Implementation and Evaluation of Priority Processing by Controlling Transmission Interval Considering Traffic Environment in a Dynamic Map

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Resume

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  - My research interest includes Dynamic Map and Edge Computing.

- **Dynamic Map 2.0 Consortium**
  - We research and develop a Dynamic Map platform that covers cloud, edge and embedded.
  - https://www.nces.i.nagoya-u.ac.jp/dm2/

Dynamic Map 2.0 Consortium

Summary

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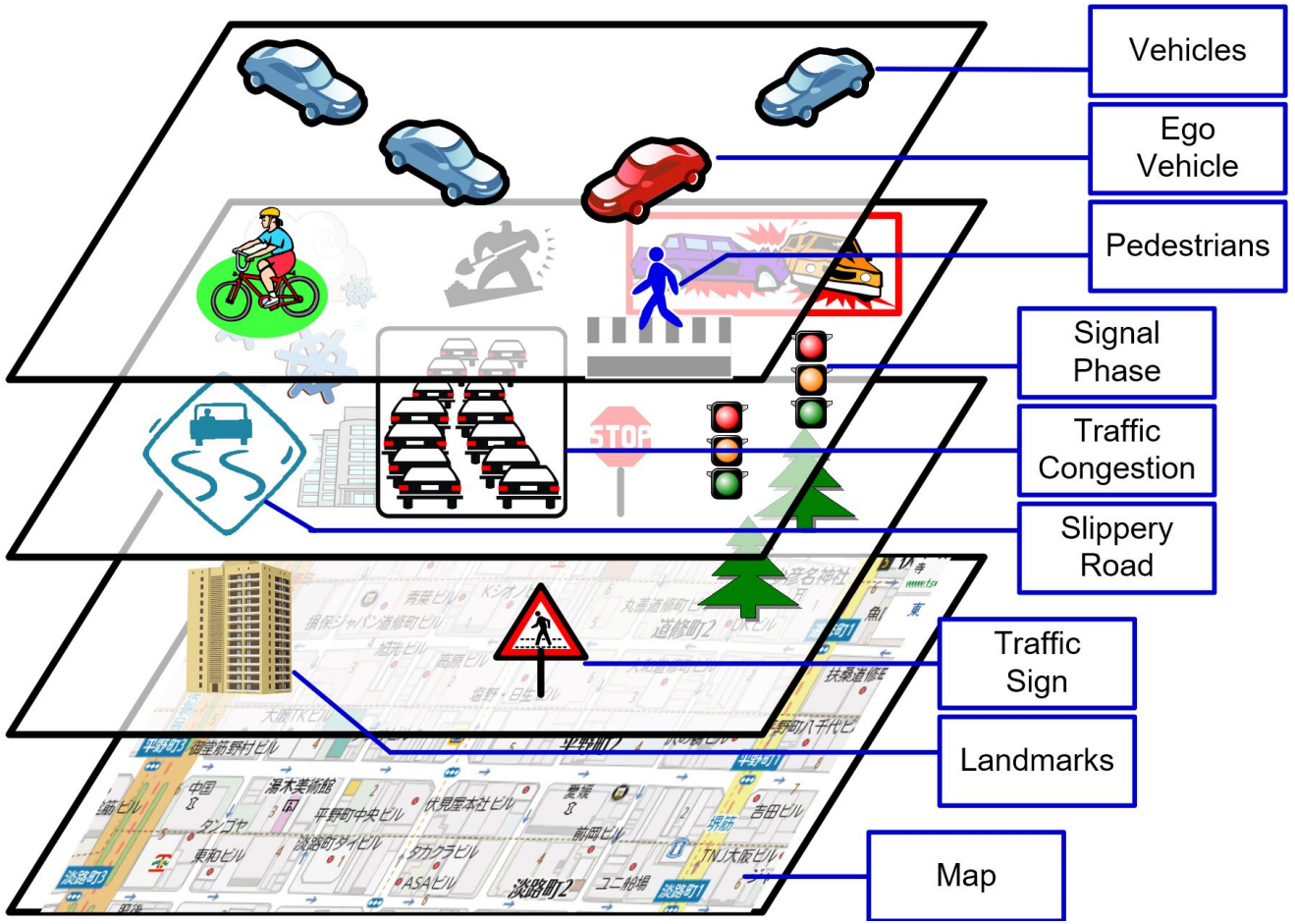
Introduction

Background, Motivation, Contribution

Background

- Recently, there has been a lot of research on **Intelligent Transport System**, which aims to improve safety by sharing sensor information on vehicles using wireless communication technology.
- However, currently the data sent by the vehicle is managed separately for each application.

  → As a means of solving the **problem of data management and processing**, **Dynamic Map**, which is integrated information and communication platforms, are focused on.

