Programmability of Multi-Connectivity in 5G

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Abstract—**Multi-connectivity is an important feature of fifth generation (5G) mobile networks as it addresses the requirements for high data rates and reliability. It enables user connectivity to several radio nodes simultaneously and tight integration between different radio access technologies. The research novelty is in opening the control on multi-connectivity functionality for mobile edge applications which enables programmability. Programmability allows applications deployed at the network edge to control user connectivity based on up-to-date radio network information e.g. congestion level, user location and requested data speeds. A new MEC service is proposed which is described by resources and operations, and data structures to be used in resource representations. The approach practicability is illustrated by modeling the multi-connectivity state as seen by the network and by MEC application. Service performance parameters are discussed in terms of latency.**

I. Introduction

Next generation mobile networks must evolve continuously in order to face the constantly increasing demands for high data speeds, ultrareliable connections, real-time operation and service continuity. Multi-connectivity, which enables a user to connect to the network using multiple radio access technologies simultaneously, appears to play a key role in ultra-dense networks. It can be exploited to improve end user experience by increasing the data rates and reducing the latency. In heterogeneous networks, multi-connectivity based on LTE, New Radio and wireless technologies such as Wi Fi can increase the reliability and throughput for end users.

Multi-connectivity is a standardized technique by 3GPP for 5G and beyond networks [1]. Multi-connectivity concept in 5G enhances the dual connectivity approach in 4G [2]. When the use case needs service continuity or high bandwidth, then the user has to be equipped with multiple connections e.g. LTE, 5G, and Wi-Fi data aggregation from different subscriptions in order to produce the high bandwidth. So, multi-connectivity may be regarded as the capability for resource utilization provided by different access technologies and configured at the user equipment

The benefits of multi-connectivity in terms of throughput increase and reliability improvement, as well as issues like energy efficiency and energy consumption are studied in [3], [4], [5], [6], [7]. In this paper, we propose an approach to open access to multi-connectivity functionality.

The open access enables external applications deployed in the vicinity to end users to control and manage the multi-connectivity. An authorized application based on specific policies may aggregate radio resources of separate access points to serve single User equipment (UE) which supports different radio access technologies. The application may change the configuration of aggregated radio resources to enable ubiquitous mobility, ultrahigh reliability and low latency. Examples of applications deployed at the network edge which can benefit from multi-connectivity include enhanced mobile broadband use cases with requirements of high-speed internet and real-time responsiveness like virtual reality and augmented reality. Mission critical applications where a highly reliable wireless service is essential in many use cases from autonomous vehicles to automated smart grid energy systems, to medical services that use robotics to operate, drone control and coordination are other examples.

The open access to radio access network functionality may be provided using Multi-access Edge Computing (MEC) technology. MEC distributes cloud intelligence at the mobile network edge, where it is needed [8], [9]. The more efficient operations of broadband-based applications, especially mobile, are achievable using MEC. This processing localization is beneficial for applications e.g. gaming with cloud components, because of closer content delivery and localized caches instead of packets crossing over the core network and gated further to another one. The overall effect is about mitigating challenges like latency reduction, throughput improvement, and carrier resources optimization when supporting big data volume applications. The real-time consumers, enterprises, and industry are the typical use cases of MEC when it comes to support applications that are sensitive with respect to latency. It is expected many applications and services such as extended reality, unmanned aerial vehicle control, autonomous cars, real-time remote control, tactile communications, and more to benefit from combination of MEC and 5G due to significant reduction in latency [10], [11], [12].

MEC facilitate also low-power devices with very limited computational capabilities, enabling traffic offloading. In contrast to centralized cloud computing, MEC enables more direct data routing which significantly reduces latency. It facilitates optimization of 5G network resources by distributing storage and computational capacity where it is needed the most.

European Telecommunications Standard Institute (ETSI) standardized MEC services which provide information about current radio network conditions and UE location, enable bandwidth management and user traffic handling. The ETSI standards are open for new services. In [13] and [14], the capabilities usage monitoring control and application control on device-to-device communications at the network edge are studied.

In this paper, we examine the capabilities for exposure of multi-connectivity functions using MEC technologies. With existing solutions, the network can configure the UE to perform measurements and based on reported measurements, it is the network that manages the multiple UE connections, e.g. secondary radio node addition/modification /release in order to utilize resources provided different radio nodes [2], [15], [16], [17]. The open access to multi-connectivity functionality enables programmability and allows third party applications to trigger the secondary node addition, modification and release based on specific application policies considering current radio conditions or UE location, or based on necessity to improve reliability. The research novelty is in delegating the multi-connectivity control to mobile edge applications, i.e. a mobile edge application may trigger the procedure of aggregating signals of different radio technologies at UE, not the network.

