Overview of Technical Development and Verification in the Connected-vehicle Field

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Abstract

As technological innovations, such as connectivity, automation, sharing, and electrification, bring major changes to the automotive industry, expectations for and the importance of information and communication technology (ICT) are increasing rapidly in the industry. The NTT Group and Toyota Motor Corporation are collaborating on the research and development of an ICT platform for connected vehicles. They conducted joint field trials from 2018 to 2020 and established the basic technology through various use cases and verification of the platform. In the Feature Articles in this issue, the NTT Group operating companies and NTT laboratories that are participating in the collaboration present the details of the field trials, the results, technologies applied, value provided, and future issues.

Keywords: connected vehicle, IoT, big data

1. Overview of connected vehicles

A connected vehicle, which is a mobility device equipped with communication capability, consists of various components, including a vehicle, communication networks (wired and wireless), and cloud computing (**Fig. 1**). To implement these components, it is necessary to develop, use, and combine a wide range of technologies, including networks for exchanging data, edge computing for data processing in the proximity of connected vehicles, a platform for storing and processing collected data, platform for analyzing and using data, and software updates.

As the potential for using big data expands, the volume of data to handle is expected to increase dramatically. Therefore, information and communication technology (ICT) platforms, such as networks and datacenters, that receive data from connected vehicles are growing in importance.

2. Potential of vehicle big data

Connected vehicles are already in use, and the market for them will continue to expand. If the large amount of data held by connected vehicles can be processed quickly and at low cost, it will become possible to use information that cannot be captured with current sensors and provide faster and more reliable services. This will in turn not only improve convenience and efficiency but also enable people to drive more safely and securely, alleviate or eliminate traffic congestion, and shorten travel time, which will contribute to achieving carbon neutrality (**Fig. 2**).

3. Purpose and areas of joint research and development

In March 2017, the NTT Group and Toyota Motor Corporation agreed to collaborate in developing, verifying, and standardizing technologies needed in the connected-vehicle field by combining Toyota's vehicle-related technologies and NTT Group companies' ICT-related technologies.

By sharing the technologies and expertise of each company and using big data obtained from vehicles, the NTT Group and Toyota will work together to research and develop the technologies needed to solve problems facing society, such as traffic accidents

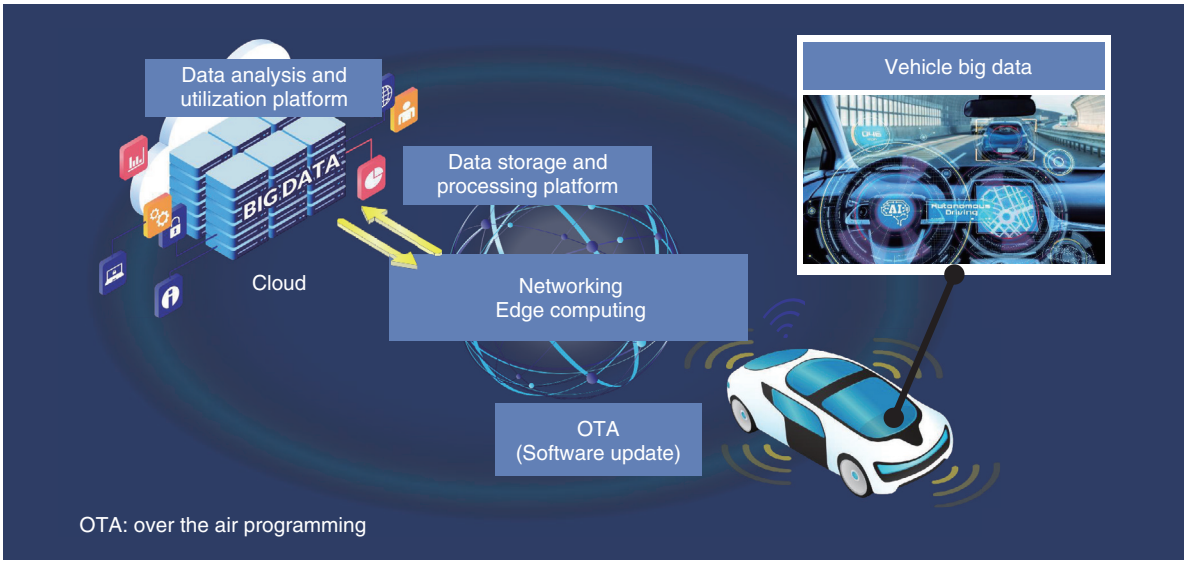

Fig. 1. Overview of a connected vehicle.

