MEC Architectural Implications for LTE/LTE-A Networks

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ABSTRACT

Towards 5G mobile networks, the low-latency and high-bandwidth services are highly anticipated; however, legacy 3G and 4G networks now suffers from the mobile data surge. In this sense, pushing network services to the network edge has the potential to improve the traffic latency, user experience, and offload Internet traffic. Although the LTE/LTE-A network can highly benefit from the Mobile Edge Computing (MEC) principle, a detailed MEC architecture is not currently in place. In this work, we propose a modular architecture for the Mobile Edge Host that is ETSI compliant and describe the functional mapping of the architecture to LTE systems. Proof-of-concept demonstrations based on the OpenAirInterface (OAI), a software implementation of LTE/LTE-A systems, present significant benefits of adopting the MEC concept in data caching use case.

CCS Concepts

•**Networks** → *Network architectures; Cloud computing; Mobile networks;*

Keywords

Mobile Edge Computing, Decentralized Cloud, Caching, 4G, 5G.

1. INTRODUCTION

In order to enable ubiquitous and personalized mobile Internet, it is required to push the boundaries of the existing network and service infrastructures. Based on the existing deployment model, endpoint services are deployed in a number of (virtualized) data centers, that serve a large number of users, connected to various Radio Access Networks (RANs). However, the centralization of resources results in a long separation between end users and the associated service, that brings large end-to-end (E2E) network delays. It restricts the rapid provisioning of new low-latency and real-time communication services that require instant contextual information about the network and users. For example, in the area of Internet-of-Thing (IoT), sensing and/or actuating devices and objects generate a tremendous amount of data and are managed in real-time. This calls for a low-latency communication interface to efficiently control and share information among different networks, providers and geographical areas.

Mobile-Edge Computing (MEC) [8, 12] is considered as a key enabler to the cloud-computing capabilities at the network edge to remedy the delay-sensitive applications and high-bandwidth requirement of current and future RAN architecture, such as cloud-RAN (C-RAN). The edge refers to one or multiple RAN nodes (e.g., LTE eNB, Wi-Fi access point, remote radio units (RRU) of C-RAN) aggregated in a (nano-)data center, called *Mobile Edge Host* (ME host), that is hierarchically located above the RAN/C-RAN architecture. The placement of the *ME host* and its supported services depends not only on the cell deployment (macro-cell, heterogeneous) and backhaul network, but also on the service requirements and the subscriber distribution of the service. While MEC exploits the relevant technologies and follows general SDN [9] and Network Function Virtualization (NFV) [7] principles, it aims to go beyond the standard SDN and NFV concepts. For instance, the MEC can adopt the SDN based unified control-plane architecture to retrieve and reconfigure real-time network control information for its data-plane use case, and also consider Virtual Network Functions (VNFs) for the implementation of its components. One of the key challenges to enable the vision of MEC is the design of a framework that is open to high-layer application development, considers for easy associated services deployment and defines the relevant communication interfaces.

The contributions of our work are the followings. We propose a ETSI compliant modular MEC architecture with plug-in design; we originally realize the concept of *ME host* in the proposed architecture and define the services and components' functionalities of the proposed MEC framework. These are necessary for higher-layer application development. Then, we demonstrate the mapping of the architectural components to the LTE/LTE-A system. Finally, a proof of concept is shown based on OpenAirInterface (OAI) [1] under the distributed content caching use case considering different placements of *ME host.* To our best knowledge, this is the first work aims to provide the *ME host* architecture considering the real RAN impact. Our initial focus stays on the applicability of the proposed architecture to LTE and its evolution; however, the proposed modular architecture remains valid for heterogeneous RAN (e.g., mmWave, Wi-Fi) via appropriate modifications on the RAN-specific MEC functions to enable software-defined 5G that are based on SDN/NFV and the Network Slicing concept [10].

