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A Study on the Verification of Traffic Flow and Traffic Accident Cognitive Function for Road Traffic Situation Cognitive System

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Abstract

Owing to the need to establish a cooperative-intelligent transport system (C-ITS) environment in the transportation sector locally and abroad, various research and development efforts such as high-tech road infrastructure, connection technology between road components, and traffic information systems are currently underway. However, the current central control center-oriented information collection and provision service structure and the insufficient road infrastructure limit the realization of the C-ITS, which requires a diversity of traffic information, real-time data, advanced traffic safety management, and transportation convenience services. In this study, a network construction method based on the existing received signal strength indicator (RSSI) selected as a comparison target, and the experimental target and the proposed intelligent edge network compared and analyzed. The result of the analysis showed that the data transmission rate in the intelligent edge network was 97.48%, the data transmission time was 215 ms, and the recovery time of network failure was 49,983 ms.

Index Terms: Intelligent transportation systems, Edge networks, Traffic awareness, Traffic information systems

I. INTRODUCTION

Research conducted to combine information and communication technologies in various industries, and research and development of cooperative-intelligent transport systems (C-ITSs) and autonomous vehicle technologies are actively underway in the smart city field. A smart city refers to an urban model that can solve various urban problems and create a sustainable city by combining new technologies such as information and communication (ICT), vast information (big data), and artificial intelligence (AI) for use in cities [1,2].

Although it is similar to the U-city project that began in 2009, the next-generation smart city integration center, which combines network technology and the AI technologies of the Fourth Industrial Revolution, collects and analyzes information generated in cities to provide information to citizens in various and efficient ways. In the transportation sector, which is a key element of smart cities, research and development are underway focusing on traffic safety and convenience using C-ITS and autonomous vehicle technology [3,4].

A C-ITS is an intelligent transportation system that can improve transportation convenience and traffic safety by collecting, managing, and providing traffic information between all components such as automobiles, road infrastructure, drivers, and pedestrians through vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications and road infrastructure [5].

To realize this, transportation services such as the continuous research and development of each element technology

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constituting the C-ITS, high-tech road infrastructure through national projects, real-time traffic information provision, and bus operation management verified through a pilot operation and introduced on-site. In addition, research and development related to the establishment of network infrastructure such as vehicle terminals, wireless access in vehicular environment (WAVE) communication, and dedicated short-range communication for vehicle-to-everything infrastructure are currently underway. As such, a C-ITS requires an environment in which technologies from various industrial fields are combined and various pieces of information are linked together [6].

However, the high-tech road infrastructure for information collection and provision is far from sufficient and is, in fact, insufficient to establish a C-ITS focused on traffic safety through recognition and transmission of road conditions. The currently established road infrastructure installed at a specific point or a certain section, such as where a change in speed occurs, aims to collect traffic and speed data, and to present communication information to road users. As the development of autonomous vehicle technology accelerates, the importance of unexpected information highlighted and the value of information utilization increases accordingly. Self-driving cars are equipped with several sensors and equipment to acquire information about their surroundings. However, unexpected situations do not always occur within the sensor detection area of an autonomous vehicle; rather, most of them occur outside the detection area. Therefore, it is necessary to secure the diversity, reliability, and speed of information by delivering information to autonomous vehicles through the surrounding infrastructure and through the method used by self-driving cars for acquiring information directly [7].

In this paper, we propose an intelligent edge network technique for organic information linkage and real-time processing of the road infrastructure in a C-ITS state-of-the-art road environment. Based on the proposed intelligent edge network, a transportation system that recognizes traffic flows and traffic accidents developed. To verify the proposed intelligent edge network construction technique and transportation system, we conducted an experiment at a road site and analyzed the experimental results.