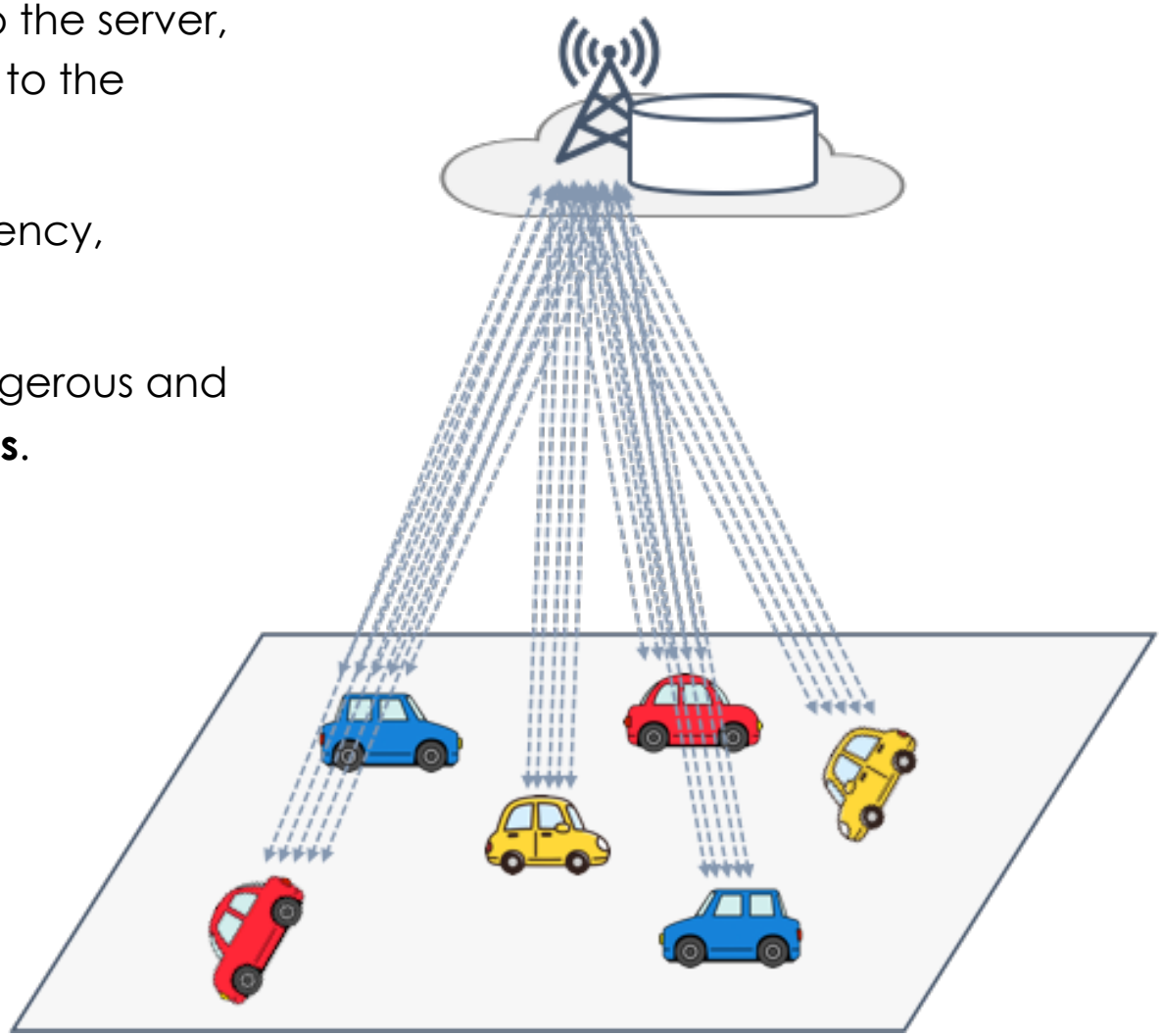


- J. Zhang, F. Wang, K. Wang, W. Lin, X. Xu and C. Chen, "Data-Driven Intelligent Transportation Systems: A Survey," IEEE Transactions on Intelligent Transportation Systems, vol. 12, no. 4, 2011, pp. 1624–1639.
- K. Sato, Y. Watanabe and H. Takada, "Dynamic Map as Common Application Platform for Dynamic Geographic Information Management," The journal of the Institute of Electronics, Information and Communication Engineers, vol. 101, no. 1, 2018, pp. 85–90.

Motivation

- The dynamic information of the vehicle is always sent to the server, which **has to process it at low latency and send it back** to the vehicle.
- If all the vehicles continue to send data at a high frequency, congestion is a concern.