The remainder of this paper is as follows. Background information and the proposed MEC architecture are described in Section 2. MEC communication interfaces and application development framework of the proposed architecture for LTE are in Section 4. The proof-of-concept demonstration is in Section 5. Conclusions and future work are in Section 6.

2. MEC CONCEPT AND RELATED WORK

MEC provides a low-latency and high-bandwidth collaborative cloud environment for application, services, and content to be placed in close proximity to the network and user.

Due to several benefits of MEC to mobile networks, like low latency, high bandwidth, instant access to the RAN, ETSI launched the MEC industry specification group (ISG) and provided the standardization initiatives (ETSI MEC 001-005) that aim to move from a simple bit pipe to a smart service pipe [8,12]. Further, the MEC allows operators to open their RAN edge service environment to authorized third-parties to rapidly deploy innovative application and service endpoints for the mobile subscribers, enterprises and vertical segments [12]. Such applications can be classified into Network-centric (e.g., local connectivity, caching), Information-centric (e.g., content optimization) or Device-centric (e.g., client computation offload) [12] (see Figure 1). In summary, the features of MEC are: (i) proximity to end-users, (ii) direct access to real-time network information, (iii) spatio-temporal context awareness, (iv) mobility support, (v) RAN agnostic, and (vi) network application distribution platform.

Several works consider applications and advantages of adopting the MEC concept. Ref. [12] provides six use-cases and the architecture blueprint of the MEC. Ref. [4] categorizes the applications for deploying services at the mobile edge. The REPLISOM architecture in [2] is to deploy cloud computing resources near IoT nodes and apply Device-to-Device links to neutralize the backhauling and routing bottlenecks. Ref. [5] proposes to offload encoding tasks from mobile devices to *ME host* and reduce the power consumption of mobile devices. Note that MEC is a complementary approach to the future cellular architecture and an explanation of how a real-time context-aware application can be built by collaborating MEC and 5G RAN is in [11]. Moreover, several similar concepts are proposed to enable the edge computing capabilities such as fog computing and cloudlet. A comparison between MEC, fog computing and cloudlet is in [13].

Most of aforementioned studies focus on a top-down view and examine the MEC concept from the application perspective; however, the underlying framework inside the *ME host* is not fully specified. The ETSI MEC ISG initiates the *ME host* framework standardization; however, only the data-plane part is considered. This paper focuses on the overall *ME host* architecture and the associated application development framework towards 5G. These will be used to enable the necessary network abstractions, considering control-plane, data-plane and radio info APIs, application development and interaction with other network entities.

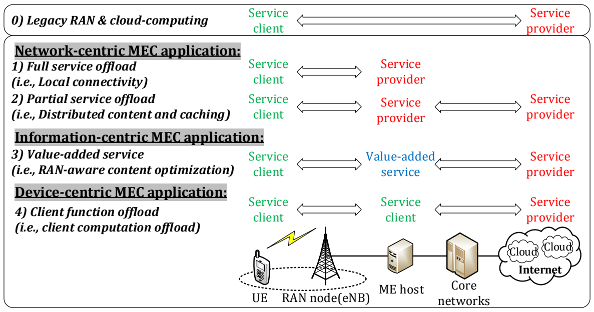

Figure 1: MEC Concept and the *ME host*

3. PROPOSED ME HOST ARCHITECTURE

Since the *ME host* architecture is still under development, it is not possible to identify the impacts and efforts of establishing communication interfaces between RAN nodes and the *ME host*. In this sense, we propose a modular and support plug-in *ME host* architecture with following main components: the *MEC RAN abstraction interface*, *MEC application development framework* that interplays with higher-layer *MEC applications* through higher layer API. See Figure 2 for a visual representation of the proposed *ME host* architecture. Our design complies with ETSI MEC architecture and is modular enough to support six use-cases stated by ETSI [12] following steps in [6]. Further, this design can inherently supports C-RAN architecture with flexible functional split among edge nodes, i.e., RRU and baseband processing units (BBU).