II. RELATED WORKS

A proposed quantitative methodology developed to determine the strength of supersaturated conditions. A signal time plan designed to minimize the saturation of major roads by measuring the queue length at the start of the red signal and by estimating the green time delay of vehicles that could not depart because of pre-signal blocking. The results showed that a clear performance improvement be achieved in the supersaturated scenario by applying a traffic delay and congestion mitigation strategy that considers the queue. We studied the development of tools to reduce fuel losses by using the traffic signal information received through the traffic signal control and vehicle connection, which account for a large portion of vehicle fuel loss at signal intersections. In fact, the connection between the vehicle and the infrastructure can provide information to the vehicle, which was previously impossible. We performed an experiment in an agent-based environment developed in MATLAB using the RPA Automotive Follow-Up Model for the V2I and V2V standards. The results of the corrected actual intersection simulation showed fuel savings of up to nearly 30% on average. The amount of fuel reduction was high for a small volume and decreased as the traffic volume increased [8].

A transit time model developed for the entire section, with the passage time and delay time caused by the intersection signal control during intermittent oversaturation, and a model developed to estimate the initial number of waiting vehicles using the queue length of the COSMOS (Cycle, Offset, Split Model for Seoul) signal control system. In particular, the initial vehicle calculation model and the travel time method evaluated using the VISSIM simulation tool for various traffic situations. Based on accurate vehicle information, an estimation algorithm of the traffic situation was developed that better reflects the characteristics of the individual vehicles presented, and a traffic light control system that can more efficiently reflect the estimates was studied. The green time calculated using the queue length obtained by the vehicle coordinates, and the average vehicle speed obtained by the vehicle speed, and additional green time allocated to consider the queue length when driving by treating the vehicles in the queue as one vehicle group. To construct the system, we assumed that the exact location of the individual vehicles tracked in real time using ultra-wideband sensors and image detectors, and that information such as speed, acceleration, and length of individual vehicles collected in real time through WAVE communication [9].

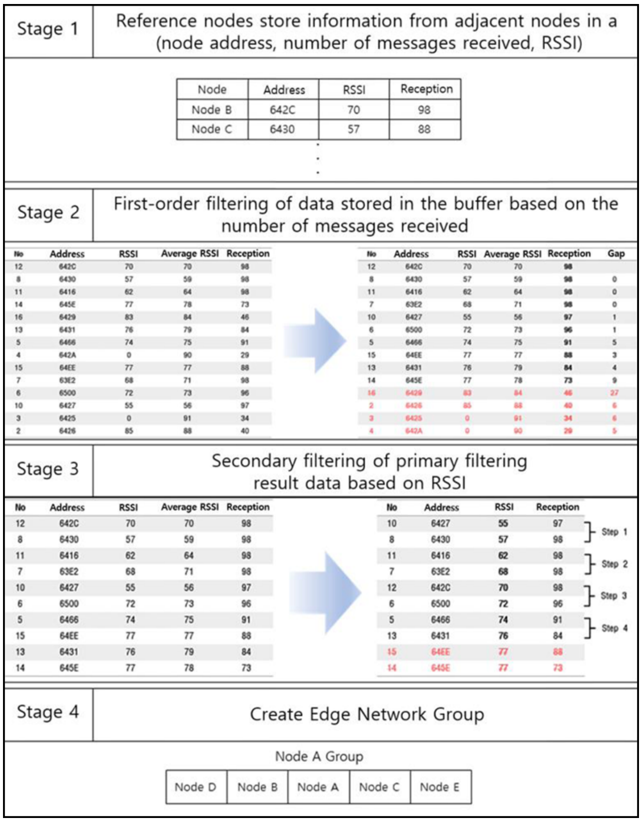
For the simulation analysis at intersections, there were difficulties in the temporal and economic phenomena. Therefore, SUMO, a microscopic traffic simulation environment, used. From the result of the analysis, it confirmed that CO_2 reduced by decreasing the average waiting time through an optimization operation for the actual intersection environment. However, it did not improve significantly in situations where the saturation increased or where worse manifestations produced in the supersaturated state. In future tasks, it seems necessary to present various control scenarios according to saturation; however, interlocking control cannot properly considered in situations where there are more than two intersections [10].

Traffic pattern learning, route searching, traffic congestion searching, and multiple intersection control algorithms proposed efficiently control the traffic volume of the intersection because of the limitation of the fixed signal control in the urban traffic environment.

