Collaborative Mobile Edge Computing in 5G Networks: New Paradigms, Scenarios, and Challenges

Tuyen X. Tran, Student Member, IEEE, Abolfazl Hajisami, Student Member, IEEE, Parul Pandey, Student Member, IEEE, and Dario Pompili, Senior Member, IEEE

Abstract—Mobile Edge Computing (MEC) is an emerging paradigm that provides computing, storage, and networking resources within the edge of the mobile Radio Access Network (RAN). MEC servers are deployed on generic computing platform within the RAN and allow for delay-sensitive and context-aware applications to be executed in close proximity to the end users. This approach alleviates the backhaul and core network and is crucial for enabling low-latency, high-bandwidth, and agile mobile services. This article envisages a real-time, context-aware collaboration framework that lies at the edge of the RAN, constituted of MEC servers and mobile devices, and that amalgamates the heterogeneous resources at the edge. Specifically, we introduce and study three strong use cases ranging from mobile-edge orchestration, collaborative caching and processing and multi-layer interference cancellation. We demonstrate the promising benefits of these approaches in facilitating the evolution to 5G networks. Finally, we discuss the key technical challenges and open-research issues that need to be addressed in order to make an efficient integration of MEC into 5G ecosystem.

Index Terms—Mobile-edge computing, 5G, multi-layer interference cancellation, collaborative caching, crowd-computing.

I. INTRODUCTION

For the past few years we have been witnessing an unprecedented growth of mobile data traffic, which is predicted to continue doubling each year or equivalently to become 1000× higher in 2020 with respect to 2010. At the same time, our daily lifestyle is increasingly exposed to a plethora of mobile applications for entertainment, business, education, health care, social networking, etc. To keep up with these surging demands and improve users’ experience, network operators have to spend enormous efforts in order to provide low-latency and high-bandwidth network access while maintaining a healthy growth in revenue. In the current framework of evolved 4G Long Term Evolution (LTE) and future 5G mobile network architectures, different proposals are suggested aiming at overcoming the capacity and latency limitations of current Radio Access Networks (RANs). The two emerging technological trends that have been gaining significant attention from the research community and industry are: (i) Cloud Radio Access Network (C-RAN), which aims at the centralization of Base Station (BS) functions via virtualization, and (ii) Mobile Edge Computing (MEC), which proposes to empower the network edge. While the two technologies propose to move computing capabilities to different direction (to the cloud and to the edge), they are complementary and each has a unique position in 5G ecosystem.

As depicted in Fig. 1 MEC servers are implemented directly at the BSs using generic computing platform, allowing the execution of applications in close proximity to end users. With this position, MEC can fulfill one of the most critical requirements of 5G networks in terms of end-to-end delay reduction. Additionally, MEC offers various network improvement, including: (i) optimization of mobile resources by hosting compute-intensive applications, such as image processing, gaming, at the edge network, (ii) pre-processing of large data before sending it (or some extracted features) to the cloud, and (iii) context-aware services with the help of RAN information such as cell load, user location, and allocated bandwidth. MEC principle is also aligned with the concept of Fog computing that envisages the extension of cloud computing capabilities to the edge of the network, presenting major opportunities for the evolution of new architectures, devices and technologies.

Fueled with the potential capabilities of MEC, we propose a real-time context-aware collaboration framework that lies at the edge of the cellular network and works side-by-side with the underlying communication network. In particular, we aim at exploring the synergies among connected entities in the MEC cloud to form a heterogeneous computing and storage resource pool. To illustrate the benefits and applicability of MEC collaboration in 5G networks, we introduce and investigate three use cases including mobile-edge orchestration, collaborative video caching and processing, and multi-layer interference cancellation. These initial target scenarios can be used as the basis for the formulation of a number of specific applications.

The remainder of this article is organized as follows: In Sect. II, we present the state of the art on MEC; in Sect. III, we provide a comparison between MEC and C-RAN in various features; in Sects. IV, V, and VI, we describe the three use cases to illustrate the applicability and benefit of collaborative MEC paradigm; in Sect. VII, we highlight some key challenges and open-research issues that need to be tackled; finally, we draw our conclusions in Sect. VIII.

II. STATE OF THE ART

Currently, MEC concept and architecture have been discussed mainly from the theoretical perspective with only a few
works discussing the practical deployment of such systems.

