



A Software Architecture Model to Manage Heterogeneous Data using Edge Computing in 5G Environment

Majid Ayoubi ^{1,2,*}, Abdul Rahman Safi ², Jawid Ahmad Niazi³

¹ School of Software Technology, Dalian University of Technology, Dalian, China

² Faculty of Computer Science, Kabul University, Kabul Afghanistan

³ Faculty of Computer Science, Ghazni University, Ghazni Afghanistan

Corresponding Author: Majid Ayoubi; ayoubi.m@ku.edu.af

ARTICLE INFO

Keywords: Mobile Edge Computing, 5G, Heterogeneous Data Service Bus, User Equipment

Received : 10, Agust

Revised : 12, September

Accepted: 18, Oktober

©2024 Ayoubi, Safi, Niazi (s): This is an open-access article distributed under the terms of the [Creative Commons Attribution 4.0 International](https://creativecommons.org/licenses/by/4.0/).



ABSTRACT

With the improvement of 5G communication service, the need for edge computing has become more apparent. The Mobile Edge Computing service (MEC) has become one of the best solutions for mobile User Equipment (UE) data processing. MEC provides more context-aware local processing of UE's data. Meanwhile, the MEC needs to manage the heterogeneous nature of UEs and the type of data format they provide. Therefore, a Heterogeneous Data Service Bus is developed to manage different types of data formats and organize them in efficient manner. We propose a software architecture model to address the management of data heterogeneity within computing edges. The architecture discussion showcases its applicability and proper handling of heterogeneous data in the Edge Computing Environment.

INTRODUCTION

Describe A computational paradigm which makes the servers on the edge of network to perform the computation tasks and storage of data in a place near to the UEs is called the Edge computing [1]. It worth mentioning that, this approach is used to extend the capability of the cloud services.

The Edge Computing, beside its benefits, brought forward different challenges to the computing: i.e. operating systems, hardware architecture, heterogeneity in data rate and transmission etc. These challenges have made the 5G technology difficult to adapt to edge computing environments. Additionally, the diversity of environments and different data formats by UEs make it difficult to build a portable solution for all of these environments. There are software-based solutions to facilitate the execution of workloads on the edge nodes. There should be a distributed computing systems which can provide collaborative work between different schemes. The parallelized split of loads can help balance the process of edge computing. There are solutions that provide better communication between heterogeneous UEs and Edge Servers stated in [2].

With the interactive nature of future generation applications, i.e. the virtual reality, the use of edge computing becomes necessity. Due to wireless nature of future technologies and the need for real-time response, it is critical to provide edge computing approaches to provide solutions to these problems [3].

The 5G communication system is different than the previous generations in terms of its focus in IoT and machine-type communications. Therefore, the 5G is not only extending the data rates of mobile broadband, but it also supports the reliable communication with lowest possible latency and enables great connectivity between IoT devices [4].

Since the UEs are having limited capabilities, the edge computing comes forward to provide the following services: a. receiving huge amount of real-time data and storing them, b. analyzing, computing and processing of the data, c. local decision making. By the aforementioned services, the edge servers are defined as mini clouds which are doing most of functionality of clouds but with a lower scale in the place which are near to the UEs to ensure lower latency, especially for the hard real-time application services [5].

Besides the mentioned technologies, the Mobile Edge Computing (MEC) delivers services of the cloud and other IT environment equipment in the area near to the end-devices, called Radio Access Network (RAN). MEC is much more near to the proximity of mobile users to ensure efficient operations of network, delivery of service, improving user experience and to reduce the latency in mobile communication [6].

The 5G and Edge computing need collaborative work to provide real solution for the real-world use cases. There are two main areas how these two technologies can provide collaboration [8]:

- 1- To enable use cases such as telesurgery, or live drone controls. There is inevitable use of 5G with edge computing to achieve low-latency and provide processing near to the UE to make the data travel shorter.
- 2- For the other use cases with data heavy applications, or HD videos, or real-time data analysis, the 5G alone cannot make a big difference, since the

travel to the centralized cloud can lower the customer experience. The MEC can help the data to be processed and filtered out before they get sent to the cloud for further analysis and storage. The process of decoupling the cloud connectivity to the edge nodes are discussed in details in .

There are some objectives of Edge computing collaboration with 5G as follows :

- 1- The data management improvement
- 2- The QoS (Quality of Service) enhancement
- 3- The prediction of network necessity
- 4- Providing context and location awareness.
- 5- Resource management.

Meanwhile, the Edge computing in 5G environment needs the real-time interaction, support of high data rate and local data processing.