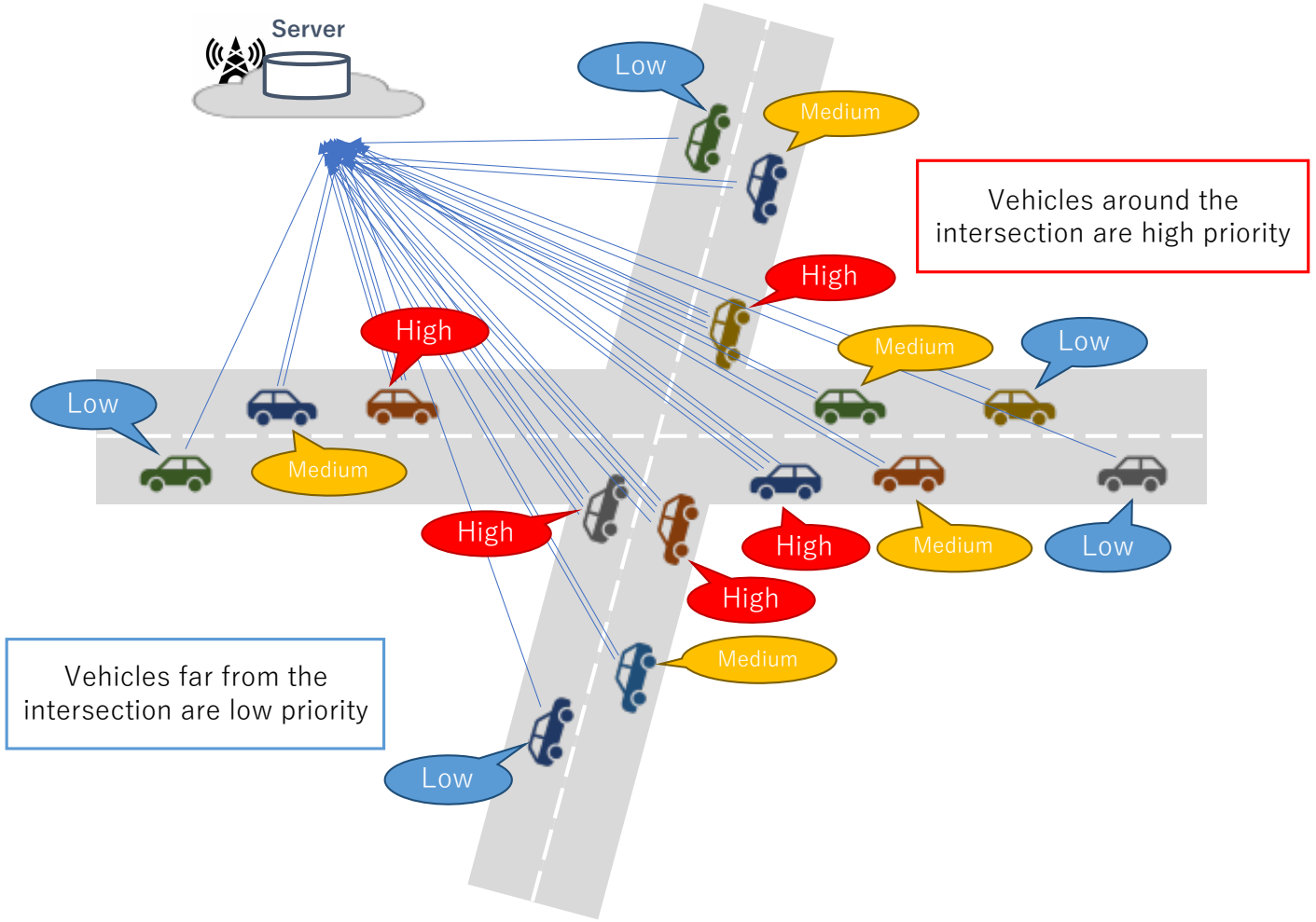
  → **A delay in the sharing of information** on highly dangerous and accident-prone vehicles **will cause safety problems**.



- S. Steven and K. Thomas, “Traffic probe data processing for fullscale deployment of vehicle-infrastructure integration,” Transportation research record, vol. 2086, no. 1, 2008, pp. 115–123.
- NTT Docomo and Pasco, “Realization of efficient updating and distribution of advanced map database.” https://smartiot-forum.jp/application/files/6414/7702/6769/sympo 20160927 02 mobility 03-03.pdf

Contribution

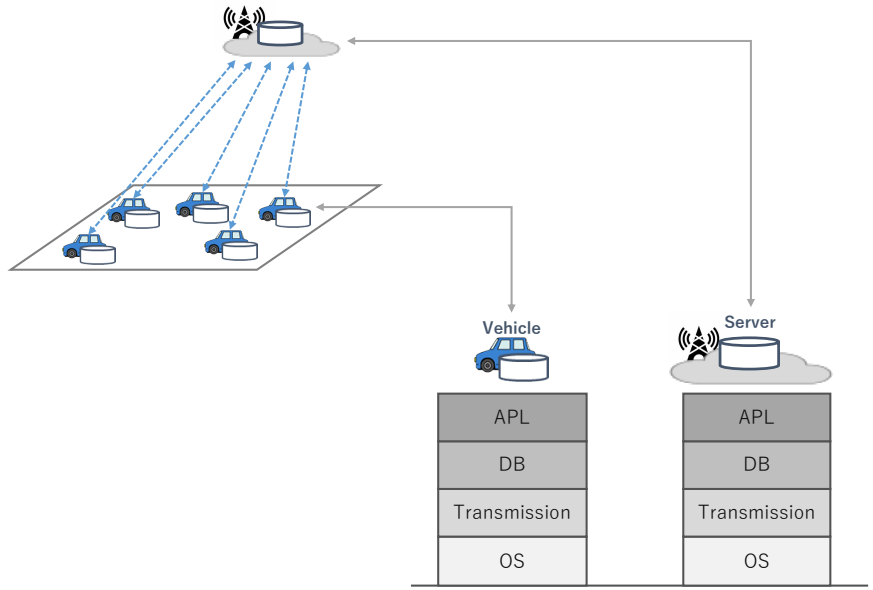
- We aim to reduce the communication load by determining the **data transmission interval based on the traffic environment** around the vehicle.
- The system divides a lane into sections (**LID**) and determines the **priority** of each section to provide a highly scalable priority processing function.
- We simulate driving on a dynamic map and evaluate the effectiveness of the vehicle.