III. SYSTEM DESIGN

The edge network proposed in this paper and the recognition system for the traffic situation based on it consist of the following:

- IoT devices for traffic information collection and provision.
- An intelligent edge network, which is a connection technique between IoT devices.
- Traffic flow and cognitive algorithms for avoiding traffic accidents.
- Monitoring software.



Stage 1 — Reference nodes store information from adjacent nodes in a (node address, number of messages received, RSSI)

Node	Address	RSSI	Reception
Node B	642C	70	98
Node C	6430	57	88

Stage 2 — First-order filtering of data stored in the buffer based on the number of messages received

No	Address	RSSI	Average RSSI	Reception
12	642C	70	70	98
8	6430	57	59	98
11	6416	62	64	98
14	645E	77	78	73
16	6429	83	84	46
13	6431	76	79	84
5	6466	74	75	91
4	642A	0	90	29
15	64EE	77	77	88
7	63E2	68	71	98
6	6500	72	73	96
10	6427	55	56	97
3	6425	0	91	34
2	6426	85	88	40

No	Address	RSSI	Average RSSI	Reception	Gap
12	642C	70	70	98	
8	6430	57	59	98	0
11	6416	62	64	98	0
7	63E2	68	71	98	0
10	6427	55	56	97	1
6	6500	72	73	96	1
5	6466	74	75	91	5
15	64EE	77	77	88	3
13	6431	76	79	84	4
14	645E	77	78	73	9
16	6429	83	84	46	27
2	6426	85	88	40	6
3	6425	0	91	34	6
4	642A	0	90	29	5

Stage 3 — Secondary filtering of primary filtering result data based on RSSI

No	Address	RSSI	Average RSSI	Reception
12	642C	70	70	98
8	6430	57	59	98
11	6416	62	64	98
7	63E2	68	71	98
10	6427	55	56	97
6	6500	72	73	96
5	6466	74	75	91
15	64EE	77	77	88
13	6431	76	79	84
14	645E	77	78	73

No	Address	RSSI	Reception	
10	6427	55	97	Step 1
8	6430	57	98	
11	6416	62	98	Step 2
7	63E2	68	98	
12	642C	70	98	Step 3
6	6500	72	96	
5	6466	74	91	Step 4
13	6431	76	84	
15	64EE	77	88	
14	645E	77	73	

Stage 4 — Create Edge Network Group

Fig. 1. Conceptual diagram of the group creation of an intelligent edge network.

Fig. 1 shows a conceptual diagram of the group creation of an intelligent edge network. The creation process of the network group listed as follows:

- Each node in adjacent nodes continues to receive messages at regular intervals.
- When a module receives a message from the adjacent communications module, the signal intensity, the address of the information, and the number of times a message received are stored in the buffer.
- Receiver of the particular communication of the buffer module receives information stored in the buffer is reached, the number of designated by the number of criteria in descending order of alignment.
- Receiver of the number of times each communication modules for maximum error occurs (primary filter based on the number of reception) remove the communications module of the index based on the (position) unstable signal.

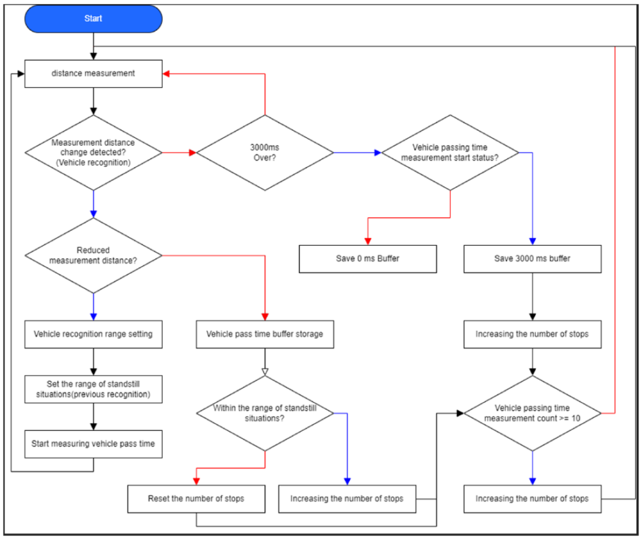


Fig. 2. Flowchart of the traffic flow.