In 2013, Nokia Networks introduced a very first real-world MEC platform [2] in which the computing platform—Radio Applications Cloud Servers (RACS)—is fully integrated with the Flexi Multiradio base station. This platform allows for access to near-real time network data that has not been exploited to date such as cell congestion, user locations, and movement direction. Under a scenario of a “smarter city” [3], IBM discusses how operators can leverage the capabilities of mobile edge network-virtualization to deploy disruptive services for consumers and enterprises, opening up the unique opportunities to monetize the mobile broadband. Saguna also introduces their fully virtualized MEC platform, so called Open-RAN [4], being able to provide an open environment for running third-party MEC applications. In Open-RAN, the MEC gateway is located in the core network while the MEC servers can be deployed at a RAN aggregation point or within the BS. Recently, the European Telecommunications Standards Institute (ETSI) formed an Industry Specifications Group (ISG), so called Mobile-Edge Computing, which is supported by Nokia Networks, IBM, Vodafone, Intel, Huawei and NTT DoCoMo, in order to standardize and moderate the adoption of MEC within the RAN [5].

From the theoretical perspective, the authors in [6] consider the computation offloading problem in a multi-cell mobile edge-computing scenario, where a dense deployment of radio access points facilitates proximity high-bandwidth access to computational resources but also increases inter-cell interference. The authors in [7] provide a collective overview of the opportunities and challenges of “Fog computing” in the networking context of the Internet of Things (IoT). Several case studies are presented to highlight the potential and challenges of the Fog control plane such as interference, control, configuration, and management of networks, etc [1].

In summary, prior works on MEC focused on the overall system architecture, feasibility of server integration, deployment scenarios, potential services and applications. In contrast to existing works on MEC, which do not explore the synergies within the MEC cloud, this article takes one step further by proposing a collaborative MEC paradigm and presents three strong use cases to efficiently leverage this collaboration space.

III. MEC VERSUS C-RAN

A redesigned, centralization of RAN is proposed in C-RAN where the physical-layer communication functionalities are decoupled from the distributed BSs and are consolidated in a centralized processing center. This architecture can enable efficient solutions to address the capacity fluctuation problem and to increase system energy efficiency in mobile networks [8]. A typical C-RAN consists of multiple Radio Remote Heads (RRHs) distributed at the cell sites and are controlled by a Virtual Base Station (VBS) pool, also known as the BaseBand Processing Unit (BBU), housed in a centralized data center. The communication functionalities of the VBSs are implemented (in software) on virtual machines (VMs) with accelerators hosted over general-purpose computing servers. With its centralized nature, C-RAN offers multi-fold benefits to the network including (i) centralized management of spectrum and computing resources, (ii) collaborative communications and (iii) real-time cloud computing capabilities on generic platforms. However, the full centralization principle of C-RAN entails the exchange of radio signals between the RRHs and VBS which imposes stringent requirement to the fronthaul connections in terms of throughput and latency. With the state-of-the-art fronthaul technologies, such requirements

\[\text{Refer to: http://Fogresearch.org}\]
are only realizable using optical fiber connections which are not available everywhere and the complete deployment is sometime prohibitively expensive. Therefore, fronthaul delay and bandwidth, coupled with CArital EXPenditure (CAPEX) and Return On Investment (ROI) become the most challenging factors that affect the adoption rate of C-RAN in 5G system.

In contrast to C-RAN, MEC proposes to empower the network edge by deploying processing and storage capabilities at the BSs [5] in order to support delay-sensitive (e.g. 1 to 5ms end-to-end latency for “Tactile Internet” applications) and context-aware services and applications. Table I shows the comparison of MEC and C-RAN on various features. One important note is that MEC does not contradict with C-RANs but rather complement them. MEC clouds are useful in reducing latency and improving localized user experience, but the amount of processing power and storage is orders of magnitude below that of the centralized cloud in C-RAN. So, for example, an application that needs to support very low end-to-end delay can have one component running in the MEC Cloud and other components running in the distant Cloud.