The rest of paper is as follows: Section 2, provides an review of the used technologies in the model. Section 3 discusses the related works. Consequently, Section 4 provides the details of proposed model, the last two Sections 5 and 6 discuss the model and provides conclusion respectively.

LITERATURE REVIEW

Most of research done in the field of edge computing in 5G focuses to provide better computation, low energy consumption etc. There are very few research available to focus how the data management happen with the heterogeneous environments.

To fulfil energy aware offloading, there is an architecture presented by Zhang et al.[12]. Their architecture enables the UEs to decide about the offloading of computational operations to MEC servers. This approach helps reduce energy consumption of MEC. There are three steps of the solution: 1. The mobile UEs are grouped based on their energy consumption. 2. They are classified according to the file transmission and 3. They are grouped based on the delay on transmission between the MEC and the UEs [12].

The collaborative real-time architecture is proposed to handle different types of resources in a context-aware manner. In this architecture, the computation abilities of it is divided into different layers of computational platforms [13].

To provide fast composite service Ridhawi et al. [14] bring forward a context-aware collaborative architecture. This architecture enables the collaboration of hardware systems such as clouds, edges etc. and the respective software capabilities.

The developed a novel event-driven architecture that is supported by a service bus for better integration of different software systems. This software architecture is highly scalable that gets its scalability from the staged event-driven architecture. The input data is coming from heterogeneous resources and the architecture process them in a unified manner.

The requirement of the modern architecture based on low-latency and high throughput are as follows :

- 1- Interaction in real-time
1. To be processed locally

2. High data rate
3. Availability
4. To support heterogeneous environment

The [9] puts forwards a distributed infrastructure to manage the heterogeneous data in an improved way. Their architecture also provide service in real-time and send the processed data to the users' applications. There is a secure middleware that support this architecture.

None of the reviewed literatures had focused to address the heterogeneous data processing channel and data exchange between MEC devices to ensure semi-cloud capabilities near to end-devices.

THE PROPOSED ARCHITECTURE

To manage different types of data, there should be an aggregation point near to the location of UEs that can handle heterogeneous types of data. This approach provides low latency, more proximity with more bandwidth. Using this, we can localize the cloud computing capabilities with better contextual information.

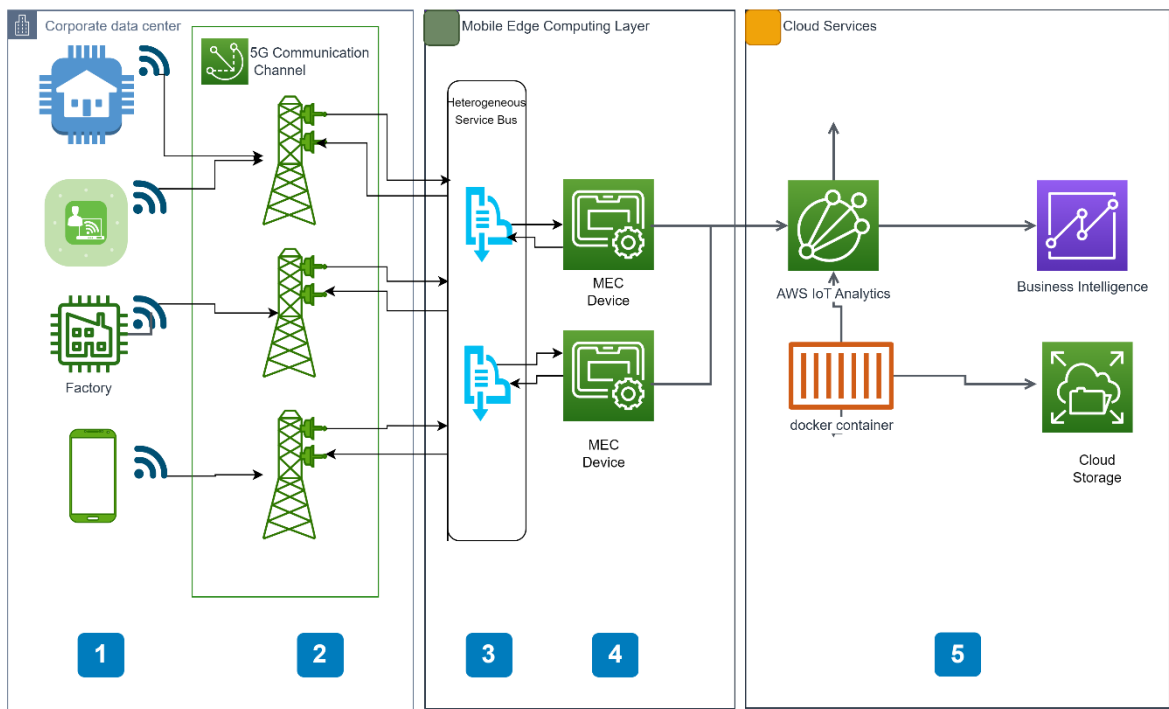


Figure 1: The Heterogeneous Data Service Bus Architecture

We used the Mobile Edge Computing technique which are contextually near to the UE mobile network called the Radio Access to provide the computation for the data coming from heterogeneous sources.