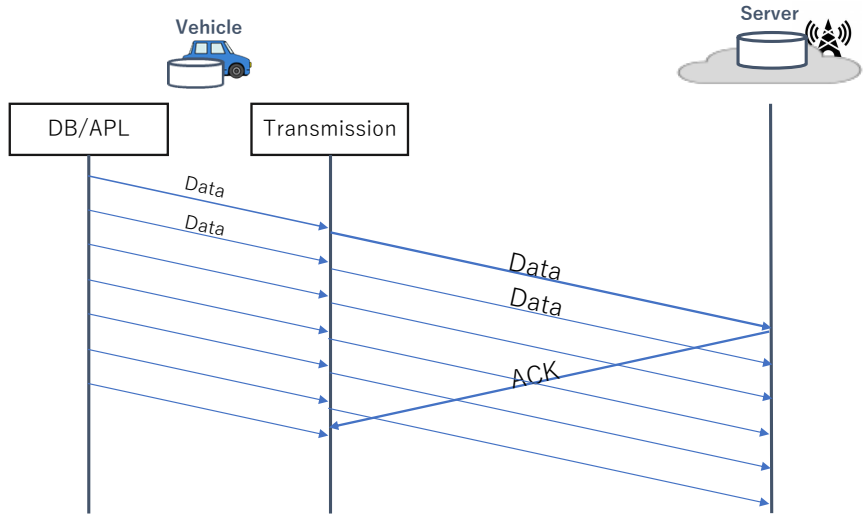


Approach

Dynamic Map

- We have developed a dynamic map consisting of vehicles and servers with **unique ID** (**SID**).
- Each node consists of four layers: OS/hardware, communication, database, and application.
- The vehicle needs to send and receive data to and from the server at high speed, so it communicates with the server using **UDP**.
- The UDP is a **connectionless** protocol and there is **no guarantee of packet delivery**.
  - Therefore, we implemented a function in which the server **sends back the acknowledgement data of receipt** (**ACK**) at the application side.



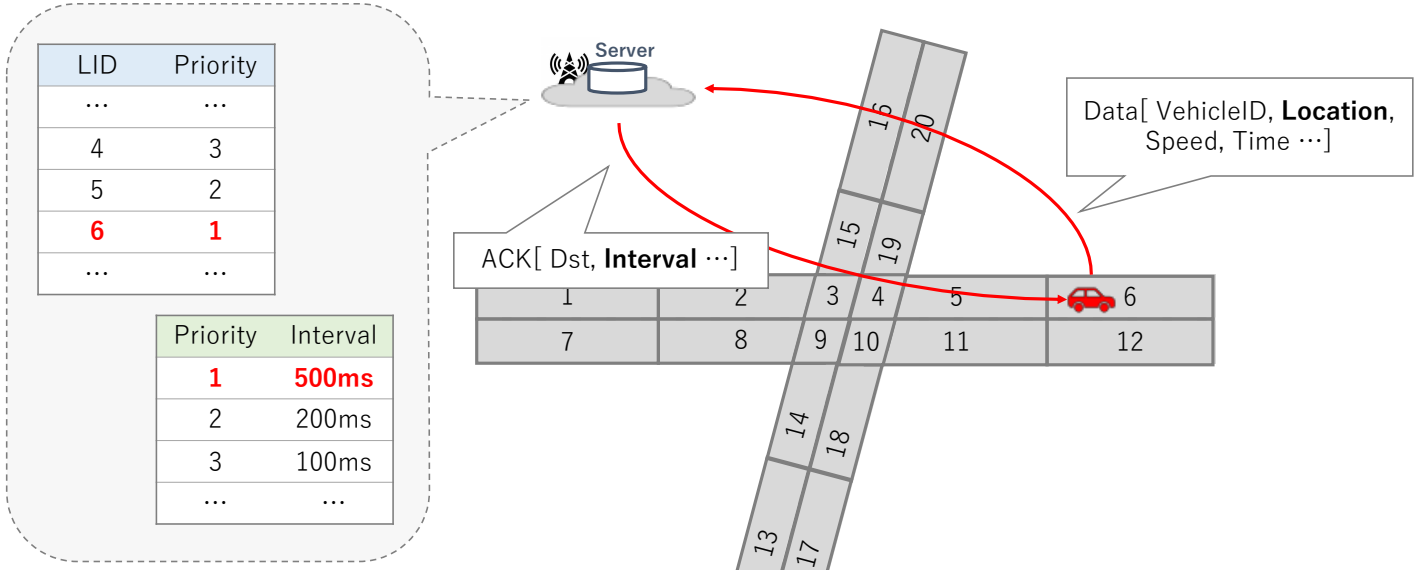


- J. Postel, "User Datagram Protocol," 1980, RFC 768.
- C. Shue, W. Haggerty and K. Dobbins, "OSI Connectionless Transport Services on top of UDP Version: 1," 1991, RFC 1240.