MEC RAN abstraction interface: It is in charge of establishing communication channels with the underlying network(s) to facilitate the control and monitoring of the RAN nodes from the *ME host*. It abstracts the details of network by providing only the necessary information to the MEC application development framework. There are three types of communication channels belonging to the proposed MEC RAN abstraction interface: (a) *Radio information interface:* provides direct access to real-time radio information through a predefined communication protocol, (b) *Control-plane interface:* processes or captures control messages between the RAN and the CN through RAN-specific protocols and (c) *Data-plane interface:* processes data plane packets between the RAN and CN.

MEC Application Development Framework: It provides services and APIs for high-layer MEC applications, and it is composed of four types of services:

- *Common services:* These services are the key services of *ME host* and facilitate the usage of the real-time network and radio information. On the control plane, the Radio Network Information Service (RNIS) provides an abstract view of the network status (e.g., topology, connectivity) by extracting the parameters of interest from the RAN with the required level of granularity. On the data plane, the Edge Packet Service (EPS) brings a native IP service endpoint to the MEC applications. It acts as a local IP agent performing network functions, like IP forwarding, packet encapsulation/decapsulation and data transcoding. A local data base exists in both RNIS and EPS to store the underlying network status and configuration.
- *Platform services:* Provide physical and/or virtual resources (e.g., computation, storage, network and I/O) with an associated abstraction offered by the service orchestrator (e.g., OpenStack Heat). Additional features and flexibility may be obtained through a platform service allowing service execution on top of the cloud infrastructure, in an isolated and tenant-based environment. SDN and NFV related operations are also part of the platform services.
- *Support services:* Provide specific functionalities common to most MEC services. These services can be regarded as basic platform services that other, more sophisticated services can utilize to facilitate their development. The minimal set of support services includes communication service, service discovery and registry, policy and charging service, monitoring service, authentication authorization accounting service, and service-level agreement service.
- *MEC services:* Serve all MEC applications and use cases. They allow to build the (distributed) network applications based on the abstracted network information on top of the local cloud. To enable MEC services correctly, the associated parameters are mapped directly/indirectly from the

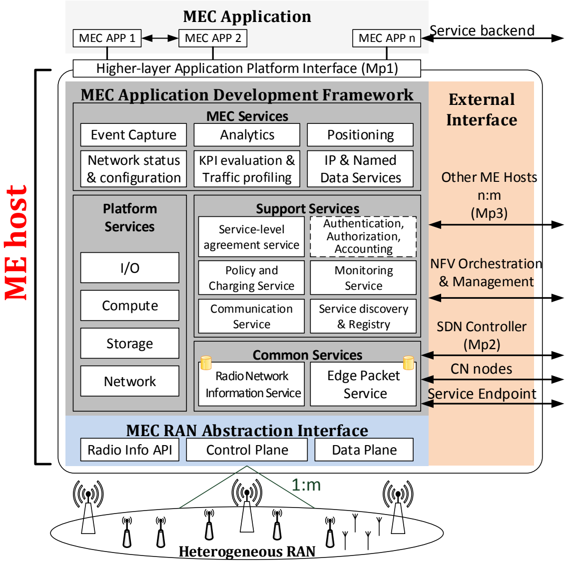

Figure 2: ME Host Architecture

MEC applications. Considered MEC services are positioning, key performance indicator (KPI) evaluation and traffic profiling, IP and named data services, event capture, analytic, network status and configuration.

Moreover, the external interfaces enable the *ME host* to interact with other *ME host*(s), CN nodes, service endpoints, NFV orchestration and Management systems and SDN controllers, if not incorporated within the *ME host*. Note that the SDN controller can be potentially incorporated inside the *ME host* between the MEC RAN abstraction interface and common services. The EPS can act as the application that interacts with SDN controller to modify the data plane policies or packet-based routing. The interfaces of the proposed architecture can be mapped to the ones suggested by ETSI (Mp1, Mp2 and Mp3 in Figure 2).

