Spatio-temporal Data Retention System with MEC for Local Production and Consumption

Daiki Nobayashi[1], Kazuya Tsukamoto[1], Takeshi Ikenaga[1], Mario Gerla[2]
[1]Kyushu Institute of Technology, Fukuoka, Japan
[2]Dept. of Computer Science, University of California at Los Angeles, Los Angeles, CA, USA
nova@ecs.kyutech.ac.jp, tsukamoto@cse.kyutech.ac.jp, ike@ecs.kyutech.ac.jp

***Abstract*—To facilitate local production and consumption (LPAC) of spatio-temporal data (STD) generated by Internet of Things (IoT) devices, we propose a STD retention system that works in collaboration with Mobile Edge Computing (MEC) infrastructure. In this paper, we will introduce the architecture of our proposed system and discuss its contributions and challenges.**

***Index Terms*—Data retention system, MEC, Vehicles.**

I. Introduction

With the development and growth of Internet of Things (IoT) technologies, various types of data collected from vast numbers of sensor devices are now being generated ubiquitously. In IoT services that depend on Internet infrastructure, such data are first stored in the cloud or at data centers and then analyzed by each service provider, after which the service providers use the analyzed data to provide various user services. However, to provide rapid services to mobile users that require low latency, it is necessary to ensure cooperation between heterogeneous networks and service providers, furthermore, and we must take the geographic proximity between users and data in consideration. This is technically difficult to achieve because of commonly results in scalability issues.

Based on the above, we believe that a network architecture that facilitates local production and consumption (LPAC) of data is necessary for such IoT services. Accordingly, we have been studying ways to produce and consume data locally and effectively using vehicular networks. We began by defining IoT device data that depends heavily on the generation time and location as spatio-temporal data (STD). Such data can include shopping districts advertisements, distribution information of people or vehicle traffic, weather information, and so on. Generally speaking, however, even though such STD are not normally stored in the cloud or at data centers, they can be utilized efficiently by geographically neighboring clients. With this point in mind, we have previously proposed an STD retention scheme that uses vehicles as information exchange hubs (InfoHubs), namely Mobile Vehicular Cloud [1][2]. In that scheme, each vehicle disseminates STD into the area as required by the data sender (such as service providers, applications, etc.), which clients receive passively and can then use. In other words, the STD collected by sensors are disseminated by vehicles and consumed by users in the target area.

Meanwhile, MEC infrastructure, in which edge servers (ESs) are installed to collect and analyze data near the user temporarily, have attracted significant attention in recent years. In a MEC setup, calculations (such as data analysis) are performed by an ES before the data is aggregated on the cloud or data centers, which can reduce the load on them. That means that the use of a MEC infrastructure can facilitate data processing closer to the user than a conventional cloud service.

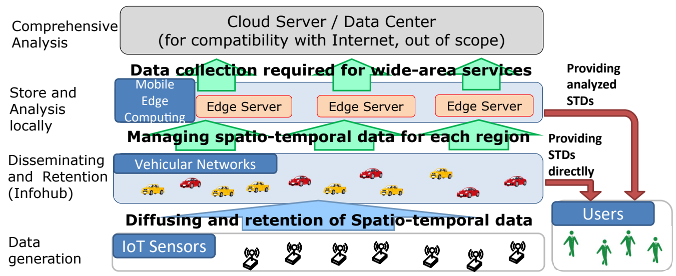

Fig. 1. Overview of our proposed architecture.

Additionally, MEC can enable the expansion of application services depended on the geographic proximity of the user, while also providing low latency and load reduction. Therefore, we have concluded that MEC is an essential technology for realizing LPAC of STD in our scheme.

With these points in mind, we propose an expanded data retention system that works in cooperation with MEC infrastructure and vehicular networks to facilitate LPAC of STD. This architecture disseminates, analyzes, maintains, and provides STD generated from any sensors within a specific region via the InfoHubs and ESs, and thus achieves the provision of a novel information and communication infrastructure that operates across different services and networks. In this paper, we will introduce the architecture of our newly proposed system and discuss its contributions and challenges.

II. Architecture

Figure 1 shows the overview of our proposed system, which consists of IoT sensors generating STD, a vehicular network for data retention, and a MEC for collecting, analyzing, and managing STD and information regarding InfoHubs. To address compatibility with IoT services using the Internet, we assume the cloud server and the data center are at the top of infrastructure, but that is outside the scope of this paper.

Data generated via the IoT sensors are transmitted to sensors, or vehicular network clouds (i.e., InfoHubs) formed on the spot, in which receiving vehicles disseminate and maintain data within the area specified by the data sender (e.g., service provider and application). This retention scheme allows users to receive and utilize the latest sensor data generated at that location for their personal applications. The effectiveness of this retention scheme was evaluated in [1][2], in which we also verified the feasibility of LPAC of the STD. However, that retention scheme faces the following constraints: (1) the user must be located within the area where the data is being disseminated by the vehicles, and (2) providing services using multiple STD types via this scheme is difficult because each STD is floated independently depending on the location where it is generated.