Adjusting the Transmission Interval 1/2 | Overview

- In intersection mediation applications, there is a need to obtain information on vehicles in and around the intersection at a high frequency.
- However, the information about the position of vehicles away from the intersection need not be so frequent.
- Therefore, **the priority is set according to the vehicle position** (**LID**), and **the transmission interval from the vehicle is adjusted** in the vehicle's communication unit itself.

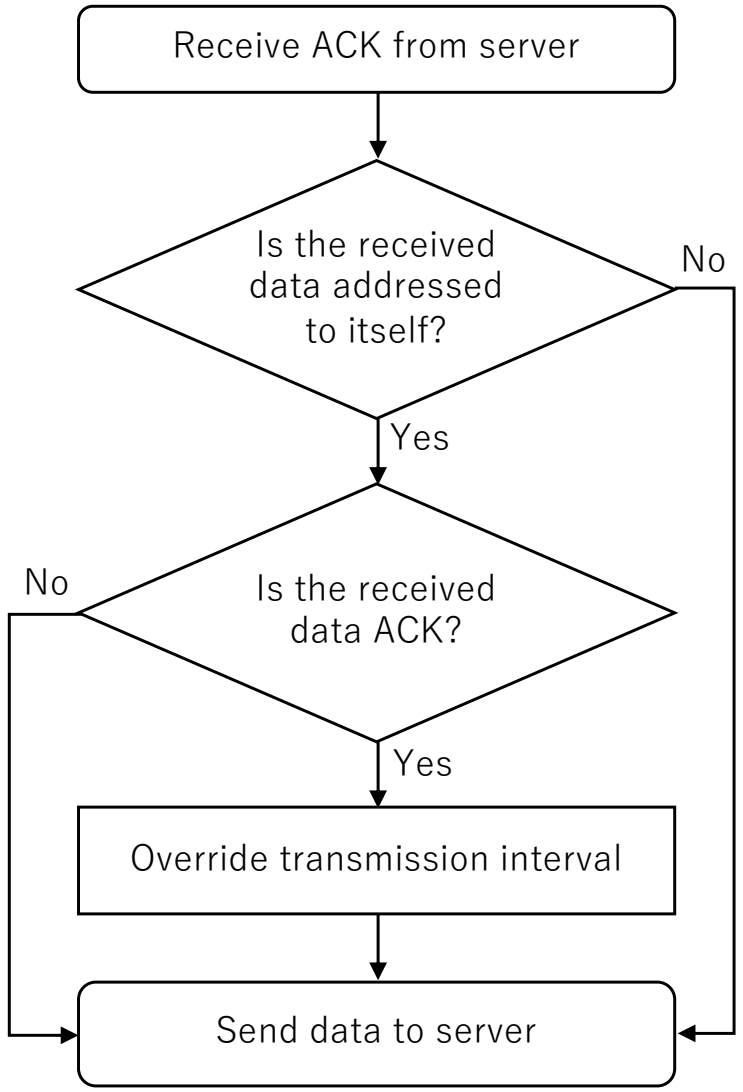
  → This is to minimize the impact on traffic, thereby **reducing communication bandwidth constraints and server processing load**.



- U. Franke, D. Gavrila, S. Gorzig, F. Lindner, F. Puetzold and C. Wohler, “Autonomous driving goes downtown,” IEEE Intelligent Systems and their Applications, vol. 13, no. 6, 1998, pp. 40–48.
- M. Gerla, E. Lee, G. Pau and U. Lee, “Internet of vehicles: From intelligent grid to autonomous cars and vehicular clouds,” 2014 IEEE World Forum on Internet of Things (WF-IoT), 2014.

Adjusting the Transmission Interval 2/2 | Flow

1. The vehicle sends the data to the server.
2. The server **judges the priority from the LID** in the data and determines the transmission interval.
3. The information is included in the ACK and sent to the vehicle.
4. The vehicle that receives the data **judges the destination from the SID in the ACK**.
5. The vehicle adjusts the transmission interval from the information in the ACK.



Prioritization in Consideration of the Traffic Environment

- The transmission interval is adjusted from the traffic environment based on the three tables.
  - Table 1: Priorities for each road feature.
  - Table 2: Transmission interval for each priority.
  - Table 3: Road characteristics for each LID and determine the transmission interval.
- Tables can be **normalized to allow for flexible changes** in operation.