In the following sections, we present our case studies where we propose novel scenarios and techniques to take advantage of the collaborative MEC Clouds.

|                          | MEC                                                   | C-RAN                                               |
|--------------------------|-------------------------------------------------------|-----------------------------------------------------|
| Location                 | Co-located with base stations or aggregation points.  | Centralized, remote data centers.                   |
| Deployment Planning      | Minimal planning with possible ad-hoc deployments.   | Sophisticated                                       |
| Hardware                 | Small, heterogeneous nodes with moderate computing resources. | Highly-capable computing servers.                   |
| Front-haul Requirements  | Front-haul network bandwidth requirements grow with the total amount of data that need to be sent to the core network after being filter/processed by MEC servers. | Front-haul network bandwidth requirements grow with the total aggregated amount of data generated by all users. |
| Scalability              | High                                                  | Average, mostly due to expensive front-haul deployment. |
| Application Delay        | Support time-critical applications that require latencies less than tens of milliseconds. | Support applications that can tolerate round-trip delays in the order of a few seconds or longer. |
| Location Awareness       | Yes                                                   | N/A                                                 |
| Real-time Mobility       | Yes                                                   | N/A                                                 |

Owing to its distributed computing environment, MEC can be leveraged to deploy applications and services as well as to store and process content in close proximity to mobile users. This would enable applications to be split into small tasks with some of the tasks performed at the local or regional clouds as long as the latency and accuracy are preserved. A number of challenging issues arise in distributing tasks of an application among edge and other clouds. When splitting of an application does happen, the mobile edge cloud takes care of the low-latency, high-bandwidth and locally relevant jobs.

We envision a collaborative distributed sensing and computing framework where resource-constrained mobile-devices outsource their computation to the edge resources, and, hence, extend their lifetime. Our novel resource provisioning framework at the edge resources will orchestrate the collaboration between mobile devices, edge, and cloud resources and make dynamic decisions on “what” and “where” the tasks in an application should be executed based on the deadline to finish the application, network conditions and device battery capacity. In Figs. 2(a, b), we illustrate two mobile applications from different domains that are good candidates of being executed at the edge. The blue blocks in these applications represent the computation-intensive tasks of the applications that can be offloaded to the remote resources (edge and cloud).

We propose a hierarchical logical-role-based computing environment in which the computing entities (mobile devices, edge, and cloud resources) may play one or more of the following logical roles: (i) *requester*, which places requests for application that require additional data and/or computing resources – this role is played by mobile devices in the field; (ii) *service provider*, which can be a data provider (a mobile device), a resource provider (a computing device) or both – this role is played by nearby edge resources, mobile devices, or cloud, and (iii) *broker*, which is in charge of handling requests and orchestrating the execution of applications on the mobile device – this role is played by edge resources. In [10] we focused on the “extreme scenario in which the resource pool was composed purely of proximal mobile devices.
There have also been few notable works in the area of mobile computing where data from local device is uploaded to the cloud for further processing [11]. In contrast to these traditional approaches, MEC introduces a new stage of processing such that it analyzes the data from nearby resources and notifies cloud resources for further processing only when there is a significant change in data or accuracy of results. In addition, sending raw-sensor values from mobile devices to the edge layer can overwhelm the fronthaul links, hence, depending on the storage and compute capabilities of mobile device and the network conditions the MEC servers can direct the mobile devices to extract features from the raw-data before sending to the edge.

In Fig. 2(c) we compare the time taken for execution of the mobile application represented in Fig. 2(a) using different strategies: (i) executing the application locally on the mobile device (Local), (ii) distributing tasks to proximal mobile devices forming a mobile device cloud (MDC) [12], (iii)- (iv) offloading the tasks to a Mobile Edge Computing server (MEC), and to collaborating Mobile Edge Computing servers (Collab MEC), respectively. For execution in an MDC we model the mobility patterns of devices in the proximity as a normal distribution with mean availability duration of devices varying with \(\mu = \{100, 200\} \) s and \(\sigma=5 \) s. We assume the local mobile devices connect with the MEC server on a 1 Mbps link. For our experiments we considered six mobile devices, namely two Samsung Galaxy Tab with Dual-core ARM CPU at 1 GHz and 1 GB RAM, two ZTE Avid N9120 smartphones with Dual-Core CPU at 1.2 GHz and 0.512 GB RAM, and two Huawei M931 smartphones with Dual-Core CPU at 1.5 GHz and 1 GB RAM. For MEC servers we used two desktops with Intel Core i7 CPU at 3.40 GHz and 16 GB RAM. In Fig. 2(c) we see that the performance of execution on a single MEC server is significantly better than the execution on a local device and MDC. The gain in terms of execution time on using collaborative MEC over execution of the application on a single MEC server is around 40%. Currently, to present preliminary results we use a simple image processing application. However, we believe that a compute-intensive application (such as real-time activity detection with significant variations in execution time of tasks) or a data-intensive application (such as real-time face-detection in a video with large volume of input data) will require a powerful computing environment as ours to make dynamic decisions of what and where the tasks to be executed based on real-time conditions, which will make application execution via collaborative MEC even more challenging.