The following sections present the proposed MEC service functionality, including resource structure and data types as well as definitions of service interfaces. Service feasibility is illustrated by modeling the UE connectivity state from the viewpoints of the network and MEC application which must expose equivalent behavior. Discussions on latency injected by the proposed service are provided.

II. Detailed Service Description

A. Service Deployment Scenarios

The most appropriate place to put the MEC platform which provides mobile edge services for MEC applications in order to receive up-to-date radio network information is in Radio Access Network. Such deployment scenario called “Bump in the wire” assumes co-location of MEC and Cloud Radio Access Network (CRAN) where MEC and CRAN share the same virtual infrastructure or MEC deployment at aggregation point in proximity of different radio nodes [18]. The first option is suitable for new Radio – New Radio Dual Connectivity, while the second option is applicable for Multi-Radio Dual Connectivity. Fig.1 illustrates both deployment scenarios.

In addition to standardized MEC services provided by the MEC platform, we propose a new mobile edge service which enables third party applications to force multi-connectivity for end. The proposed MEC service, named Multi-connectivity Control Service (MCCS), enables MEC applications to initiate adding/modifying/release of secondary node, to initiate changing of secondary node, to initiate inter-master node handover with or without secondary node change, master mode change and to receive notifications about multi-connectivity events occurred in the network. The application can control the multi-connectivity state of users served by radio nodes which are associated with the MEC server.

Typical use cases where a MEC application may initiate multi-connectivity for end users include mission critical communications. When the human life is in danger, enhanced broadband and reliable communications are crucial. For example, in case of critical situation, a user with a terminal supporting multiple radio access technologies places a video call to first responders. Due to the dense environment the quality of service is bad. A dedicated MEC application may enforce multi-connectivity for the user in danger to provide reliable public safety video service. To do this MEC application may use the MCCS interfaces, provided by the MEC platform. Remote database access, live video, geo-location services are other examples for third party triggered multi-connectivity.

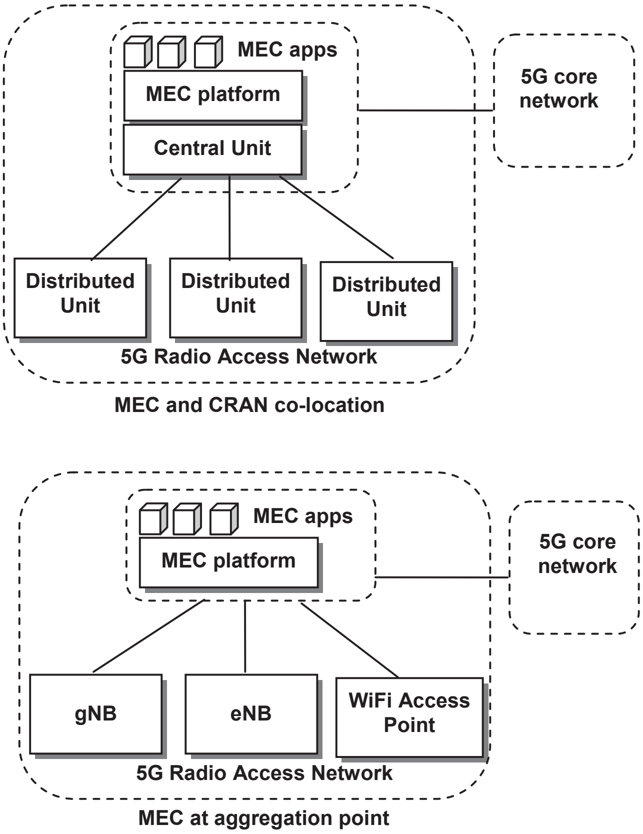

Fig.1 MEC deployment options in case of “Bump in the wire” approach

The service design follows the REST (Representational State Transfer) architectural style adopted by ETSI. In REST, an abstraction of information is represented as a uniquely identified resource with associated data and methods that operate on it.

The MCCS needs subscription to receive notifications about UE activity and mobility in order to make decisions for initiation of multi-connectivity procedures in the network based on actual information. Triggers for initiation of multi-connectivity procedures may be based upon the following events:

- Notifications from MEC Radio Network Information Service about radio resource management, e.g. initial establishment of radio resources.
- Notifications from MEC Radio Network Information Service about cell changes, e.g. in case of successful handover.
- Notifications from MEC Location Service about UE location, e.g. the UE enters specific geographic area.

- Notifications from MEC Bandwidth Management Service about reservation of resources with specific Quality of Services, e.g. the UE activates a broadband application.