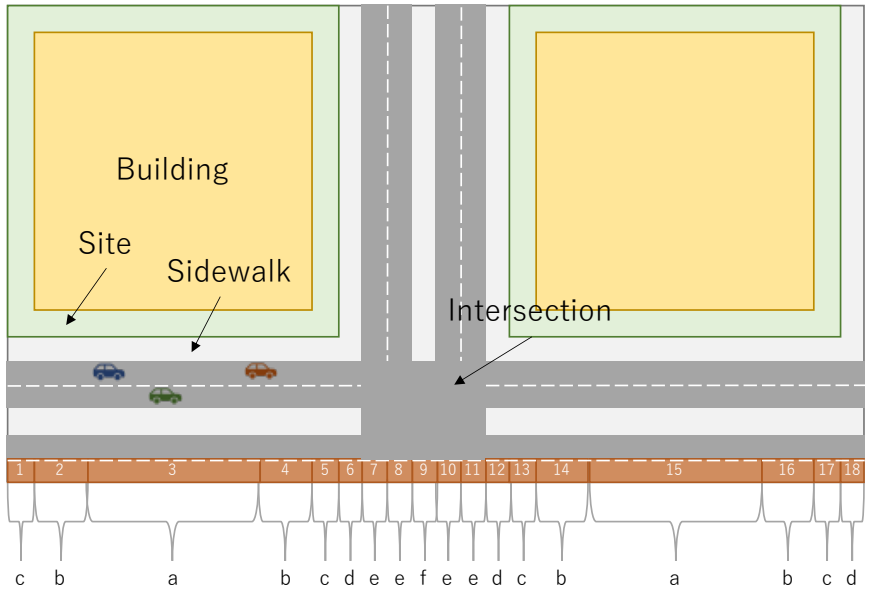


Table 1

Symbol in the figure	Road characteristics	Priority
a	Building site center	1
b	Building site	2
c	Building site edge	3
d	Sidewalk / Side road	4
e	Lane	5
f	Intersection center	6

Table 2

Priority	Transmission interval
1	500ms
2	300ms
3	200ms
4	100ms

Table 3

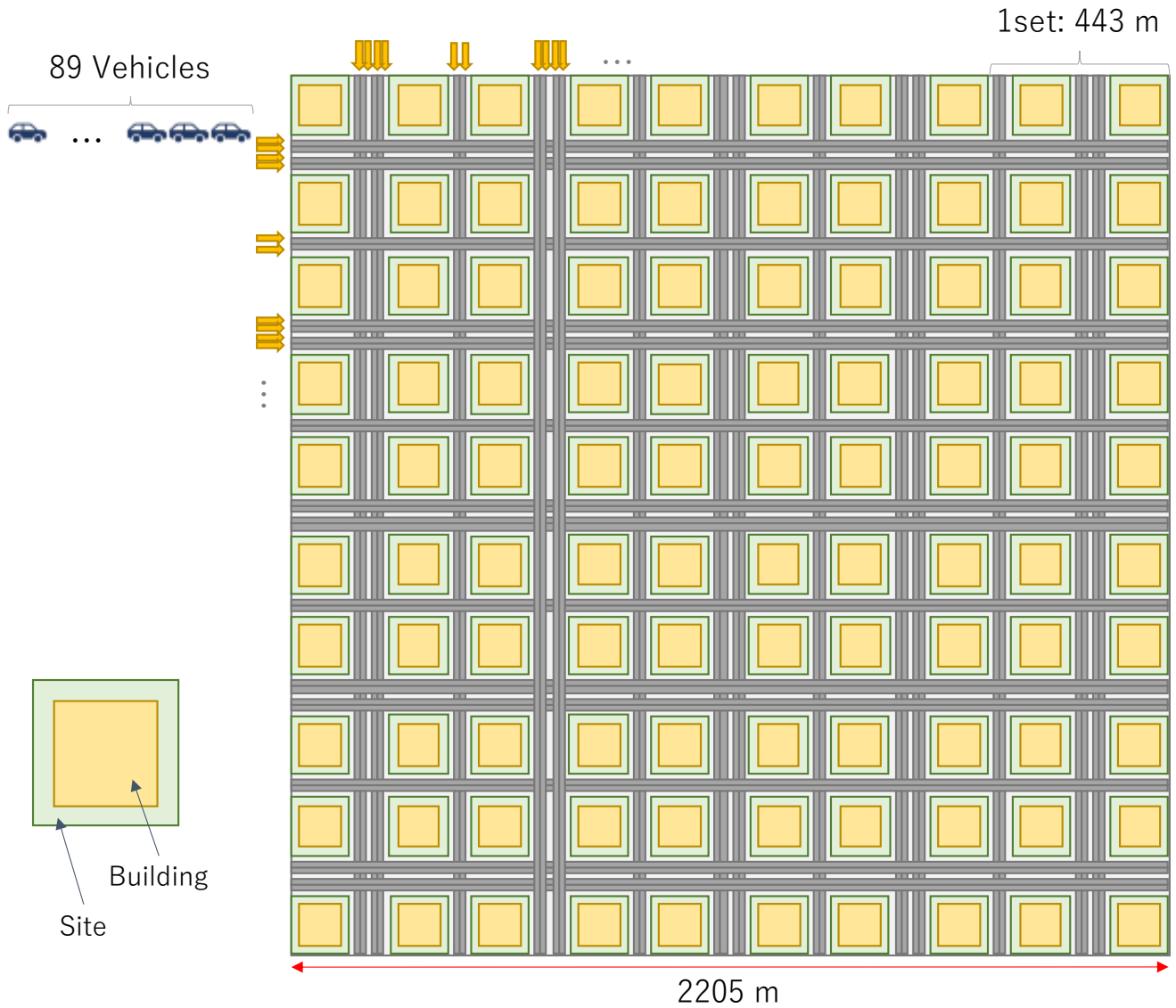
Lane ID	Transmission interval
1	200ms
2	300ms
3	500ms
4	300ms
5	200ms
…	…

Evaluation

Evaluation System

- We simulated driving on **a Manhattan model** with alternating two-lane and four-lane roads.
- In the simulation, a **4.7-meter-long vehicle** runs in **a formation with 20-meter intervals** and the transmission interval is adjusted according to the road characteristics.