Fig. 2 shows a flow chart of the traffic flow. The processing contents are as follows:

- Cognitive distance measured and stored through the laser sensors.
- If the difference between the currently measured distance value and the previously measured distance is more than 100 cm, it considered as traffic recognition situation.
- If the measurement distance reduced, the vehicle recognition range updated by determining that a new vehicle has passed, and the vehicle detection time is measured after storing the existing vehicle recognition range in the stop situation range.
- If the measurement distance increases, the time required for a passing vehicle measured by determining the passing completion (termination) condition of the vehicle using the road safety facility and then it is stored in a buffer.
- The number of stops increased to determine the accident situation if the increased measurement distance is within

the stop situation range, and then the number of stops initialized if it is outside the stop situation range.

- If the measured distance does not change beyond a certain range (100 cm) for 3000 ms, the vehicle is determined to be stationary or free of traffic.
- If a measurement of the vehicle detection time initiated, the vehicle is determined to be stationary; 3000 ms of flow information is stored in the buffer and the number of stops is increased.
- If no pass start time exists, 0 ms of flow information is stored in the determination buffer, indicating that there is no vehicle passing.
- If the number of vehicle passing times accumulated in the buffer more than 10 times, the vehicle (traffic) recognition results for the current road conditions calculated by the vehicle flow correction weight.

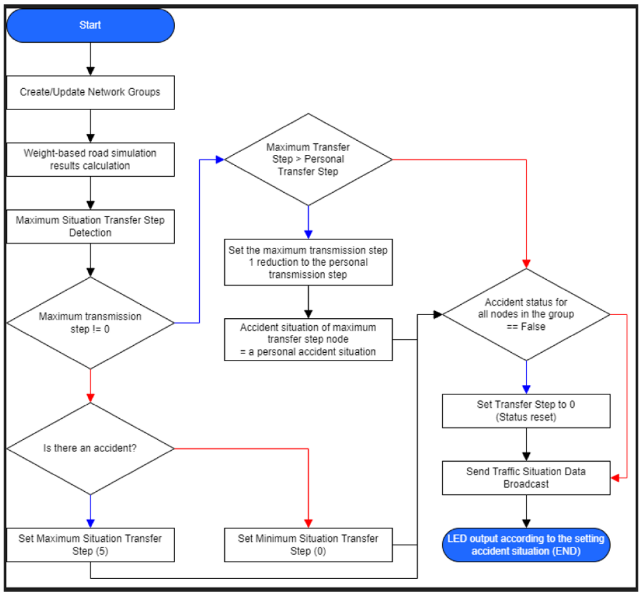


Fig. 3. Flowchart for monitoring traffic accidents.

Fig. 3 shows a flowchart for monitoring traffic accidents. The processing details are as follows:

- Create the network groups using the network deployment algorithm and periodically update them for the neighboring nodes.
- Calculate and store the road conditions according to weights using the adjacent distance step.
- Check the maximum situation step levels in a network group.
- If the maximum situation transfer step is not 0, determine whether it is an accident situation for nodes in the group or whether an event has occurred for renewal.
- Using the maximum situation transfer step, set the number reduced by 1 from the transfer step of the node to your own situation transfer step and save the incident situation information as your own accident situation information.
- If the maximum situation transmission step is 0, determine that all nodes in the group are detecting a normal traffic flow.
- Set the maximum situation transfer step, depending on whether it is an accident situation.
- If not all nodes in the group are accident-aware, set the situation-transmitting step of the network group, including its own situation-transmitting step, to the minimum number (accident ≥ condition when updated to the normal road situation).
- Collect your own road situation results, situation transmission steps, and accident situation information, and send a broadcast message.
- Output LED color/effects according to the accident situation.