Regarding the MEC applications, these customized control and monitoring programs developed, based on the MEC application development framework. They can be chained together locally following the NFV service function chaining (SFC) principle to address a particular use-case. Moreover, they can learn from the past experience and adapt based on cognitive methods to generate knowledge. In particular, these applications may predict future network and user behaviors to forecast potential solutions according to the historical data with the lowest level of uncertainty. This increases the intelligence of the network and helps automating network operation. Further, the associated arguments, which are used to abstract the application behaviors in high-level, are applied through higher-layer APIs.

3.1 ME host operation flow

The operation flow of the proposed *ME host* architecture is provided in Figure 3. Firstly, the MEC application and associated arguments are provided through higher-layer API to the support services. Some parameters can be mapped directly (e.g., update frequency, operate period) from the arguments to the parameters of the MEC services in step 2a. However, indirect mappings (e.g., user identity to radio network temporary identifier, application identity to radio bearer identity) are done by RNIS/EPS based on their internal data base in step 2b. Then, the MEC services enable the RAN operation (measurement, state and configuration update) through EPS/RNIS and underlying MEC RAN abstraction interface in step 3 and 4. The results are reported from RAN through RNIS/EPS to MEC services for the value-added information computation in step 5 and 6. Finally, all raw and value-added RAN information are reported back to the MEC applications through the support services in step 7 and 8.

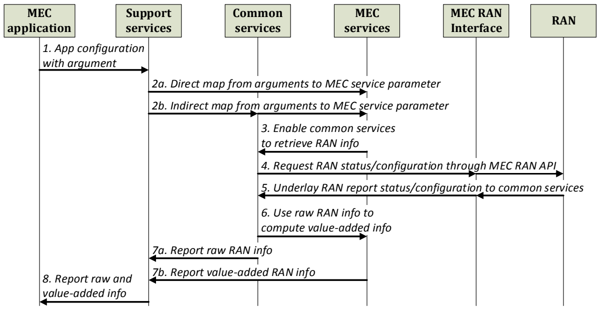

Figure 3: ME Host Operation Flow

4. APPLICATION IN LTE NETWORKS

In this section, the main components of the proposed *ME host* architecture and the relevant interfaces are realized for the case of LTE systems.

4.1 MEC RAN Abstraction Interface

The RAN abstraction in Figure 2 provides a RAN-specific interface between the *ME host* and underlying physical or virtual network. It enables the *ME host* to act as a network entity able to communicate with other entities through the RAN-specific control-plane and data-plane interfaces. For example, in LTE network, the *ME host* communicates with the Mobility Management Entity (MME) through S1 interface in control plane (S1-C), the serving gateway (S-GW) and Packet data network gateway (P-GW) through the S1 interface in data plane (S1-U) and the eNBs through both X2 control plane (X2-C), S1 and X2 data plane (X2-U, S1-U) in Figure 4. To enable low-latency services, the data plane connection through S1-U/X2-U between the eNB and S/P-GW must go through the *ME host*. For instance, the user may demand a video that is cached at the *ME host* rather via the service endpoint. However, the S1-C connection that carries control plane information between MME and eNB is not interrupted by MEC except for the cases of low latency control signaling (e.g., fast handover [3]). In hence, the S1-C interface between MME and eNB is applied to carry control information that can be accessed by *ME host* via the S1-C interface between MME and *ME host*. Moreover, the *ME host* can have some functions of policy and charging enforcement function (PCEF) and lawful interception, and those functions in *ME host* have interfaces (Gx,X1_1,X2,X3) to the policy and charging rules function (PCRF), administration function (ADMF) and delivery functions (DFs).

The MEC RAN interface handles configuration and status information on per user, radio bearer and carrier basis. Configuration information is static or semi-static that can be read or updated, whereas status information changes over time. This interface and the accompanying protocol are based on the common request/response messages for both information. An indicative list of messages is in Table 1.

The following paragraphs describe three types of MEC RAN abstraction interface of the *ME host* in LTE.