Number of lanes	**56**
Vehicles per lanes	**89**
Speed	**40km/h**
Vehicle length	**4.7m**
Distance between vehicles	**20m**
Total vehicles	**4984**



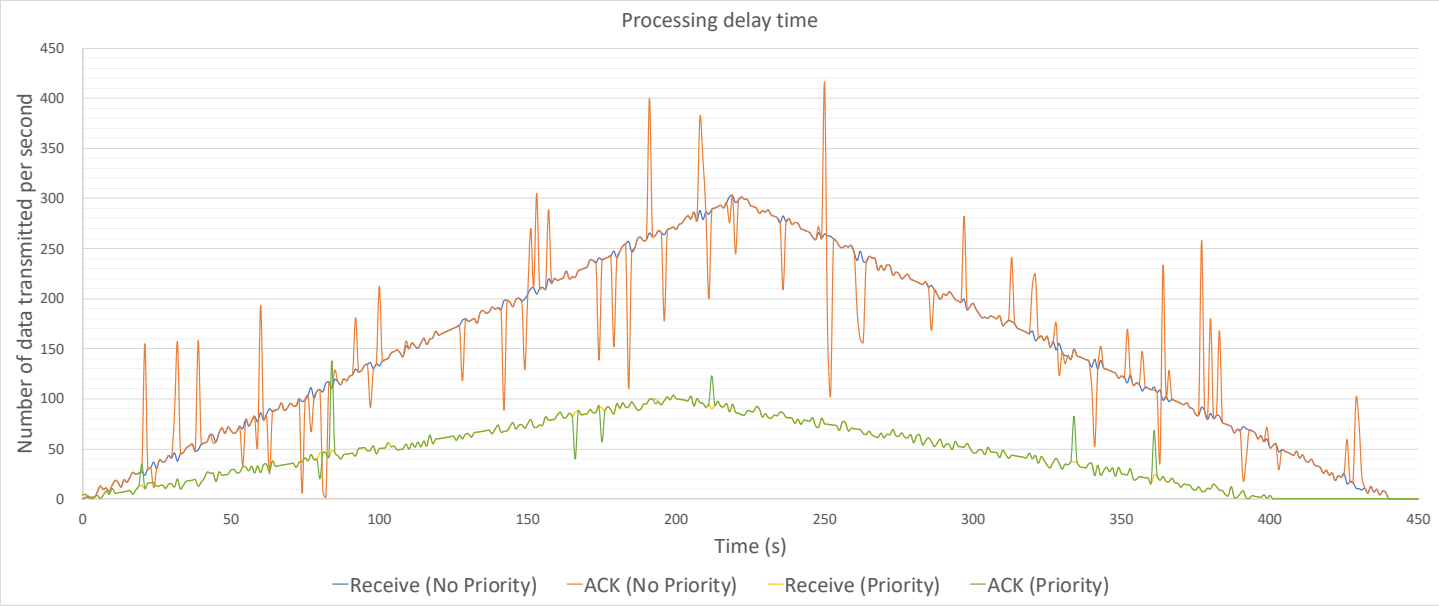
Result 1/3 | Number of Data Received

- We evaluated the **maximum number of data received by the server per second** from the vehicle.
  - **Packet loss has been reduced to zero** by the resend function.
  - The maximum number of data received is higher than that without resend function is only **instantaneous**, and **the total number of data received remains almost the same**.
- The priority processing reduces the maximum number of data received by about **75%** and the total number by about **70%**.

System	Total Receive Data	Packet Loss rate
No Resend & No Priority	**9867726**	**0.006%**
Resend & No Priority	**9868313**	**0%**
Resend & Priority	**3083852**	**0%**