The radio node which serves the UE and provides the control plane connection to the core network is master node. Secondary node does not have a control plane connection to the core network but provides additional resources to UE. A UE may have associated one master node and zero or more secondary nodes.

As a precondition for application initiated multi-connectivity control, the application needs to know which Radio Access Technologies (RATs) are supported by the UE. The UEs served by the radio nodes associated with the MEC server and the UE supported capabilities are presented as resources. The part of service resource structure related to UE capabilities is shown in Fig.2, where {**apiRoot}/mccs/v1}** is the root followed by URIs of service resources which can be discovered in service registry. The **UEs** resource represents all UEs served by radio nodes associated to the MEC server, and the **UE** resource represents a particular UE. The **capabilities** resource contains information about the capabilities supported by the UE including supported RATs.

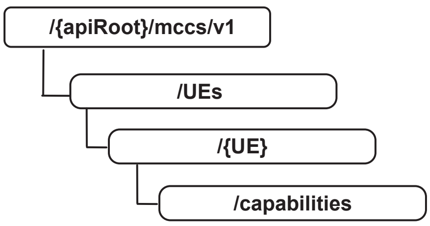

Fig.2 Structure of MCCS resources related to capabilities of UEs served by radio nodes associated to the MEC server

As the MEC application is allowed only to read information about UEs, service resources support only HTTP GET method.

Fig.3 shows the message flow when the MEC application sends a request to receive information about UE supported RATs. The requested information in the response is provided in the message body. The **ueCapInfo** data type represents information on UE capabilities and it lists RATs technologies supported by UE. It is a structure of **supportedRAT** which identifies the RAT supported by UE and describes respective frequency bands (**rfBands**).

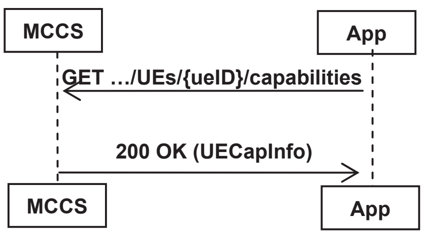

Fig.3 Message flow of application requesting UE capability information

B. Requesting Multi-Connectivity Action

The requests of MEC applications for multi-connectivity actions are represented as resources. Fig.4 shows the structure of resources related to application initiated multi-connectivity actions.

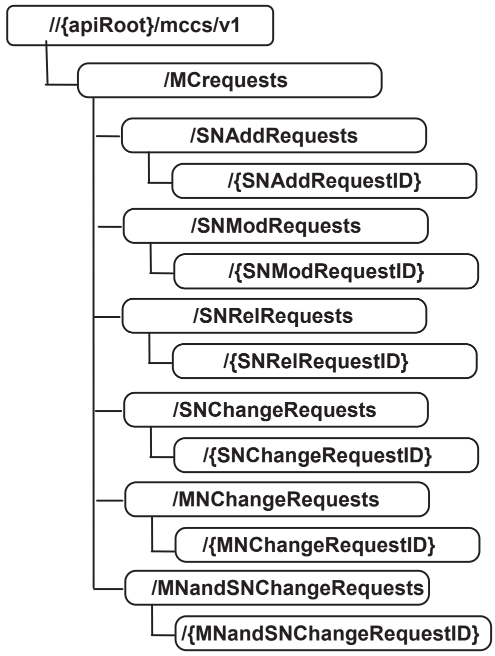

Fig.4 Structure of resources related to application initiated multi-connectivity actions

The **MCrequests** resource is a container for all resources representing multi-connectivity actions triggered by MEC application. The **SNAddRequests** resource represents all requests sent by authorized MEC applications for adding a secondary node and **SNAddRequestID** resource represents an existing request for secondary node addition. Fig.5 shows the message flow for MEC application initiated adding of secondary radio node. When the application decides to request addition of secondary node it sends a HTTP POST request to the **SNAddRequests** resource. The request body contains information about the UE and the target secondary node including information about resources to be allocated. The request triggers Secondary Node Addition procedure in the network as described in [1]. The response from the service contains the body with data structures specific to that addition described in JSON format. The **SNInfo** data type represents information about secondary node. It is a structure of timestamp, **appInsId** - unique identifier for the MEC application, **cellID** – cell global identity which for 3GPP networks contains Mobility Country Code, Mobile network Code and Cell Identifier, **ueID** – information on UE.

The information on UE is a structure of **bearInfo** containing information about unique identifier if the bearer (**bearerId**), QoS parameters of the bear (**bearerQoSParameters**) including QoS class identifier (**qos**), maximum downlink and uplink bit rates (**bearerMDL** and **bearerMUL**), and guaranteed downlink and uplink bit rates (**bearerGDL** and **bearerGUL**).