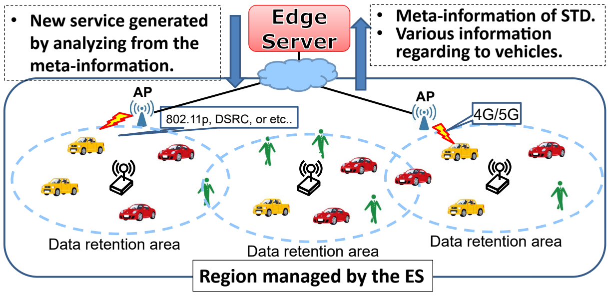

Fig. 2. Proposed network topology.

With these points in mind, we introduced the MEC infrastructure to improve the efficiency of user access to the STD. In our newly proposed scheme, the MEC layer is composed of an ES that manages the vehicles and STD for a certain region. Using the vehicles, the ES collects metadata including service types, retention ranges, and so on.The ES then uses that metadata to perform analyses to find the most relevant information for the region. In addition, since the data are collected directly through the vehicles, our proposed system enables data-driven analyses to be performed beyond the service boundaries. Furthermore, to accurately maintain the retention status, the ES periodically collects location and movement information related to the participating vehicles.

The configuration of the ES in our proposed scheme is shown in Figure 2. In our proposed system, we assume that all vehicles have a wireless interface for short-distance communication as outlined in the IEEE 802.11p standard, DSRC standard, etc., and that some of the vehicles have a wireless interface for 4G/5G communication. At this point, the vehicles update the information to the ES via an access point (AP), a roadside unit (RSU) capable of short-range wireless communication or a wireless wide area wireless (WWAN). After collecting this information, the ES can analyze the data to extract useful materials for users or applications.

III. Contributions and Challenges

Our proposed STD retention system, which works in collaboration with MEC, can provide the following contributions:
(a) Accelerating the LPAC of the STD: The proposed system can provide new services by analyzing multiple data based on geographic proximity using MEC infrastructure, not simply by providing direct real-time data delivery to a user, as is used in our prior retention schemes. Our proposed system effectively generates, disseminates, and utilizes the STD within the regions while also accelerating LPAC. Moreover, since the STD present in the region is centrally managed by MEC, coordination between heterogeneous networks and service providers is easy.
(b) Extended STD retention scheme using vehicles: The use of MEC makes it possible to reinforce the weak points of the STD retention scheme. Because vehicles have high mobility, the network topology changes continuously. This makes STD retention difficult when the node density is low. However, since vehicle mobility within the region can always be grasped by MEC, the ES can easily comprehend and compensate for such network topology changes.

To achieve our proposed STD retention scheme using MEC, it will be necessary to address the following challenges:
(i) Considering MEC infrastructure based on geographic proximity: To realize the above contributions, we will need to manage the STD in each region effectively. Since the STD must be managed by entities that depend on the location rather than service providers or communication carriers, it is necessary to consider expanding the MEC infrastructure that centrally manages information related to InfoHubs and the STD for each region, and to consider how to efficiently operate the MEC based on each region.
(ii) Optimizing data collection from all vehicles: Since each vehicle has different communication interfaces, it becomes difficult to transmit various information to the MEC infrastructure if no AP exists near a vehicle with short-range wireless communication interface or in the situation where a vehicle is located outside the WWAN service area. Thus, to make it possible for all vehicles in the area to reliably transmit data to the MEC, it is necessary to consider the data transmission method using vehicle-to-everything (V2X) communication, disruption tolerant networking (DTN), etc [3].
(iii) Facilitating STD identification within the region: Since the STD is retained by vehicles within the region and the metadata is aggregated into MEC, it is necessary to search using geographic information and content information to perform data retrieval. Given the availability of content-centric network (CCN) technologies and geographic routing, we will need to consider the most effective data retrieval services based on geographic proximity. One solution that has the potential to solve this problem is the use of an r-Space system [4] which can provide the architecture for real-time communication based on geographical information and the physical location of the user.
(iv) Discovery of new services from multiple STD: By aggregating STD at the MEC infrastructure, it becomes possible to extract useful information (services) for the user or region. Accordingly, it will be necessary to consider service extraction technologies to discover new services that can be created from the metadata of various sensor types. For example, by using STDs in wide area, it is possible to update from store information to shopping mall information.
(v) Effective STD retention: Since the topology of the vehicular networks envisioned in this system fluctuates continuously, effective data retention will become difficult if the network node density is low. Therefore, it will be necessary to provide an effective STD retention system based on the node density by using the MEC that have information of all vehicles.

IV. Conclusion

In this paper, we proposed a new data retention system that uses MEC infrastructure and vehicular networks to realize LPAC of the STD and showed its potential contributions and challenges. In our future works, we will address the above challenges and propose a more efficient STD utilization scheme.

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