Another benefit of MEC is being able to provide location-awareness that is not available with centralized cloud resources. In particular, the storage resource at the MEC servers can be used to store data that is frequently accessed by mobile devices in an area. For example, the MEC server in an area can store frequently accessed information such as navigation direction frequently accessed by the mobile users in the area, frequently accessed webpages (such as weather app). This will help the devices to save energy by time as they no longer need to access the long-distance link to the Cloud.

Edge resources can play a significant role in collaborative mobile sensing, also called crowd-sensing, to enable variety of application such as pollution monitoring, traffic monitoring, and collaborative image search. Nevertheless, MEC faces several challenges in enabling collaborative sensing applications, e.g., a collaborative traffic monitoring application, where data from several mobile devices is used to estimate the traffic in a region. Data from all the devices in a densely populated area may not be required as it can be highly correlated. As a result, the edge may choose to retrieve data points from only few mobile devices in a region, which will in turn help in saving the energy of other mobile devices. From the system point of view, Application Programming Interfaces (APIs) need to be carefully designed to enable communication with heterogeneous mobile devices and services. This will hide the differences in various physical sensor access applications and also make our framework reusable across various device platforms.
Due to the ever-advancing multimedia processing features on mobile devices, coupled with the plethora of Over-The-Top (OTT) video content providers, on-demand video streaming traffic has become the major factor driving the burgeoning traffic demand in mobile networks. According to the prediction of mobile data traffic by Cisco, mobile video streaming will account for 72% of the overall mobile data traffic by 2019. This explosion of mobile video traffic poses immense pressure on the capacity of mobile networks. While ultra-dense small cell deployments with their improved area spectral efficiency do mitigate the demand in RAN capacity, at the same time they challenge the backhauling efficiency. For many operators, deploying high-speed backhaul between increasingly large numbers of small cell BSs and the core network becomes prohibitively expensive. In order to prevent the backhaul capacity from becoming 5G system bottleneck (especially during peak traffic hours), edge caching has been recognized as a promising solution, by which popular videos are cached in the BSs or access points so that demands from users to the same content can be accommodated easily without duplicate transmission from remote servers; hence backhaul usage can be substantially reduced.

There has been a vast body of works concentrated on development of advanced mobile content caching and delivery techniques (see e.g. [13] and references therein); however, these works rarely exploit the synergy of caching and computing at the cache nodes. Due to the limited cache storage at each BS, the cache hit rate is still moderate. To overcome this limitation, several approaches have considered collaborative caching, in which a video request can be served using not only the local BS’s cache, but also the cached copy at neighboring BSs via the wireless backhaul [14], [15].

With the emergence of MEC, it is possible to not only perform edge caching but also edge processing. Our approach will leverage edge processing capability to improve caching performance/efficiency. Such joint caching and processing solution will trade off storage and computing resources with backhaul bandwidth consumption, which directly translated into sizable network cost saving.

Due to the heterogeneity of users’ processing capabilities and the variation of network connection bandwidth, user preference and demand towards a specific video might be different. For example, users with highly capable device and fast network connection usually prefer high resolution videos while users with low processing capability or low-bandwidth connection may not enjoy high quality videos because the delay is large and the video may not fit within the device’s display. Leveraging such behavior, Adaptive Bit Rate (ABR) streaming techniques have been developed to improve the quality of delivered video on the Internet as well as wireless networks. In ABR streaming, the quality of the streaming video is adjusted according to the user device’s capabilities, network connection and specific request. Examples of such techniques include Apple HTTP Live Streaming (HLS), Microsoft Smooth Streaming and Adobe Systems HTTP Dynamic Streaming. Existing video caching systems often treat each user request equally and independently, whereby each bitrate version of a video is offered as a disjoint stream (data file) to the user, which is a waste of storage.