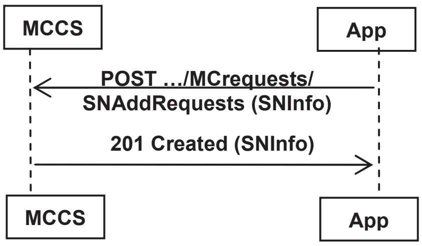

Fig.5 Message flow of application requesting secondary node addition

An example of application request for adding a secondary node looks like:

```
POST…/exampleAPI/mccs/v1/MCrequests/SNAddRequests
HTTP/1.1
Host:example.com
Accept:application/json
Content-type:application/json
Content-length:331

{ "timestamp":"2019-08-23T12:15:03.521Z",
 "appInsID":"D014F8",
  "cellID":{
  "mcc":"333",
  "mnc":"5",
 "cellid":"C65F",
 },
 "ueID":"BB2231",
 "bearerInfo":{
 "bearerID":"1F7A",
 "bearerQoSParameters":{
  "qos":10,
  "bearerMDL":"100Mbps",
  "bearerMUL":"50Mbps",
  "bearerGDL":"80Mbps",
  "bearerGUL":"50Mbps",
   }
 }
}
```

The application can retrieve information about existing request for secondary node addition by sending a HTTP GET request to the **SNAddRequestID** resource as shown in Fig.6. The response contains information about the previously added secondary node.

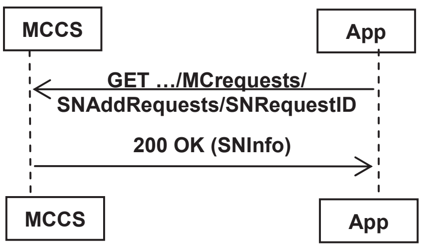

Fig.6 Message flow of application requesting information about added secondary node

To delete information about secondary node added by it, the application sends a HTTP DELETE request to the respective **SNAddRequestID** resource as shown in Fig.7.

The rest of resources shown in Fig.4 are as follow:

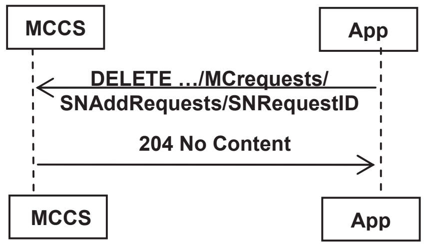

Fig.7 Message flow of application request for deleting information about added by itself secondary node

- The **SNModRequests** resource represents all requests for modifying a secondary node and the **SNModRequestID** resource represents an existing request. An application requests a secondary node modification when it wants to modify established radio resources. This requests triggers Secondary Node Modification procedure in the network as described in [1];
- The **SNRelRequests** resource represents all requests for secondary node release and the **SNRelRequestID** resource represents an existing request. An application-initiated request for secondary node release triggers Secondary Node Release procedure in the network as described in [1];
- The **SNChangeRequests** resource represents all requests for change of secondary node and the **SNChange-RequestID** resource represents an existing request. When an application sends a request for secondary node change a Secondary Node Modification procedure is initiated in the network as described in [1];
- The **MNChangeRequests** resource represents all requests for change of master node and the **MNChangeRequestID** resource represents an existing request. These resources represent master node changes without secondary node changes. The change of master node is results in execution of Inter-Master Node handover procedure in the network as described in [1];
- The **MNandSNChangeRequests** resource represents all requests for change of master node with change of secondary node and **MNandSNChangeRequestID** resource represents an existing request. A request for change of master node with change of secondary node triggers Inter-Master Node handover procedure the network as described in [1].

The container resources **SNModRequests, SNRelRequests, SNChangeRequests, MNChangeRequests, MNandSNChange-Requests**, support HTTP method GET which retrieves information about all contained resources respectively, and HTTP method POST which creates a new resource of the respective container type.

C. Subscriptions and Notifications about Multi-connectivity Events

To be aware about any multi-connectivity related events occurred in the network, the MEC application needs to have subscription for notifications. Fig.8 illustrates the part of service resource structure related to subscriptions about multi-connectivity events.

The resources shown in Fig.8 represent containers for subscriptions or existing subscriptions for notifications about occurrence of different types of multi-connectivity events related to secondary node modification/release/change and master node change without/with secondary node change respectively. The container resources shown in Fig.8 support the HTTP method GET which retrieves information about all subscriptions of the respective subscription type and the HTTP method POST which creates a new subscription of the respective subscription type.