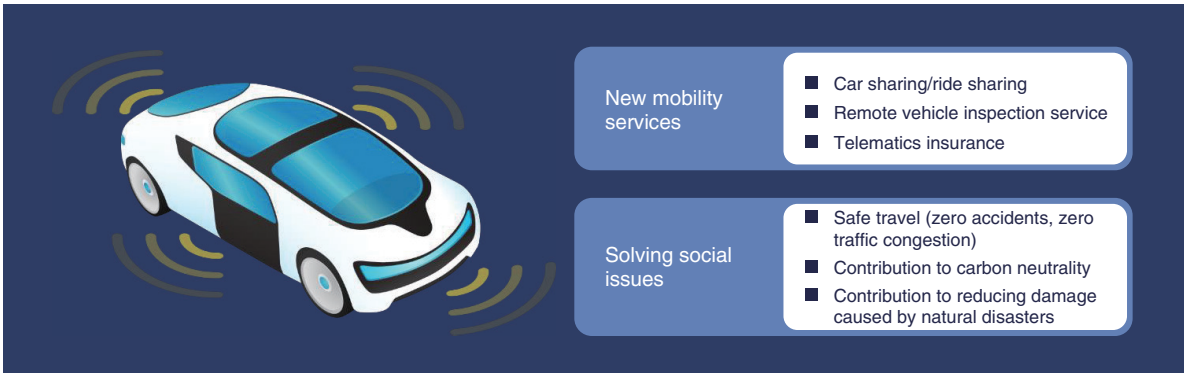

Fig. 2. Value provided by vehicle data.

and congestion, and provide new mobility services to customers. The collaboration is aimed at creating a sustainable smart mobility society from a global perspective.

The collaboration activities can be broadly divided into the following three technical areas:

(1) Data collection/storage/analysis platform: Establish a mechanism for storing and analyzing data sent from millions or tens of millions of vehicles.

(2) Internet of Things (IoT) network and datacenter: Establish an optimal arrangement of networks and datacenters for collecting data from vehicles around the world.

(3) Next-generation communication technology: Verify technology for vehicles to use the 5th-generation mobile communication system (5G) and verify the applicability of edge computing.

In December 2018, we set the goal of processing a large volume of data from within and outside vehicles to reproduce the physical space in the real world in real time (within seconds) and with a precision of tens of centimeters. We carried out field trials that covered the end-to-end mobility system including vehicles, networks, and datacenters.

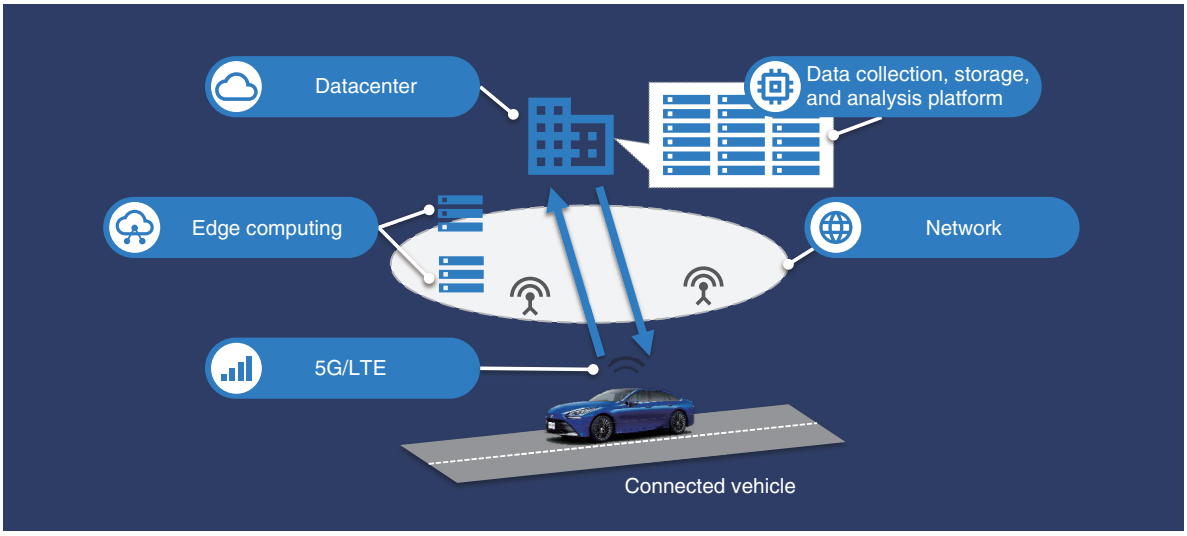

Fig. 3. Overview of the ICT platform for connected vehicles.

4. ICT platform for connected vehicles

The ICT platform for connected vehicles connects vehicles equipped with communication capability with edge computing nodes and the cloud through LTE (Long-Term Evolution), 5G, and IoT networks. It also uses computing resources to collect, store, and analyze data that are held or collected by vehicles (**Fig. 3**).