In this case study, to the best of our knowledge, we are the first to propose the use of both ABR streaming and collaborative RAN caching to improve the caching benefits beyond what can be achieved by traditional approaches. In Fig. 3 we illustrate the collaborative video caching and processing framework deployed on MEC network. Given the real-time transcoding capability, the MEC servers dynamically transcode video objects to different variants to satisfy the user requests in heterogeneous environment. Each variant is a bit-rate version of the video and a higher bit-rate version can be transcoded into a lower bit-rate version. For example, a video at bit-rate of 5 Mbps (720p) can be transcoded from the same video at bit-rate of 8 Mbps (1080p). We extend the collaborative caching mechanism to a new dimension where MEC servers assist each other to not only provide the requested video but also transcode it to an appropriate bit-rate version. In this way, the requested bit-rate version of a video can be transcoded by any MEC server on the delivery path from where the original video is located (data provider node) to the home MEC server (delivery node) of the end user. When a user make a request for a specific bit-rate version of a video, the following events are defined.

- **Exact hit**: the requested version of the video exists in one of the caches.
- **Soft hit**: the requested version does not exist in the caches, but a transcodable version exists. In this case, the central cache manager will decide whether to transcoded the video at the MEC server providing the transcodable version or at the MEC server serving the user, depending on the current processing load at each server.
- **Miss**: the requested or the transcodable version of the video does not exist in the caches. In this case the

---

1 Refer to “Global Mobile Data Traffic Forecast Update 2014–2019. White Paper c11-520862” by Cisco Visual Networking Index.

2 Refer to: https://en.wikipedia.org/wiki/Adaptive_bitrate_streaming
The potential benefits of this strategy are three-fold: (i) the content origin servers need not generate different bit-rate versions of the same video, (ii) heterogeneous users with various network conditions will receive videos that are suited for their capabilities, as content adaptation is more appropriately done at the network edge, and (iii) collaboration among the MEC servers enhances cache hit ratio and balance processing load in the network.

To illustrate the potential benefits of the proposed approach, we perform numerical simulation on a representative RAN consisting of 7 BSs, each equipped with a MEC server that performs caching and transcoding. We assume a library of 10,000 videos available for download. The video popularity requested at each BS follows a Zipf distribution with parameter 0.8, i.e., the probability that an incoming request for the $i$-th most popular video is proportional to $1/i^{0.8}$. In order to obtain a scenario where the same video can have different popularities at different locations, we randomly shuffle the distributions at different BSs. Video request arrival follows a Poisson distribution with the same rate at each BS. In Fig. 4(a, b) we compare the performance of four caching strategies in terms of backhaul traffic reduction. It can be seen that utilizing processing capabilities significantly helps reducing the backhaul traffic load. In addition, our proposed CoPro-CoCache strategy explores the synergies of processing capabilities among the MEC servers, rendering additional performance gain. Fig. 4(c) illustrates the processing resource utilization of CoPro-CoCache scheme versus different video request arrival rates and cache capacity. We observe that the processing utilization increases with arrival rate and moderate cache capacity, however it decreases at high cache capacity. This is because with high cache capacity, we can store almost all the popular videos and their variants and thus there are fewer requests requiring transcoding.

VI. CASE STUDY III: TWO-LAYER INTERFERENCE CANCELLATION

Current practice to enhance spectral efficiency and data rate supported by the RAN is to increase the number of BSs and go for smaller cells so to increase the band reuse factor. However, the densification of small cells makes the inter-cell interference (ICI) problem become more prominent, which calls for advanced interference management techniques.