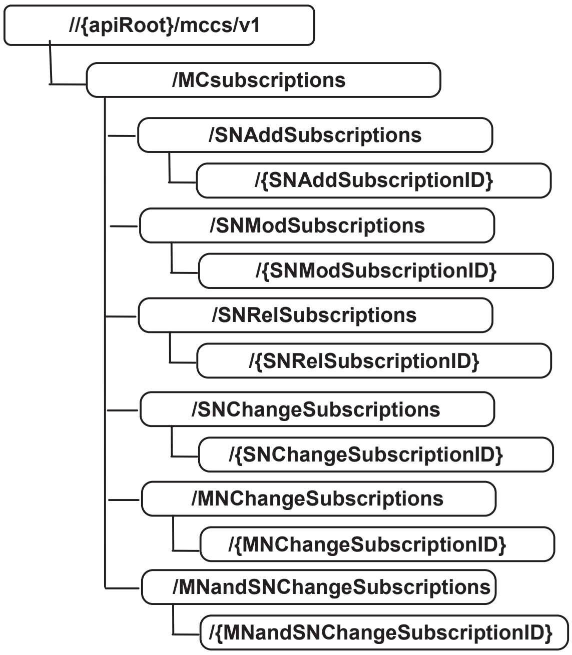

Fig.8 Structure of resources related to subscriptions for notifications about multi-connectivity events

Fig.9 illustrates the message flow for MEC application subscription for notifications about additions of secondary node. The request body contains filter criteria and the address where the application wishes to receive notifications about additions of secondary node. The service responds with "201 Created" with message body containing data structure with the address of the created resource and the subscribed multi-connectivity event type.

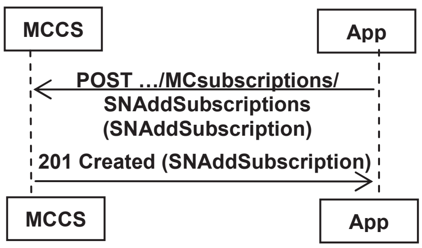

Fig.9 Message flow of subscribing for notifications about secondary node addition

The **SNAddSubscription, SNModSubscription, SNDelSubscription, SNChangeSubscription, MNChangeSubscription,** and **MNandSNChangeSubscription** data types are subscription structures. The main attributes of these data type include **appAddress** - URI selected by application to receive notification, **expiryDeadline, filterCreteria** – list of criteria for subscription including **ueID** – information on UE, **masterNode** – information on master node (**mcc, mnc** and **cellId**) and **secondaryNode** – information on secondary nodes associated with the UE.

The response of the subscription request sent by the service may include an expiry time for multi-connectivity event subscription. In this case, the service may send a notification (HTTP POST request) to the address provided by the application prior the subscription expiry. It is responsibility of the application to update the subscription.

The MEC application may modify or terminate an existing subscription for notifications about multi-connectivity events by sending HTTP PUT request or HTTP DELETE request to the leaf-resource representing the subscription for the respective multi-connectivity events. Fig.10 shows the message flows for modification of existing subscription for notifications about secondary node addition respectively.

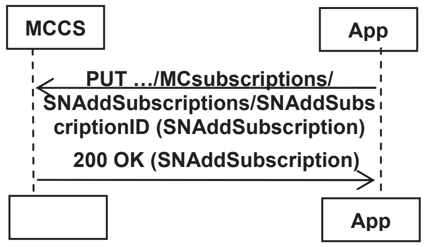

Fig.10 Message flow of updating subscription for notifications about secondary node addition

Upon occurrence of multi-connectivity event of interest, the application with active subscription is notified, as shown in Fig.11. In Fig. 11, the MCCS sends a POST request to the address provided by the application with message body containing the **SNAddNotification** data structure. The **SNAddNotification, SNModNotification, SNDelNotification, SNChangeNotification, MNChangeNotification,** and **MNand-SNChangeNotification** data types are notification structures. They represent a notification from MCCS with regards of multi-connectivity procedure occurred in the network. The attributes of these data type include information on timestamp, information on UE, master node information and secondary node information including associated bearers.

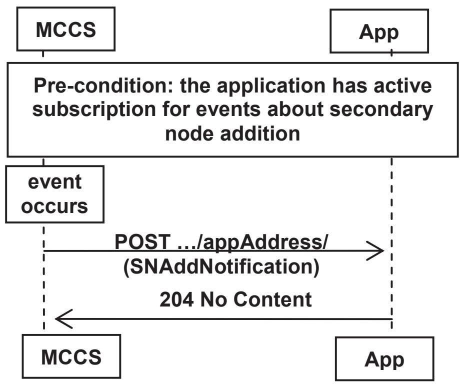

Fig.11 Message flow of notifications about secondary node addition

III. Service State Models

The feasibility of the proposed approach is demonstrated by modeling the multi-connectivity state from MEC application and network point of view. Models have to expose equivalent behavior, i.e. the transitions to single- or multi-connectivity states have to be synchronized as to the application logic and in the network.