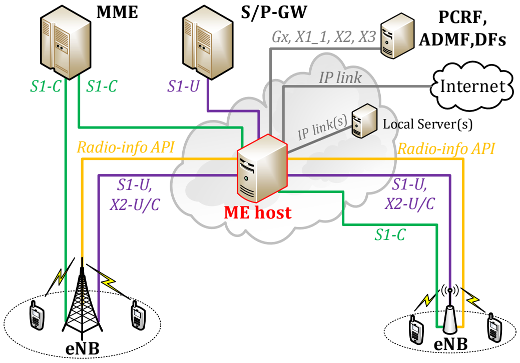

Figure 4: MEC RAN Interfaces for LTE

Table 1: Messages on MEC RAN abstraction interface

Message	Field	Usage
Configuration request	Configuration type	Type of configuration, either set or get
	eNB configuration flag	Bit map of the requested eNB configuration
	eNB configuration list	List of cells (in IDs) to request configuration
	UE configuration flag	Bit map of the requested UE configuration
	UE configuration list	List of UEs (in IDs) to request configuration
Configuration reply	eNB configuration	Requested cell configuration report
	UE configuration	Requested UE configuration report
Status request	Status type	Can be periodical, one-shot, event-driven
	Status period	Period in Transmission Time Interval (TTI)
	eNB status flag	Bit map for the requested eNB status
	eNB list	List of eNBs (in IDs) to request the status
	UE status flag	Bit map for the requested UE status
	UE status list	List of UEs (in IDs) to request the status
Status reply	eNB status	List of eNB including the statistic reports
	UE status	List of UE including the statistic reports

- *Radio Information Interface:* It is used to collect information related to UE/eNB lower layers (Physical , Medium access control (MAC), Radio link control (RLC), Packet Data Convergence Protocol (PDCP) layers) parameters and capabilities. The collected information is either of configuration or status belongs to UE or eNB and is stored for further analyses (e.g., network statistics, measurements).
- *Control-plane Interface:* This interface is used to retrieve information related to UE/eNB control-plane, i.e., Upper layer control information (Radio Resource Control (RRC) and Non-access stratum (NAS) layer), S1-C/X2-C parameters and messages, used for network control and monitoring purposes. These information can be further categorized into UE status or eNB status.
- *Data-plane Interface:* The data-plane interface is used to capture, analyze, and process data packets and provide low-latency data services. This interface communicates through X2-U and S1-U with eNB and S/P-GW separately. These information are categorized into either of configuration or status belongs to UE or eNB.

4.2 MEC Application Development Framework

As mentioned earlier, the MEC application development framework is composed of support services, platform services, common services and MEC services, as in Figure 2. This framework acts as a middleware between the applications and the real RAN element and signaling, and it makes the application developers focus on their specific application purpose rather on the details functionality of underlying RAN. Inside this framework, all four types of services work jointly to provide the top-down network abstraction and bottom-up value-added information provisioning.

4.2.1 MEC Services

MEC services are used to provide value-added information for both control-plane and data-plane, by taking into account UE, RAN, and CN elements. They jointly work with the common services (RNIS, EPS) to have a knowledge of the network element information and user traffic characteristics. Further, they compute the value-added information and response for information provisioning. To enable the MEC services correctly, the associated parameters (e.g., Update frequency, Operate period, Network element, Target user) are necessary to be indicated explicitly. These parameters are mapped from the arguments of MEC application directly (e.g., Update frequency, Operate period) or indirectly (e.g., Network element, Target user). In the following, we introduce the following six MEC services:

Positioning: Computes user geo-location, with different granularity levels, based on the available control-plane measurement information. The location technology (e.g., LTE, GNSS) and location method (e.g., Distance-based, Timing-based, Satellite) are selected based on the granularity level.

Analytics: Analyze the raw control-plane state information from RNIS and provide the value-added information (e.g., radio interference map, network load balancing).

Network status and configuration: Enables *ME host* as the RAN controller to adjust control plane configuration and data plane policy through RNIS and EPS. The updated information is from MEC applications rather than *ME host*.