Our proposed model in Figure 1 consists of the following parts:

a. The User Equipment

The IoT and other smart devices and sensors are using the 5G communication channel to reach to MEC devices. The UEs can be different in nature especially in terms of data source types. The UE sends data to Heterogeneous data service bus for better recognition and categorization of data in respect to its data source type.

b. The 5G communication Channel

The 5G communication channel is one of the important features which makes sure that there is a lowest latency possible in a data transmission. The uses of 5G with Mobile Edge computing makes this approach even more realistic. In the proposed architecture, the communication between the UE and MEC Devices are maintained by the 5G technology.

c. Heterogeneous Data Service Bus

The Heterogeneous Service Bus has the responsibility of composing and decomposing data to the required format to get processed by the MEC device. Each request to the edge is identified by a device type identifier which will later help in decomposing and provide faster data source recognition. We store the UE's data source type along with the meta-data for the process of composing and decomposing of data.

d. The MEC devices layer

This layer is used to provide local data processing and decision making based on the input data and deployed patterns. The useful data from this stage will be sent to the cloud servers for storage and analytic purposes.

e. The Cloud Services Layer:

As the name implies, this layer provides the analytics, business intelligence and storage services for the useful data come from MEC devices.

The Heterogeneous Data Service Bus consists of three main parts which are working together to provide Machine-to-Machine (M2M) communication, data collection and management (Figure 2).

MODEL DISCUSSION

In some of applications the UEs need to have low-latency communication between each other. The M2M module is used to provide the UEs communication through the data service bus with lower latency.

To enable efficient M2M communication in heterogeneous environments, the Service Bus initially gets data from multiple sources which are using different formats of data transmission. In the filtering stage the redundant data is removed and the data fields are stored in the corresponding metadata fields. Meanwhile the data normalization applies on the data to adjust them into a defined range

and if needed the filtered and normalized data is transformed into the other end Machine's understandable format for further processing and communication.

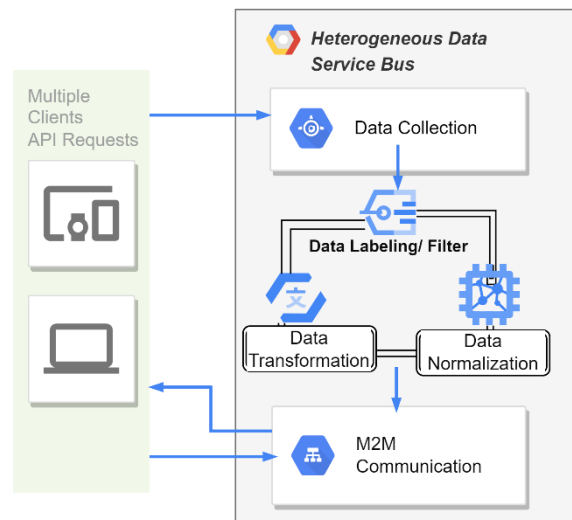


Figure 2: The Heterogeneous Service Bus Internal Details

This architecture can provide better management of data through edge computing service and can enable low-latency M2M communication.

This architecture is designed to focus on integrating different User Equipment and their respective various data source types, hence enabling the Heterogeneous Data Service Bus toward higher level recognition and categorization. With low-latency communication over the 5G channel, the system enables high responsiveness and real-time decision-making. For the main role of the Heterogeneous Data Service Bus in data transformation, it provides increased capability for recognition and further processing of various types of data, thanks to device-specific identifiers, providing more optimized interactions between UEs and MEC devices.

Furthermore, the architecture clearly defines the responsibilities across five distinct layers from User Equipment to the Cloud Services Layer in terms of how it contributes to a seamless workflow for the processing and analytics of local data and its storage. The MEC devices are of a high essence in terms of the role in localized decision-making capabilities, while the Cloud Services Layer complements such with strong analytics and business intelligence capabilities. The proposed structured approach further enhances efficiency, effectiveness in data management, and strengthens overall architectural resilience by enabling scalability in service integration and adaptability to evolving technological demands. On the whole, the proposed model offers a comprehensive framework that addresses the complexity of heterogeneous data processing in a 5G-enabled edge computing environment.