For the sake of simplicity, the models do not include application requests for secondary node change, inter-master node handover, and notifications about multi-connectivity events occurred in the network.

The simplified model representing the application view on UE multi-connectivity state is shown in Fig.12. In **MNconnected** state, the UE is connected only to the master node, while in **MNandSNconnected** state, the UE is connected also to one or more secondary nodes. The transient states **SNAddition, SNmodification**, and **SNRelease** represent states in which Secondary Node Addition, Secondary Node Modification and Secondary Node Release procedures take place in the network. The requests for multi-connectivity issued by MEC application trigger state transitions.

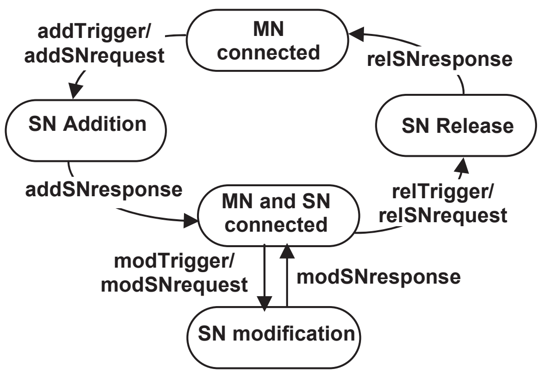

Fig.12 Multi-connectivity state model as seen by MEC application

The simplified multi-connectivity state model as seen by the master node is shown in Fig.13.

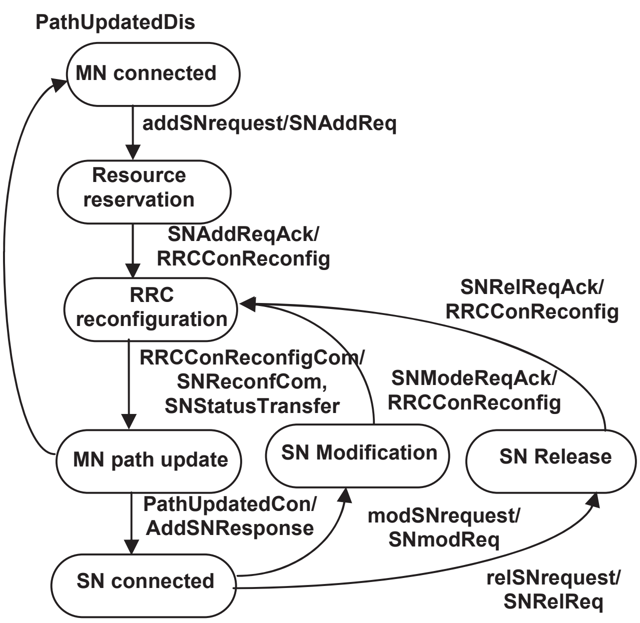

Fig.13 Multi-connectivity state model as seen by the master node

Network procedures related to adding/modifying/release of secondary node include resource reservation in the target node, RRC connection reconfiguration and path update including UE context transfer/release.

Each model is formally described as a quadruple of set of states, set of actions, set of transitions and set of initial states. The equivalence of the state models is proved mathematically by identification of bi-simulation relation between them.

The multi-connectivity state model supported by application control logic is formally described as $T^{app} = (S^{app}, Act^{app}, \rightarrow^{app}, s_0^{app})$, where

- S^{app} = {MNconnected [s_1^{app})], SNAddition [s_2^{app}], SNModification [s_3^{app}], SNRelease [s_4^{app}), MNandSN-connected [s_5^{app}]};
- Act^{app} = {addTrigger [t_1^{app}], modTrigger [t_2^{app}], relTrigger [t_3^{app}], addSNresponse [t_4^{app}], modSN-response [t_5^{app}], relSNresponse [t_6^{app}]};
- $\rightarrow^{app} = \{(s_1^{app}\ t_1^{app}\ s_2^{app}), (s_2^{app}\ t_4^{app}\ s_5^{app}), (s_5^{app}\ t_2^{app}\ s_3^{app}), (s_3^{app}\ t_5^{app}\ s_5^{app}), (s_5^{app}\ t_3^{app}\ s_4^{app}), (s_4^{app}\ t_6^{app}\ s_1^{app})\}$;
- $s_0^{app} = \{s_1^{app}\}$.