KPI Evaluation and Traffic profiling: Computes data plane KPIs (e.g., E-UTRAN Radio Access Bearer (E-RAB) accessibility, E-RAB mobility, delay jitter). It also provides traffic profiles to MEC applications for further analysis.

Event Capture: Captures and analyzes the occurrence of specific events from the data stream for reporting. The report includes the event occurrence flag and event analysis result after successful capture.

IP and Named Data Services: Transports data-plane traffic between the *ME host* and target network element. The IP protocol or Named data networking (NDN) can be applied for packet delivery.

4.2.2 Support Services

Support services are responsible for RAN-independent services to enable the both common service and MEC service functionalities. The minimal set of support services is listed in Sec. 3. The communication service as well as the service discovery and registry that belong to this set, are described in the following paragraphs, as examples.

Communication services provide well-defined APIs to facilitate communication between the MEC applications and the MEC application development framework as well as internal interaction between MEC services. The communication can be established via many different architectures depending on vendor design options, e.g., publish/subscribe (PUB/SUB), REST, and distributed shared memory (DSM). Most of these architectures provide APIs running on top of hypertext transfer protocol (HTTP), and being protected by security mechanisms against malicious insiders. This mechanism aids to support abstraction of the underlying network easing communication between the MEC applications and the MEC application framework.

The service registry identifies the available services, supported by the *ME host*. Common protocol messages provided by the communication services are used to inform the MEC application about the availability of different MEC services, as well as the end-points of the provided ones. The component aids the MEC applications to verify if the desired information is available from the underlying network.

This mechanism can be implemented as a data base that includes the holistic information of the available MEC services orchestrating the explicit applications demand.

4.2.3 Common Services

Common services provide underlying raw RAN information via RAN-specific protocols, and they are categorized into RNIS or EPS associated with different MEC RAN abstraction interfaces. These two services are the most important services of *ME host*, and all other services rely on these two services to provide edge computing capabilities.

Radio network information services (RNIS): It interacts through the radio information API and control-plane with the underlying network to provide the requested RAN information. Both are used to collect UE/eNB related content that is stored in a local data base including configuration and status information. Moreover, there are many implementation options regarding the RNIS signaling message mapping to specific 3GPP ones, supported by the RAN[1], but this is beyond the scope of this paper.

Edge Packet Service (EPS): It provides data-plane traffic transportation through corresponding data-plane via SDN-based packet switching and routing. For the routed traffic, the EPS routes the traffic flow passing through the *ME host* to reach the users and vice versa. For the cached traffic, the *ME host* acts as the end-node network element that communicates with the users. Further, EPS also have the knowledge of packet statistics through data-plane.

4.3 MEC Applications

The MEC applications may belong to a specific use-case depending on the intended functionality. In addition, they can be chained together according to the service bundle definition and communicate with each other as well as with the external world (e.g., a local server in Figure 4). Specific arguments are associated with each MEC applications to acquire information from the underlying RAN. These arguments include the type of information that is requested, the update frequency (i.e., how often this information is sent), operate period (i.e., the measurement/observation period of this information), concerned geo-region (i.e., explicit network element) and target user (i.e., specific UE). Finally, these arguments are mapped directly or indirectly to the parameters of related MEC services as the flow in Figure 3. Detail steps on how the six use-cases in [12] apply the MEC application as well as the related MEC services are in [6].

5. PROOF OF CONCEPTS

The proof of concept demonstration of the Distributed content caching use-case based on the OAI is provided. This use-case is one of the six cases provided by ETSI [12], and the OAI is a software-based LTE/LTE-A system implementation spanning the full protocol stack of 3GPP standard both in E-UTRAN and evolved packet core (EPC). As we will demonstrate, using an actual LTE system, caching the content at *ME host* can reduce the average RTT and the RTT variance no matter if the *ME Host* is co-located at the eNB or the packet data network (PDN).