IV. SYSTEM IMPLEMENTATION

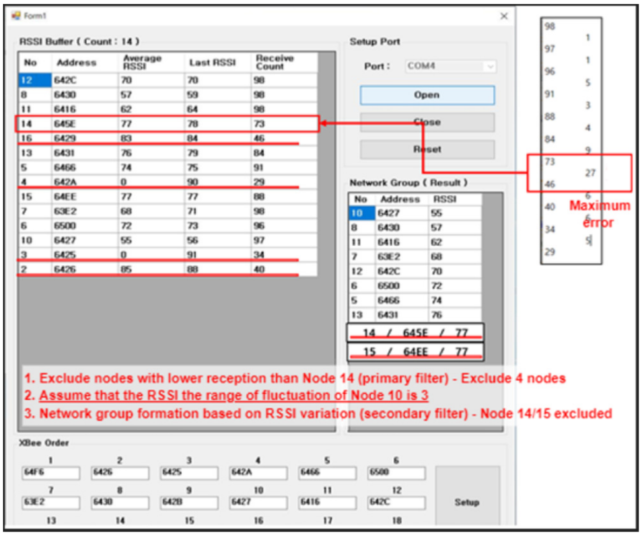
A. Spatial

In this paper, we propose an IoT device that recognizes communication information and unexpected information on the road and provides them visually to road users. The detailed configuration of the IoT device is as follows:

- ATMEGA328 Dual MCU
- A separate network area and event detection area for each MCU, and a link algorithm with internal UART communication
- A module for optimizing the power supply (charge, boost circuit) and configuring the battery connectivity (3.7 V, 3000 mAh)
- An acceleration sensor (MPU9250), which is a nine-axis acceleration sensor for detecting impact and accident intensity
- A module for configuring the health monitoring LED display

B. Intelligent Edge Network

Intelligent edge networks are networking techniques in which each node that makes up a network forms a group with adjacent nodes. We used the monitoring tools in Fig. 4 to validate the implementation results. For monitoring purposes, a specific node designated as a reference node, and the RSSI value and the number of messages received from each adjacent node to the reference node listed. Based on this, a network group finally formed through the first and second filtering processes.



RSSI Buffer (Count : 14)

No	Address	Average RSSI	Last RSSI	Receive Count
12	642C	70	70	98
8	6430	57	59	98
11	6416	62	64	98
14	645E	77	78	73
16	6429	83	84	46
13	6431	76	79	84
5	6466	74	75	91
4	642A	0	90	29
15	64EE	77	77	88
7	63E2	68	71	98
6	6500	72	73	96
10	6427	55	56	97
3	6425	0	91	34
2	6426	85	88	40

Port : COM4

Network Group (Result)

No	Address	RSSI
10	6427	55
8	6430	57
11	6416	62
7	63E2	68
12	642C	70
6	6500	72
5	6466	74
13	6431	76

14 / 645E / 77

15 / 64EE / 77

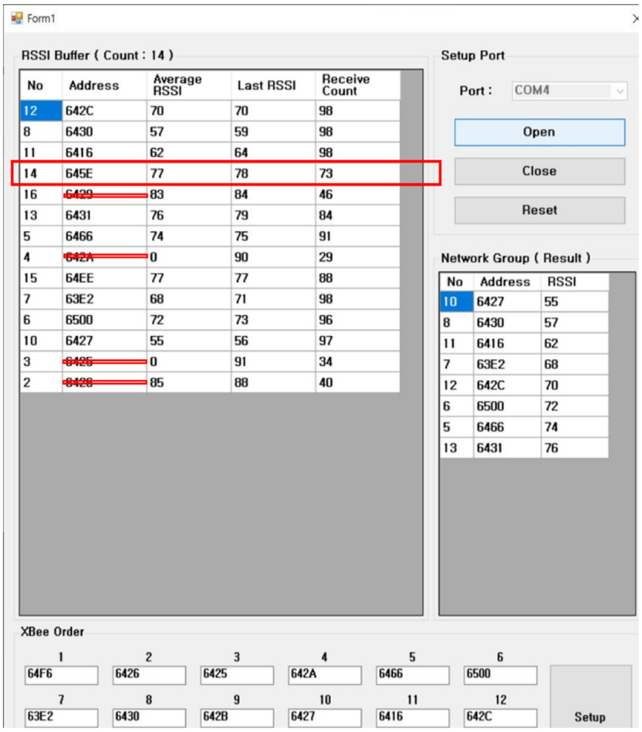
1. Exclude nodes with lower reception than Node 14 (primary filter) - Exclude 4 nodes
2. Assume that the RSSI the range of fluctuation of Node 10 is 3
3. Network group formation based on RSSI variation (secondary filter) - Node 14/15 excluded