We use short designations for names of states and actions shown in brackets.

The multi-connectivity state model supported by the master node is formally described as $T^{mn} = (S^{mn}, Inp^{mn}, \rightarrow^{mn}, s_0^{mn})$, where

- S^{mn} = {MNConnected [s_1^{mn})], ResourceReservation [s_2^{mn}], RRCreconfiguration [s_3^{mn}], MNPathUpdate [s_4^{mn}), SNConnected [s_5^{mn}], SNModification [s_6^{mn}), SNRelease [s_7^{mn}]};
- Act^{mn} = {addSNrequest [t_1^{mn}], SNAddReqAck [t_2^{mn}], RRCConReconfigCom [t_3^{mn}], PathUpdatedCon [t_4^{mn}], changeSNrequest [t_5^{mn}], SNchangeReqAck [t_6^{mn}], relSNrequest [t_7^{mn}], SNRelReqAck [t_8^{mn}], PathUpdatedDis [t_9^{mn}]};
- $\rightarrow^{mn} = \{(s_1^{mn}\ t_1^{mn}\ s_2^{mn}), (s_2^{mn}\ t_2^{mn}\ s_3^{mn}), (s_3^{mn}\ t_3^{mn}\ s_4^{mn}), (s_4^{mn}\ t_4^{mn}\ s_5^{mn}), (s_5^{mn}\ t_5^{mn}\ s_6^{mn}), (s_6^{mn}\ t_6^{mn}\ s_3^{mn}), (s_5^{mn}\ t_7^{mn}\ s_7^{mn}), (s_7^{mn}\ t_8^{mn}\ s_3^{mn}), (s_4^{mn}\ t_9^{mn}\ s_1^{mn})\}$;
- $s_0^{mn} = \{s_1^{mn}\}$.

Proposition: The behavior of T^{app} simulates the behavior of T^{mn} and both state transition systems are in weak bisimulation relation.

Proof: Let $R \subseteq (S^{app} \times S^{mn})$ where $R = \{(s_1^{app}, s_1^{mn}), (s_5^{app}, s_5^{mn})\}$. Then the following mapping between moves of T^{app} and T^{mn} can be identified:

1. The MEC application requests secondary node addition: for $(s_1^{app}\ t_1^{app}\ s_2^{app}), (s_2^{app}\ t_4^{app}\ s_5^{app}) \exists (s_1^{mn}\ t_1^{mn}\ s_2^{mn}), (s_2^{mn}\ t_2^{mn}\ s_3^{mn}), (s_3^{mn}\ t_3^{mn}\ s_4^{mn}), (s_4^{mn}\ t_4^{mn}\ s_5^{mn})$.
2. The MEC application requests secondary node modification: for $(s_5^{app}\ t_2^{app}\ s_3^{app}), (s_3^{app}\ t_5^{app}\ s_5^{app}) \exists (s_5^{mn}\ t_5^{mn}\ s_6^{mn}), (s_6^{mn}\ t_6^{mn}\ s_3^{mn}), (s_3^{mn}\ t_3^{mn}\ s_4^{mn}), (s_4^{mn}\ t_4^{mn}\ s_5^{mn})$.
3. The MEC application requests secondary node release: for $(s_5^{app}\ t_3^{app}\ s_4^{app}), (s_4^{app}\ t_6^{app}\ s_1^{app}) \exists (s_5^{mn}\ t_7^{mn}\ s_7^{mn}), (s_7^{mn}\ t_8^{mn}\ s_3^{mn}), (s_3^{mn}\ t_3^{mn}\ s_4^{mn}), (s_4^{mn}\ t_9^{mn}\ s_1^{mn})$.

Therefore, the relation R is weakly bi-similar one, which means that the behavior of T^{app} simulates the behavior of T^{mn} i. e. both state transition systems are synchronized. ■

IV. Discussion on Service Performance

The proposed MCCS contributes to the overall latency, so it might be assessed by aggregating along the signaling path (α) the message transfer time and (β) processing time within each node. To assess theoretically the latency introduced by the proposed MCCS we consider Secondary Node Addition procedure in case of multi-radio dual connectivity with 5G core network [1]. Thus, it allows us to estimate theoretically the 'injected' latency for MEC application initiated Secondary Node Addition as follows:

$$L_{MECSNadd}=11\alpha+10\beta+2\,\beta_{MEC} \quad (1)$$

where the latency in the core network related to path update is not included.

