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# DOCOR: Sensing Everything From Route Buses


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***Abstract*—With the spreading of digital tachographs for transportation systems, IoT is coming to route bus fields as well. The primary purpose is to make an operation of route buses efficient by glancing over the status of the bus operation in real-time. The digitization and the connectivity of the bus not only enhance the bus company business but also contribute to enriching the smart city features with providing their sensor data to communities in the city. This paper shows the design and implementation of the bus IoT system and a showcase of its applications.**


## I. Introduction

The severe shortage of bus drivers in Japan due to the aging population will spread all over the world. The aging population is a global issue (e.g., in 2050, 80% of older people aged 60 years and older will outnumber children younger than five years[1]). Japan already faces this kind of problem with a shortage of workers. The bus companies that already face this need to improve their business efficiency with technologies.

Digital tachograph took the initiative in improving the bus business. Tachograph, which logs speeds of a vehicle and an engine onto a paper disk, has been used to help bus managers manage, analyze, and instruct drivers. The analog one is going to be replaced with the digital one. Once the analog device is digitized, it can send data via a digital network, and the data can be reused for improving not only driving behavior but also business efficiency.

Digital tachographs can install various kinds of sensors and act as a sensor hub in a bus, thanks to the digitalization. This paper shows the design of DOCOR (Driver Or car COndition Reading), which is an IoT (Internet of Things) system implemented by a bus company, Minato Kanko Bus. The paper will share how to strengthen bus business with IoT. We have used this system for not only visualizing real-time sensor data but also analyzing driving behaviors and environmental information outside the bus. We expect that the described design and application examples will activate a meaningful discussion about the bus IoT field.

## II. Design of DOCOR

Fig.1 shows the design of the DOCOR system. Each bus has a digital tachograph unit with sensors that transmits sensor data to a server via the cellular network. Various kinds of applications subscribe to the sensor data.

The digital tachograph unit is specially designed for mounting into a running bus. It can work under most road conditions, even in buses with shabby suspensions, and at temperatures of up to 60 °C, which is often possible inside a dashboard during the summer. The unit consists of a Compute Module 3, which is a special Raspberry Pi 3 intended for industrial application, a power circuit with a supercapacitor, and various sensors. The connected sensors are described at the bottom of Fig.1. Vehicular speed and engine speed are directly collected from the vehicle itself, and the others are attached or included in the digital tachograph unit. Though the digital tachograph unit includes an accelerometer, a gyroscope, and a magnetometer, we have not yet utilized them all. Things inside the bus which have not yet been connected (e.g., the activities of windshield wipers, the front/rear doors, the bell cord/signal strip, and the wheelchair lift) could be useful too.

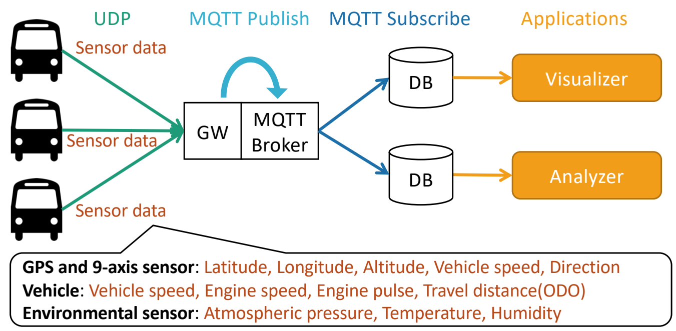


Fig. 1. Design of DOCOR system.

The combination of UDP and MQTT (based on TCP) effectively works for high-frequency transmission in the field. According to the government's requirement regarding the sampling rate of vehicle speed and engine speed, the node has to record these data points every 0.5 seconds, at least. We voluntarily set the same interval for transmitting. UDP transmission can avoid stacking errors when wireless connections are unstable. Once GW receives sensor data, it can use any commodity protocol among stable networks. We employ MQTT to let every stakeholder subscribe to the sensor data with adequate scalability. It only has to replicate the MQTT brokers when the last broker saturates.

Each application subscribes necessary data from the MQTT broker and stores them into its database, then produces the results according to its purpose. Some applications form web applications for bus managers, and others act as analyzers for multi-purposes such as logging, analyzing, and placing into machine learning algorithms. They do not affect the regular

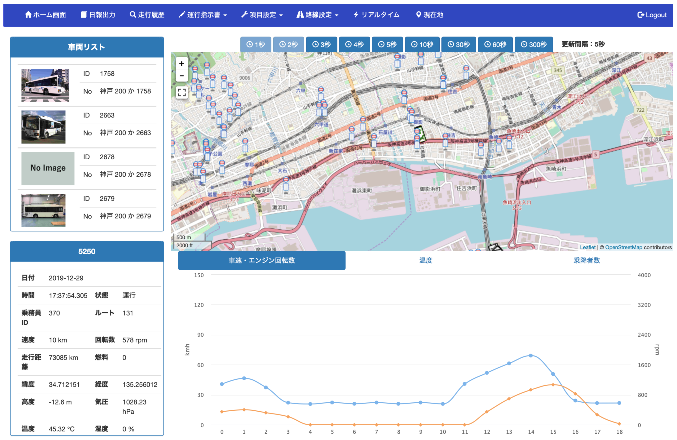

Fig. 2. A screenshot of the visualizer.