The Coordinated MultiPoint (CoMP) transmission and reception technique is a promising solution to mitigate the average interference and increase the spectral efficiency at the cost of a higher receiver complexity. In CoMP, a set of neighboring cells are divided into clusters; within each cluster, the BSs are connected with each other via a fixed Backhaul Processing Unit (BPU) and exchange Channel State Information (CSI) as well as Mobile Station (MS) signals to cancel the intra-cluster interference. The limitation of CoMP, however, is that it is not able to mitigate the inter-cluster interference. Hence, the achieved system capacity - while improved - is still significantly far from the interference-free capacity upper bound. Furthermore, one of the main requisites of the 5G systems is the very low level of latency: the additional processing required for multi-site reception/transmission and CSI acquisition as well as the communication incurring among different BSs could add delay significantly and limits the cluster size. In addition, certain users (especially in cell-center region and close to the BS) may only experience light interference, which makes the CoMP with reasonable computational complexity largely ineffective.

To overcome the existing challenges of CoMP and reduce the latency and bandwidth between the BSs and the BPU, we advocate a two-layer interference cancellation strategy for an uplink MEC-assisted RAN. In particular, based on the channel quality indicator (CQI) of each user, our solution identifies “where” to process its uplink signal as to reduce complexity, delay and bandwidth usage.

Since the cell-center MSs experience a high level of Signal-to-Interference-plus-Noise-Ratio (SINR) and do not cause in-
tense interference to the neighboring BSs, it is not necessarily to apply CoMP for such users. Consequently, since in the MEC network we have access to the computational processing in the BSs, the signal demodulation of the cell-center MSs can be done in local BSs (layer 1). This means that the system performance for cell-center MSs relies on simple single transmitter and receiver. On the other hand, the cell-edge MSs often experience a very low level of SINR, their signals should be transmitted to the BPU (layer 2) for further processing. In this case, the BPU has access to all the cell-edge MSs from different cells and is able to improve the SINR by coordinated processing. It should be mentioned that the BPU is able to dynamically adjust the size of BS clusters and the cooperating VBSs based on the position of MSs in different cells.

As illustrated in Fig. 5, each red dotted circle indicates the interference region of the corresponding cell which is defined as a region in which if MSs from other cells moved in, they could produce an “intense” interference at the BS serving the cell. Since MS #1 is a cell-center MS and is outside the interference region of BSs #2 and #3, its interference at BSs #2 and #3 is low due to the path-loss; hence, there is no need that VBSs cooperate with each other in order to cancel the interference caused by MS #1 and the signal demodulation can be performed at the edge. Conversely, since MS #2 is a cell-edge MS and is located in the interference region of BSs #2 and #3, there may be an intense interference from MS #2 to BSs #2 and #3; thus, coordination of different VBSs in the upper layer is needed to cancel this interference and the BS should transmit the raw data to the upper layer for further processing.

VII. CHALLENGES AND OPEN-RESEARCH ISSUES

The decentralization of cloud computing infrastructure to the edge brings various benefits but it also introduces new issues that must be carefully considered. In the following, we highlight some of the key challenges and open-research issues that need to be addressed in order to make MEC a strong component in 5G evolution.

- Limited resources: The computing and storage resources in MEC platform are expected to be limited and may be able to support a constrained number of applications with moderate needs of such resources. Some current solutions may become too heavy and we might want consider alternative approaches such as MEC as a Service.
- Interoperability: MEC stations owned by different network providers should be able to collaborate with each other as well. This necessitates the specification of how the different elements of the architecture can collaborate with each other, and also how the VMs can access certain information (e.g., network and context information) regardless of their deployment place.
- Monitoring and synchronization: To facilitate collaboration of distributed resources in various entities and locations, there must exist a set of mechanisms that enable the discovery and monitoring of such resources as well as accurate synchronisation across all devices.
- Mobility support: In a small cell network the range of each individual cell is limited. Mobility support becomes more important and solution for a fast process migration may become necessary.
- Fairness: Ensuring fair resource sharing and load balancing is also an essential problem. There is potential that a small number of nodes could carry the burden of processing, while a large number of nodes would contribute little to the efficiency of the distributed network.
- Security: MEC introduces novel scenarios whose security mechanisms have not been widely studied. Highly heterogeneous hardware and software platforms requires complex mechanisms to ensure the security of the whole system. For instance, the MEC cloud might consists of microservers that lack the hardware protection mechanisms of commodity servers, or legacy devices with limited connectivity which restrict the authentication protocols that can be deployed. Furthermore, the security mechanisms need to take into account the existence of mobile devices which can make use of the edge resources anytime and anywhere.