XBee Order

1	2	3	4	5	6
64F6	6426	6425	642A	6466	6500
7	8	9	10	11	12
63E2	6430	642B	6427	6416	642C
13	14	15	16	17	18

Fig. 4. Network monitoring tools.

In the case of the primary filtering process of the network tool, nodes representing lower reception times are excluded the basis of the nodes whose message reception times are rapidly lowered (node 14 in Fig. 5).



RSSI Buffer (Count : 14)

No	Address	Average RSSI	Last RSSI	Receive Count
12	642C	70	70	98
8	6430	57	59	98
11	6416	62	64	98
14	645E	77	78	73
16	~~6429~~	83	84	46
13	6431	76	79	84
5	6466	74	75	91
4	~~642A~~	0	90	29
15	64EE	77	77	88
7	63E2	68	71	98
6	6500	72	73	96
10	6427	55	56	97
3	~~6425~~	0	91	34
2	~~6426~~	85	88	40

Port : COM4

Network Group (Result)

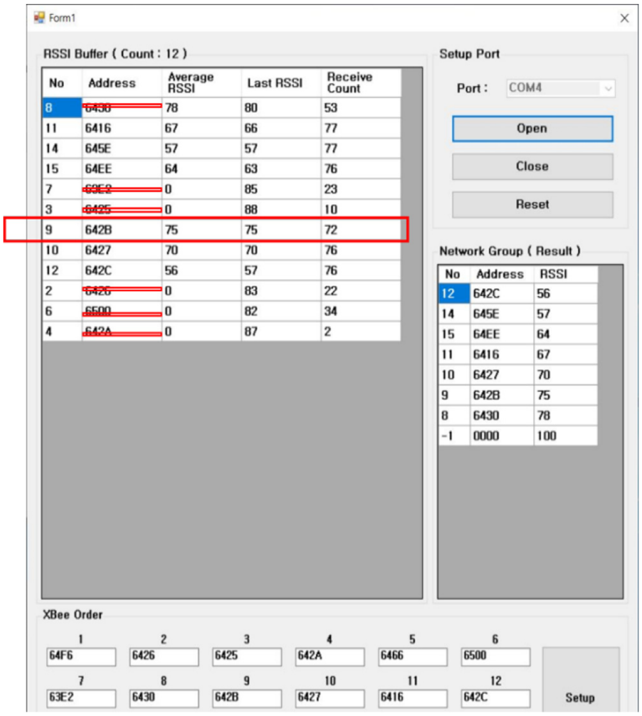
No	Address	RSSI
10	6427	55
8	6430	57
11	6416	62
7	63E2	68
12	642C	70
6	6500	72
5	6466	74
13	6431	76

XBee Order

1	2	3	4	5	6
64F6	6426	6425	642A	6466	6500
7	8	9	10	11	12
63E2	6430	642B	6427	6416	642C

Fig. 5. First filtering process.

For the secondary filtering process, nodes representing a lower RSSI value are excluded the basis of the nodes whose RSSI is rapidly lowered (node 9 in Fig. 6).