The original packet delivery and MEC cached packet delivery schemes are in Figure 5. We denote the round-trip time (RTT) of the original scheme and MEC cached scheme (between *ME host* and user) as d_C and d_M. Further, the RTT between the *ME host* and data center is d_N, while assume that the *ME host* can cache a packet (P_o bytes) locally. If the packet is not in the *ME host*, it is in the data center. Assume pieces of P_c bytes, ($P_c < P_o$) of the cached packet requested and delivered to all N users. The step 1 and 2 of the original packet delivery scheme is used for every request of each user to get content from the remote data center. However, for the MEC cached packet delivery scheme, the caching steps (Step 2 and 3 of MEC cached packet delivery scheme in Figure 5) occur only once (when the content is not at the *ME host*), while the Step 1 and 4 occur every time when the user request the content from the *ME host*.

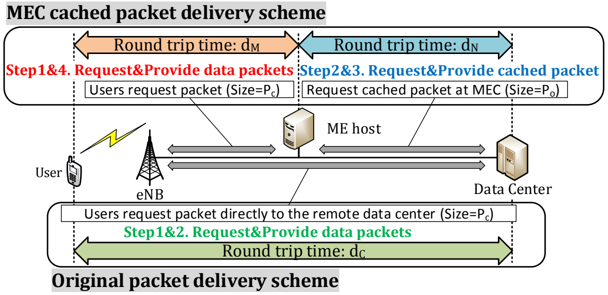

Figure 5: Different packet delivery schemes.

For simplicity, we denote T as the number of requests per user for the P_c bytes on the cached packet (P_o bytes) which is the same for all users. Thus, there are total $N \cdot T$ requests from all users. The reduction on the average RTT (R_{rtt}) and the RTT variance (R_{var}) by applying MEC cached packet delivery scheme to replace the original scheme are shown in Eq. (1) and Eq. (2) respectively. Note that $E[.]$ denotes the expected value and $Var(.)$ denotes the variance. These formulations represent the gain of adopting the MEC cached packet delivery scheme. The derivation is based on the RTT that is distributed as $d_M + d_N$ with probability $p = \frac{1}{N \cdot T}$ and as d_M with probability $1 - p = 1 - \frac{1}{N \cdot T}$.

$$R_{rtt} = E[d_C] - \left(E[d_M] + \frac{E[d_N]}{N \cdot T} \right) \tag{1}$$

$$R_{var} = Var(d_C) - \left(Var(d_M) + \frac{Var(d_N) + \left(1 - \frac{1}{N \cdot T}\right) E[d_N]^2}{N \cdot T} \right) \tag{2}$$

To characterize the RTT in terms of different placements of the content, we conduct experiments on the RTT through different traffic patterns generated by ping utility, namely 64, 768, 2048, 4096, 8192 packet sizes in bytes, and 1, 0.8, 0.4, 0.2 inter-departure time (IDT). Three different content placements are considered: the first two cases are caching data at *ME host* that is co-located at eNB or PDN and the rest case considers a remote data center in San Francisco without any *ME host*. The measured RTT in box-plot of these three placements are in Figure 6(a), 6(b) and 6(c). Note Figure 6(a) and 6(b) contain both the RTT from UE to the *ME host* and RTT from *ME host* to the data center, whereas only RTT from UE to data center is in Figure 6(c) due to the lack of *ME host* in the original scheme of Figure 5. A commercial LTE UE terminal (Huawei E392 USB dongle) that is located 10 meters from an operational OAI LTE eNB (5MHz bandwidth, FDD, SISO) is used.