CONCLUSION

In this paper we have proposed a software architecture to enable the edge computing to provide unified services to manage heterogeneous data coming from different types of devices in 5G environment. The architecture model makes the interaction of data more understandable to the edge computing layer and other UEs, and hence, reduces the time takes for composing and decomposing of data within the layer. The suggested model provides a thorough framework that tackles the intricacy of processing heterogeneous data in an edge computing environment enabled by 5G.

FURTHER STUDY

We will elaborate the possible ways of interactions within the Heterogeneous Data Service Bus to reduce latency within the 5G environments by simulating the architecture to further improve the heterogenous communications.

REFERENCES

- [1] W. Z. Khan, E. Ahmed, S. Hakak, I. Yaqoob, and A. Ahmed, "Edge computing: A survey," *Future Gener. Comput. Syst.*, vol. 97, pp. 219–235, Aug. 2019.
- [2] Najmul Hassan, Kok-Lim Alvin Yau, And Celimuge Wu, " Edge Computing in 5G: A Review ", *IEEE Access*, vol. 7, pp. 127276-127289, 2019.
- [3] Popovski, K. F. Trillingsgaard, O. Simeone, and G. Durisi, "5G wireless network slicing for eMBB, URLLC, and mMTC: A communication theoretic view," *IEEE Access*, vol. 6, pp. 55765–55779, 2018.
- [4] Zhao S , Li Z , Medhi D , et al. Study of user QoE improvement for dynamic adaptive streaming over HTTP (MPEG-DASH)[C]// 2017 International Conference on Computing, Networking and Communications (ICNC): Multimedia Computing and Communications
- [5] A. Ahmed and E. Ahmed, "A survey on mobile edge computing," in *Proc. 10th Int. Conf. Intell. Syst. Control (ISCO)*, Jan. 2016, pp. 1–9.
- [6] *Mobile Edge Computing - a key technology towards 5G* (book)
- [7] 5G Vision: The 5G Infrastructure Public Private Partnership: the next generation of communication networks and services. From The 5G Infrastructure Public Private Partnership: <https://5g-ppp.eu/wp-content/uploads/2015/02/5G-Vision-Brochure-v1.pdf>
- [8] Tilly Gilbert (2022) Available at: <https://stlpartners.com/articles/edge-computing/5g-edge-computing/>, accessed: 02/10/2023.
- [9] Ion-Dorinel Filip, Andrei Vlad Postoaca, Radu-Dumitru Stochitoiu, Darius-Florentin Neatu, Catalin Negru, "Data Capsule: Representation of

Heterogeneous Data in Cloud-Edge Computing", *IEEE Access*, vol. 9, pp. 49558-49567, 2019.

[10] Najmul Hassan, Kok-Lim Alvin Yau, And Celimuge Wu, " Edge Computing in 5G: A Review ", *IEEE Access*, vol. 7, pp. 127276-127289, 2019.

[11] K. Yeow, A. Gani, R. W. Ahmad, J. Rodrigues, and K. Ko, "Decentralized consensus for edge-centric Internet of Things: A review, taxonomy, and research issues," *IEEE Access*, vol. 6, pp. 1513-1524, 2017.

[12] K. Zhang, Y. Mao, S. Leng, Q. Zhao, L. Li, X. Peng, L. Pan, S. Maharjan, and Y. Zhang, "Energy-efficient offloading for mobile edge computing in 5G heterogeneous networks," *IEEE Access*, vol. 4, pp. 5896-5907, 2016.

[13] T. X. Tran, A. Hajisami, P. Pandey, and D. Pompili, "Collaborative mobile edge computing in 5G networks: New paradigms, scenarios, and challenges," *IEEE Commun. Mag.*, vol. 55, no. 4, pp. 54-61, Apr. 2017.

[14] I. A. Ridhawi, M. Aloqaily, Y. Kotb, Y. A. Ridhawi, and Y. Jararweh, "A collaborative mobile edge computing and user solution for service composition in 5G systems," *Trans. Emerg. Telecommun. Technol.*, vol. 29, no. 11, Jun. 2018, Art. no. e3446.

[15] Ayoubi, M., Ravichandra S., "SEDA-SOA: A Scalable Event-Driven Context-Aware Service Oriented Architecture," in *ICCNT*, Bangalore, India, 2018.