VIII. CONCLUSIONS

Mobile-Edge Computing (MEC) enables a capillary distribution of cloud computing capabilities to the edge of the radio access network. This emerging paradigm allows for execution of delay-sensitive and context-aware applications in close proximity to the end users while alleviating backhaul utilization and computation at the core network.

This article proposes to explore the synergies among connected entities in the MEC cloud to form a heterogeneous
computing and storage resource pool. We introduce and investigate three use cases including mobile-edge orchestration, collaborative video caching and processing, and multi-layer interference cancellation to illustrate the benefits of MEC collaboration in 5G networks. Technical challenges and open-research issues are highlighted to give a glimpse idea on the development and standardization roadmap of mobile-edge ecosystem.

REFERENCES

[1] F. Bonomi, R. Milito, J. Zhu, and S. Addepalli, “Fog computing and its role in the internet of things,” in Proc. 1st Workshop on Mobile Cloud Computing (MCC), pp. 13–16, ACM, 2012.
[2] Intel and Nokia Siemens Networks, “Increasing mobile operators’ value proposition with edge computing,” Technical Brief, 2013.
[3] IBM Corporation, “Smarter wireless networks; add intelligence to the mobile network edge,” Thought Leadership White Paper, 2013.
[4] Saguna and Intel, “Using mobile edge computing to improve mobile network performance and profitability,” White paper, 2016.
[5] Y. C. Hu, M. Patel, D. Sabella, N. Srecher, and Y. Young, “Mobile Edge Computing – A Key Technology Towards 5G,” ETSI White Paper, vol. 11, 2015.
[6] S. Sardellitti, G. Scutari, and S. Barbarossa, “Joint optimization of radio and computational resources for multicell mobile-edge computing,” IEEE Trans. Signal Inf. Process. Over Netw., vol. 1, no. 2, pp. 89–103, 2015.
[7] M. Chiang and T. Zhang, “Fog and IoT: An Overview of Research Opportunities,” IEEE Internet of Things Journal, vol. PP, no. 99, pp. 1–12, 2016.
[8] D. Pompili, A. Hajisami, and T. X. Tran, “Elastic resource utilization framework for high capacity and energy efficiency in Cloud RAN,” Communications Magazine, IEEE, vol. 54, no. 1, pp. 26–32, 2016.
[9] E. Cuervo, A. Balasubramanian, D.-k. Cho, A. Wolman, S. Saroiu, R. Chandra, and P. Bahl, “MAUI: Making Smartphones Last Longer with Code Offload,” in Proc. of the Intl. Conf. on Mobile Systems, Applications, and Services (MobiSys), (San Francisco, CA), June 2010.
[10] H. Viswanathan, P. Pandey, and D. Pompili, “Maestro: Orchestrating Concurrent Application Workflows in Mobile Device Clouds,” in Workshop on Distributed Adaptive Systems at Intl. Conf. on Autonomic Computing (ICAC), (Wurzburg, Germany), July 2016.
[11] M. S. Gordon, D. A. Jamshidi, S. Mahlke, Z. M. Mao, and X. Chen, “COMET: Code Offload by Migrating Execution Transparently,” in Proc. of the USENIX Conf. on Operating Systems Design and Implementation (OSDI), (Hollywood, CA), Oct. 2012.
[12] H. Viswanathan, E. K. Lee, I. Rodero, and D. Pompili, “Uncertainty-aware Autonomic Resource Provisioning for Mobile Cloud Computing,” IEEE Transactions on Parallel and Distributed Systems, vol. 26, no. 8, pp. 2362–2372, 2015.
[13] E. Bastug, M. Bennis, and M. Debbah, “Living on the edge: The role of proactive caching in 5G wireless networks,” IEEE Commun. Mag., vol. 52, no. 8, pp. 82–89, 2014.
[14] T. X. Tran and D. Pompili, “Octopus: A cooperative hierarchical caching strategy for cloud radio access networks,” in Proc. IEEE MASS, pp. 154–162, 2016.
[15] T. X. Tran, P. Pandey, A. Hajisami, and D. Pompili, “Collaborative Multi-bitrate Video Caching and Processing in Mobile-Edge Computing Networks,” in Proc. of the IEEE Annual Conference on Wireless On-demand Network Systems and Services (WONS), Feb. 2017.