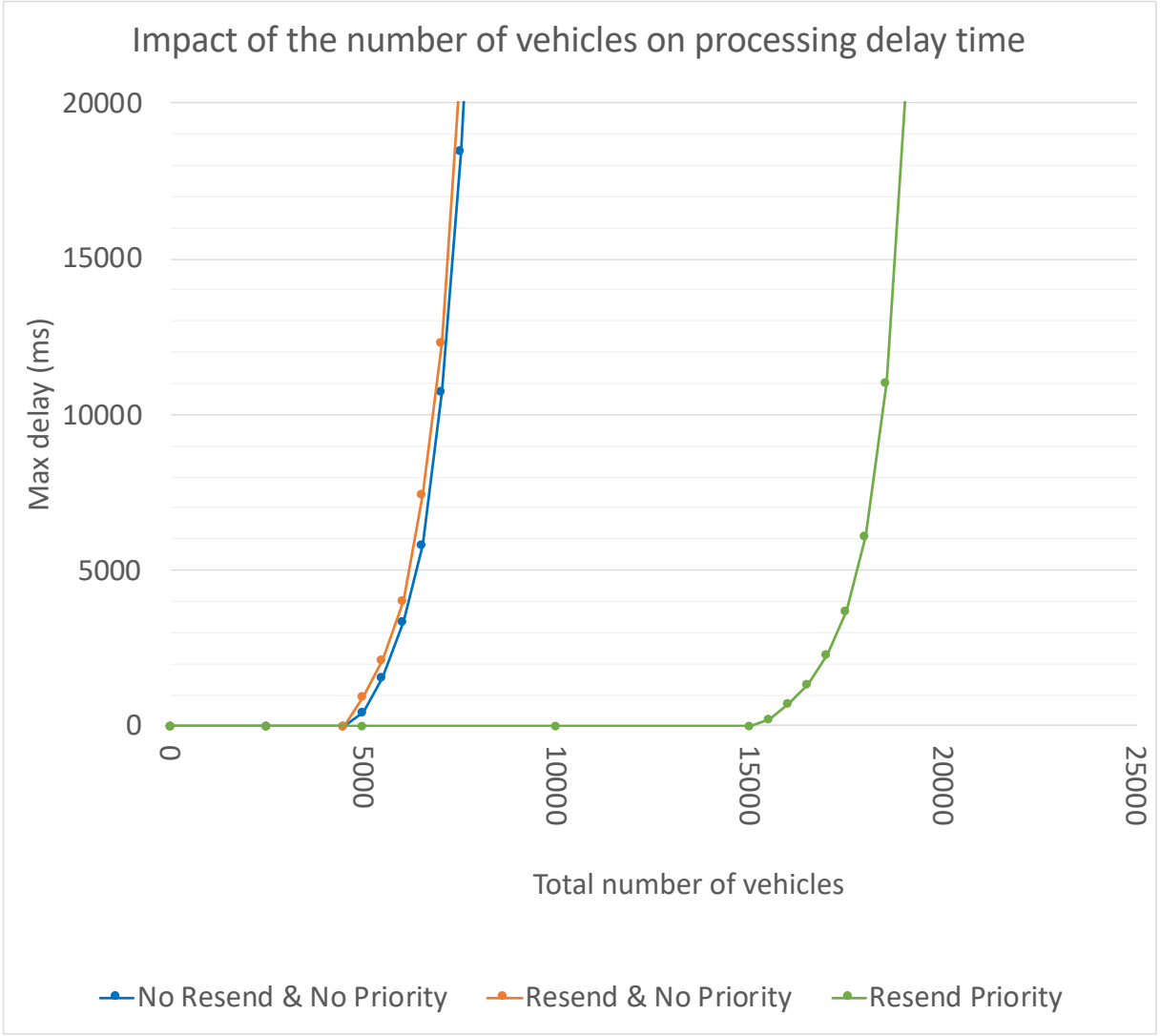
Result 2/3 | Trends in the Number of Data Sent and Received

- We evaluated the **amount of data sent and received per second** by the server.
- With the priority processing function, data were sent and received with a peak of 200 seconds after the start of the most vehicles in the simulation environment, and **data were communicated and processed without delay**.
- Without the priority processing function, **the application on the server is overloaded** because of the large number of data sent and received, which **causes delays in processing** because of the accumulation of data even when the number of vehicles exceeds 200 seconds, which is the peak number of vehicles.



Result 3/3 | Scalability of Each System

- We evaluated the **scalability of each system** by adjusting the number of vehicles on the road by varying the range of roads in the simulation environment and **by measuring the processing delays**.
- As for the existence of the resend function, the average number of data sent and received remained almost the same, and the number of marginal vehicles was almost the same.
- The dynamic map with a priority processing function **was able to process about three times as many vehicles without delay as the dynamic map without it**.



Discussion, Conclusion

Discussion

- Although the **resend** function **increased the instantaneous maximum data** sent and received by the server, **the average amount of data sent and received remained the same**, and **packet loss was reduced**.
- In addition, **the amount of data was efficiently reduced** by the **priority processing** function.

> **Since more connected cars are expected to communicate with servers in the future, our system contributes to the problem of scalability for dynamic maps without any impact on safe traffic.**

- **Future Work**
  - Considering factors other than intersections, more specific prioritization methods are discussed.
  - Considering the priority vehicles, we plan to develop **an efficient prioritization method on the server side** instead of adjusting the transmission interval on the vehicles themselves.

Conclusion

Goal	In a dynamic map, priority processing is achieved by adjusting the data transmission interval for efficient data delivery.
Approach	We implemented a resend function based on the response data (ACK) of the server to the data sent from the vehicle. The server decides the transmission interval based on the vehicle position (LID), loads it onto the ACK and sends it back to the vehicle, and then adjusts the transmission interval on the vehicle side.
Results	We have reduced the number of data transmissions efficiently compared to the conventional dynamic map with constant transmission intervals.