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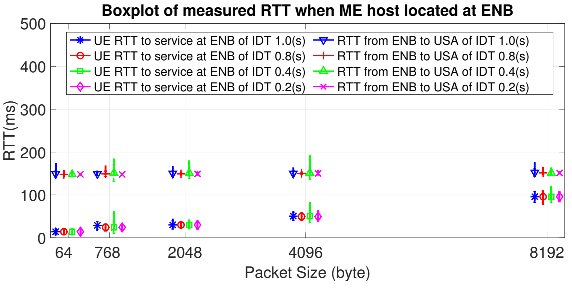
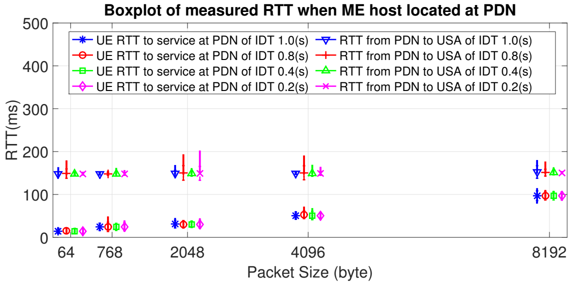
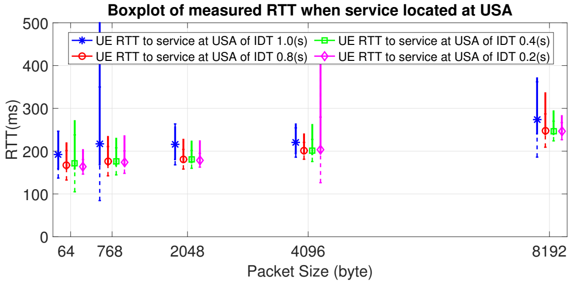
[1] For instance, an agent acts as an intermediate between the RNIS and the RAN to make the appropriate signaling message translation according to 3GPP standards.



(a) Measured RTT when ME host is at eNB



(b) Measured RTT when ME host is at eNB



(c) Measured RTT from UE to data center at USA

Figure 6: Measured RTT of different start and end points

Based on the experiments, the gain of applying content caching at the *ME host* that is co-located with eNB or PDN are in Table 2 in percentage forms. Here we apply the experimental results when IDT is 0.4; however, the same trend can be observed for other IDTs. The percentage forms are derived by dividing the reduction in (1) and (2) with the value of original scheme. Results of different combinations of user number (N), number of requests from each user (T), request packet size (P_c) and cached packet size (P_o) are derived. We observe more benefits on average RTT and RTT variance as the cached data are requested more times with the increment of the number of the users (N) or the number of requests per user (T).

Table 2: Gain of average RTT, RTT variance

ME host location	N	T	P_c	P_o	R_{rtt} (%)	R_{var} (%)
eNB	1	64	64	4096	90.43	27.00
	1	128	64	8192	91.11	62.56
	2	128	64	8192	91.46	80.66
	6	128	64	8192	91.69	92.80
PDN	1	64	64	4096	90.15	29.04
	1	128	64	8192	90.83	63.09
	2	128	64	8192	91.17	81.01
	6	128	64	8192	91.40	93.04

Moreover, in the considered two *ME host* placements scenario (eNB or PDN), the differences are almost negligible due to the proximity of eNB with respect to PDN. In such case, placing the *ME host* at the PDN can potentially serve more requests due to its higher level of aggregation and larger geographical coverage area. Nevertheless, the benefits of placing the *ME host* very close to eNBs is more significant in scenarios where the one-way-delay between the eNB and PDN in either direction is large or has high variability.

6. CONCLUSIONS AND FUTURE WORK

This paper proposes a ETSI compliant modular *ME host* architecture that is able to support a rich network application development environment. It is composed of the following components, (1) MEC RAN abstraction interface, and (2) MEC application development framework for high-layer MEC application development. Then, the proposed architecture is analyzed in the LTE/LTE-A system. Proof-of-concept demonstrates the benefits of applying the *ME host* in the distributed content caching case that save more than 90% of the average RTT and RTT variance of two possible *ME host* placements. Going forward, we plan to demonstrate further proof-of-concepts for other MEC use cases leveraging the OAI software platform, while also consider in more detail for the interactions between the *ME host* with the remote cloud and the SDN/NFV system framework.

7. ACKNOWLEDGMENTS

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