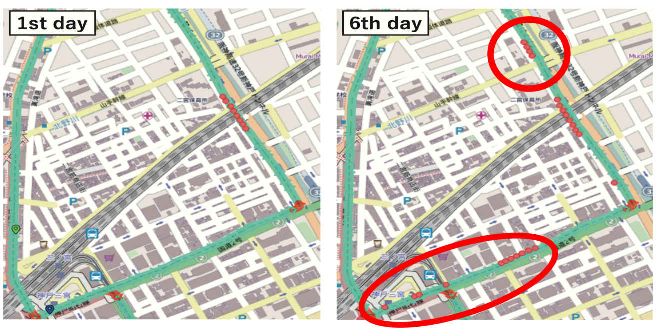


Fig. 3. Consecutive days driving increases hard brakes.

bus operation because we separate the database.

## III. Application

This section shows examples of applications that utilize real-time sensor data or stored data. We also discuss the possibility of other applications for not only the current bus operation management but also research aspects.

Just showing real-time sensor data with a map, charts, and a dialog helps bus operation management. As shown in Fig. 2, bus operation managers can glance at all the positions of the operating buses with the visualizer. The current Japanese regulation allows a bus operation manager to manage up to 39 buses at once. It is impossible to grasp all running buses without such an IoT system. If a bus manager thinks a bus run is unusual, he/she will click the bus icon and see the vehicle speed, engine speed, and the other sensors' values. If a speeding occurred, this visualizer alerts the bus manager to ask the driver to reduce the speed. A bus operation manager also can visualize the past data by inputting a bus number and the operated date and time. The bus operation managers' behaviors that were affected by the sensor data could be a material for the next generation automated management system.

The bus data interests academic researchers and stimulate the consideration of practical issues. Fig. 3 shows hard-breaking points on the first and the last days of work for a driver who worked for six days in a row, clearly showing that a driver should avoid working for too many consecutive days. This analysis only had to plot the GPS coordinates that had strong de-accelerations. To reduce the number of operation of drivers during driving, we have developed some functions such as inferring both the bus operation states[2] and the number of passengers by fusing sensor data and images of a driving recorder[3]. Fig. 4 shows the atmospheric-pressure sensor data that was obtained from a bus driving 5 km/h or faster from 8 a.m. to 9 a.m. on October 30, 2018. Since buses run every 15 minutes, and a bus route has two directions—upstream and downstream—this system can work as a collective sensor system for fixed-point observation at approximately 7-minutes intervals, showing that any environmental sensing system can be deployed with this bus IoT system.

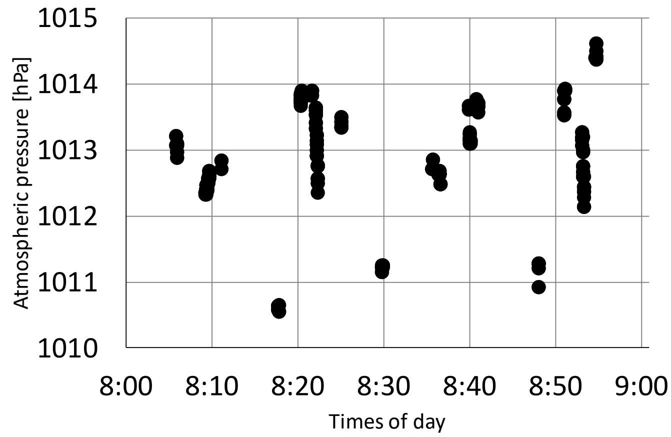


Fig. 4. Air pressure data from a couple of buses at an area.

## IV. Conclusion

As the demand for IoT grows, we introduced the involvement of route buses and explained the design of DOCOR, which is a well-considered implementation of a bus IoT system. The bus-mounted device is quite stable as both a digital tachograph and a sensor hub inside a bus; the Pub/Sub-based MQTT sensor network is scalable, which may contribute to not only the bus company but also the city community by sharing the sensor data widely collected from the buses running around the city. We will continue creating killer applications of efficient bus operation systems and smart cities.

## References

[1] World Health Organization, "Aging and health," https://www.who.int/news-room/fact-sheets/detail/ageing-and-health, February 2018.

[2] T. Yonezawa, I. Arai, T. Akiyama, and K. Fujikawa, "Random forest based bus operation states classification using vehicle sensor data," in *2018 IEEE International Conference on Pervasive Computing and Communications Workshops (PerCom Workshops)*, March 2018, pp. 747–752.

[3] H. Nakashima, I. Arai, and K. Fujikawa, "Passenger counter based on random forest regressor using drive recorder and sensors in buses," in *2019 IEEE International Conference on Pervasive Computing and Communications Workshops (PerCom Workshops)*, March 2019, pp. 561–566.