^M s_1^M), (s_4^M t_5^M s_2^M), (s_2^M t_6^M s_2^M), (s_2^M t_7^M s_1^M)}

s_0^{MEC}={ s_1^M }.

Having formal description of the models representing the location service status as seen by mobile edge application and network, we can prove that these models are synchronized i.e. they expose equivalent behavior.

Intuitively, in terms of observed behavior, two LTSs are equivalent if one LTS displays a final result and the other LTS displays the same result. The idea of equivalence is formalized by the concept of bisimilarity [9]. In practice, strong bisimilarity puts strong conditions for equivalence which are not always necessary. Weak bisimilarity allows internal transitions to be ignored.

Proposition: The labeled transition systems L_{App} and L_{MEC} are weakly bisimilar.

Proof: As to definition of weak bisimulation, it is necessary to identify a bisimilar relation between the states of both LTSs and to identify respective matching between transitions. Let U_{AppMEC} be a relation between the states of L_{App} and L_{MEC} and U_{AppMEC}= {(s_1^A, s_1^M), (s_3^A, s_4^M)}. Then for the following events the respective transitions are identified:

1. The application requests for location information: for (s_1^A t_1^A s_3^A) $\exists$ (s_1^M t_2^M s_3^M) $\sqcap$ (s_3^M t_3^M s_4^M).
2. The application creates subscription for location information: for (s_1^A t_2^A s_2^A) $\sqcap$ (s_2^A t_3^A s_3^A) $\exists$ (s_1^M t_1^M s_2^M) $\sqcap$ (s_2^M t_3^M s_4^M).
3. The location information requested on demand is provided: for (s_3^A t_4^A s_1^A) $\exists$ (s_4^M t_5^M s_1^M).
4. The application is notified about location information: for (s_3^A t_5^A s_3^A) $\exists$ (s_4^M t_5^M s_2^M) $\sqcap$ (s_2^M t_4^M s_4^M).
5. The application modifies the subscription for location information: for (s_3^A t_5^A s_3^A) $\sqcap$ (s_3^A t_6^A s_4^A) $\sqcap$ (s_4^A t_7^A s_3^A) $\exists$ (s_4^M t_5^M s_2^M) $\sqcap$ (s_2^M t_6^M s_2^M) $\sqcap$ (s_2^M t_4^M s_4^M).
6. The application terminates the subscription for location information: for (s_3^A t_8^A s_5^A) $\sqcap$ (s_5^A t_9^A s_1^A) $\exists$ (s_4^M t_5^M s_2^M) $\sqcap$ (s_2^M t_7^M s_1^M).

Therefore L_{App} and L_{MEC} are weakly bisimilar.■

V. CONCLUSION

Location service retrieves real-time geographical data for mobile devices or smartphones to provide information, entertainment or security. Some applications allow consumers to "check in" at restaurants, coffee shops, stores, concerts, and other places or events. Deployment of location service in MEC environment enables customized applications for safety, security and big data analytics. In this paper, we study the way Mobile Edge Location Service may be implemented in the radio access network. We examine the mapping of Location API onto LPP procedures, propose models representing the application and MEC platform views on the location service state and a formal method for their verification.

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