Data from connected vehicles are uploaded to datacenters through the mobile network and edge nodes. The datacenter then collects, stores, and analyzes the data and returns the analysis results to vehicles through the network as necessary. Although this data flow is not much different from that of smartphones and small IoT devices, a mechanism for real-time, large-scale, and accurate processing of such data will become one of the important infrastructures for supporting people's daily lives and society at large.

5. Method of conducting joint research and development

The joint research and development was conducted in two alternating activities: technical studies by a working group and verification of its study results using actual vehicles (**Fig. 4**).

In the working group weekly meetings, engineers from the two parties discussed multiple themes in parallel. The working group's discussion results were verified using a testbed that involved more than a hundred physical servers, 5G, other communication links, and actual vehicles. The verification results were then fed back to the working group. This cycle was then repeated over a short period. The working group members were proud of the fact that the two parties grew together by bringing together their technologies and expertise and by repeating the above cycle, therefore quickly solved various technical issues.

6. Activities in the collaboration on connected vehicles

The field trials of the ICT platform for connected vehicles were conducted from FY2018 to FY2020. The following two articles in this issue give an overview and the details of the field trials from the perspectives of NTT DATA and NTT Communications, which played a central role in the trials. These articles also introduce the technical results and achievements obtained and future challenges identified in the trials.

(1) Activities and results of field trials—reference architecture for a connected-vehicle platform: The overall architecture and verification of the platform through use cases and verification results are presented [2].

(2) Activities and results of field trials—network edge computing platform: An overview, the features, and methods of the platform are presented [3].

The ICT platform for connected vehicles involves a

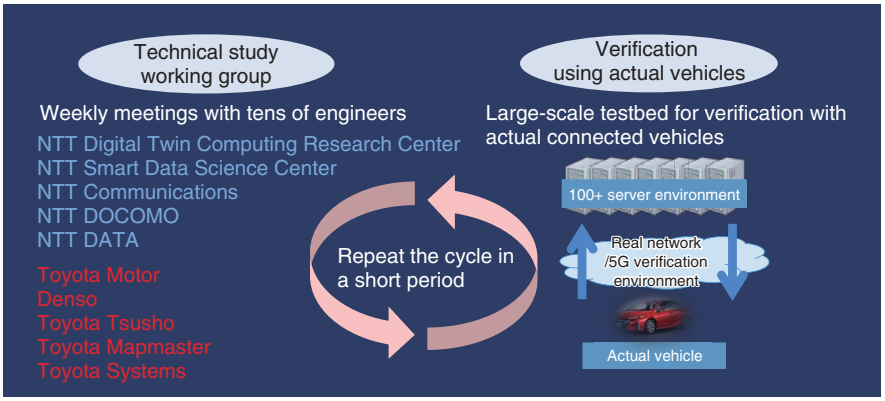

Fig. 4. Method of conducting the joint research and development.

variety of technical challenges. The following five articles in this issue focus on representative technologies that have been studied and developed to solve these challenges and provide overviews of these technologies and value they provide, including verification through use cases and field trials, and identify remaining challenges.

(3) Real-time spatiotemporal data-management technology (Axispot™): This technology stores, searches, and analyzes large volumes of data on dynamic objects [4].
(4) Selective vehicle-data-collection algorithm: This technology determines data-collection priorities on the basis of meta-information, such as vehicle positions and time, observation range, and the effects of shielding by surrounding vehicles [5].
(5) Vertically distributed computing technology: This technology effectively uses limited server resources by dynamically changing the response-processing server on the basis of vehicle status [6].
(6) Lane-specific traffic-jam-detection technology: This technology detects lane-specific traffic jams by collecting and analyzing dashcam video and driving data to achieve optimal lane navigation [7].
(7) Technology for calculating suddenness index for aggregated values: To reduce the amount of processing on the ICT platform, this method calculates an index for periodic and sudden changes in aggregated values collected from vehicles on the basis of the degree of deviation from the ordinary state [8].

7. Results and future outlook

"The Technical Document on the ICT Platform for Connected Vehicles" was compiled and published in November 2021 to report on the results and challenges of the three-year field trials [9]. We are hoping that the results of our activities will be widely used not only by those in the ICT and mobility industries but also by those in other industries.

The NTT Group and Toyota will continue to improve the speed, efficiency, and sophistication of the ICT platform for connected vehicles in preparation for the further spread of such vehicles. We will also continue to develop technologies that will contribute to solving problems facing society, such as traffic accidents and congestion, by effectively using big data collected from vehicles and by creating value from such data.

We will also use the obtained technical results to plan social implementation of the ICT platform for connected vehicles and the deployment of the verified technologies in smart cities. We will develop technologies for providing high-speed, high-capacity communications and vast computing resources beyond the limits of the conventional platform and collaborate with various companies, organizations, and service providers to create and provide new mobility services, thereby contributing to achieving carbon neutrality and creating a sustainable smart mobility society that brings safety and security to people.

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