The processing time at the gNB/UE is approximately 0.3ms while message transfer requires 0.1ms, as to [18]. So, the execution at MEC takes time as follows:

$$\beta_{MEC}=L.X/f \quad (2)$$

In (2) the input task size (the packet size) is regarded as information block of size in bits (L), the complexity of the input task is reflected as necessary CPU cycles per bit (X), and the MEC's server CPU frequency is marked as (f). Then, as to [19], the parameters used are: 4000 bits for information size (for the example POST request shown above); 1000 cycles per bit for complexity; and CPU frequency at 2.2 GHz.

So, we obtain the following,

$$L_{MECSNadd} = 1{,}1 \text{ ms} + 3 \text{ ms}+3{,}8 \text{ ms} =7{,}9 \text{ ms} \quad (3)$$

The provided MEC latency assessment in [20] shows data from an experiment where the fibber-wireless access is tested by the authors, using round trip time (RTT). The original experiment is ping-based, but in order to consider the MEC processing time, we add a summand. Further, trying to find the distributions, we use as underlying basis the empirical data. Using the well-known distributions like Weibull, LogNormal, Gamma, and Normal, for assessment of MEC initiated secondary node addition, we search for a fit of the cumulative distributed function (CDF), shown in solid-black in Fig.14.

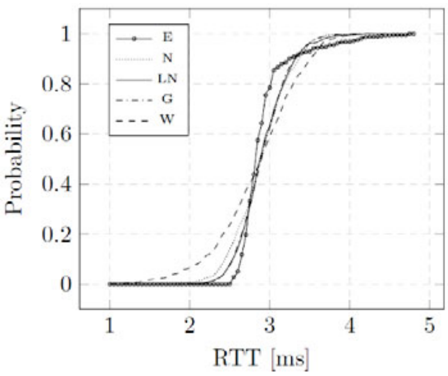

Fig. 14 Empirical and theoretical CDFs of RTT as key performance indicator for latency in secondary node addition triggered by MEC application

In Fig.14 the annotations are E for the RTT Empirical CDF, 'W' for Weibull, 'G' for Gamma, 'LN' for LogNormal, and 'N' for Normal, with parameters (k = 6.446237; λ = 3.073411), (α = 82.60575; β = 28.42070), (μ = 1.0608995; σ = 0.1059133), and (μ = 2.906545; σ = 0.347701) respectively.

The fitted distributions are compared to the empirical one as it is shown in Table 1, where the lower values mean lower 'mismatch' with respect to the original data. The statistics abbreviations, used in Table I, are 'AD' for Anderson-Darling, 'CvM' for Cramer-von Mises, and 'KS' for Kolmogorov-Smirnov.

TABLE I. Goodness-of-Fit Statistics

	KS	CvM	AD
LogNormal	0.1912351	8.9521432	50.2061145
Gamma	0.19621410	9.8154410	56.0099720
Normal	0.22110951	12.1045092	68.1143217
Weibull	0.24318756	19.5613571	103.3287692

The best in the group three of fits turns out to be the LogNormal distribution as she shows lower results at all types of statistics. The use of the resulting distribution might be in cases when it comes to model compactly the latency instead of using the huge amount of the original data e.g. in the service or application development process.

Such CDF might be helpful in development of applications/services when latency estimation is needed.

V. Conclusion

Multi-connectivity feature in 5G enables tight integration of multiple radio access technologies and thus contributes to latency reduction and data rate improvement simultaneously. It also improves reliability by providing multiple links between the source and the destination. The open access to multi-connectivity functionality in radio access network enables third party applications deployed at the network edge to control the configuration of radio resources. Customized application logic for triggering secondary node addition, modification release as well as inter-master node handover may be based on bandwidth requirements, user location, and current radio conditions e.g. the level of congestion in radio access network. Applications with ultra-high reliability requirements where safety, timeliness and dependability are vital attributes may benefit of the open access to multi-connectivity control in the vicinity of end users.

In this paper, we propose an approach to programmability of multi-connectivity control by using Multi-access Edge Computing. A new MEC service is designed which enables applications deployed the network edge to control multi-connectivity procedures for users with demands for high speeds and ultra-reliability. The service description is demonstrated by typical use cases. The service data model defines resources, data types and supported methods. The approach feasibility is illustrated by modeling the multi-connectivity state from application and network perspectives. The latency 'injected' by the proposed service is theoretically evaluated.

The paper contribution is in delegating the control on multi-connectivity to mobile edge applications which are aware about current radio conditions, user location or reliability requirements and may manage the multiple user connections in order to address the requirements for network performance optimization or higher quality of experience for end users.

The proposed approach is useful in media rich use case which require high level of reliability especially in mission critical communications.

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