RSSI Buffer (Count : 12)

No	Address	Average RSSI	Last RSSI	Receive Count
8	~~6430~~	78	80	53
11	6416	67	66	77
14	645E	57	57	77
15	64EE	64	63	76
7	~~63E2~~	0	85	23
3	~~6425~~	0	88	10
9	642B	75	75	72
10	6427	70	70	76
12	642C	56	57	76
2	~~6426~~	0	83	22
6	~~6500~~	0	82	34
4	~~642A~~	0	87	2

Port : COM4

Network Group (Result)

No	Address	RSSI
12	642C	56
14	645E	57
15	64EE	64
11	6416	67
10	6427	70
9	642B	75
8	6430	78
-1	0000	100

XBee Order

1	2	3	4	5	6
64F6	6426	6425	642A	6466	6500
7	8	9	10	11	12
63E2	6430	642B	6427	6416	642C

Fig. 6. Secondary filtering process.

V. SYSTEM VERIFICATION

In this section, we discuss the recognition system for the traffic situation as operated in an actual road environment to verify the traffic flow and recognition functions of the traffic accident, which are the core functions of the implementation system. First, the experimental environment and method explained, and then the analysis contents of the experimental results described.

In this paper, we propose an intelligent edge network to establish a network by installing IoT devices in a finer section than the existing information collection range (several tens of kilometers) and to collect and provide road traffic information. To verify the field applicability of the proposed network, we derive an effective installation interval for the IoT devices. To this end, the number of messages received and the RSSI values according to the distance between the IoT devices are measured.

First, to calculate the appropriate installation interval of the IoT devices through the number of messages received, we conducted a measurement test according to the distance difference between adjacent nodes using a Zigbee communication device. The test procedure is as follows:

- Line up 14 nodes at 4-m intervals relative to a particular node (define the minimum distance as 4 m for incident detection)
- When the maximum number of broadcast messages

reaches 100 times, check the number of receptions of each node stored in the buffer
- Repeat the received measurement test result

Fig. 7 shows the number of messages received by the IoT devices installed at 4-m intervals. The result of the measurement test showed that the reception rate of the broadcast messages received from the neighboring nodes outside the effective communication range had a larger difference than that of the adjacent nodes. In addition, at a certain distance or longer, a flexible message reception rate during communication between nodes confirmed. The message reception sensitivity of the node in the fourth step (16 m) began to decrease, and it decreased significantly for the node in the seventh step (28 m). Accordingly, the maximum effective installation interval of the IoT devices based on the number of messages received was about 30 m.

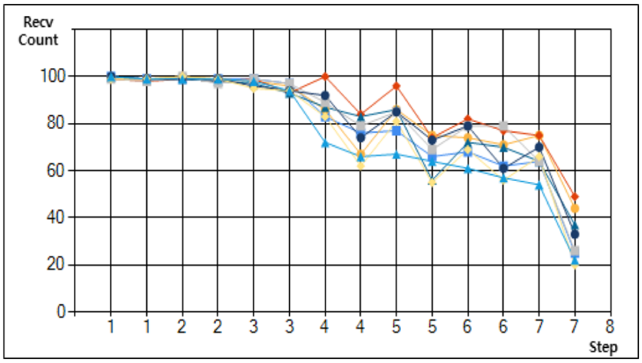


Fig. 7. Number of messages received from the IoT devices installed at intervals of 4 m.

To calculate the appropriate installation interval of the IoT devices using the RSSI value, we conducted an RSSI measurement test according to the distance difference between adjacent nodes using a Zigbee communication device. The test procedure is as follows:

- Align 14 nodes 4 m apart relative to a particular node
- Measure the RSSI value between a specific node and an adjacent node together when validating the broadcast message reception
- Perform eight consecutive iterations to determine the amount of change and the flow range of the RSSI according to the step interval

Fig. 8 shows the RSSI change according to the step interval (4 m). The measurement result showed that, when a wireless network formed, the width of the RSSI for adjacent nodes over a certain range increased in proportion to the distance. Some RSSI noise that occurred in the nodes in the fourth step (16 m) and the sixth step (24 m) showed no significant correlation with the installation distance owing to the noise in RSSI values.

The IoT device proposed in this paper requires no more than 30 m of interval. The maximum effective range is different though. However, the network of modules performed in accordance with the performance of the IoT devices. The network modules used for industrial use showed excellent performance based on usage and may require hundreds of meters of interval for maximum effective communications.

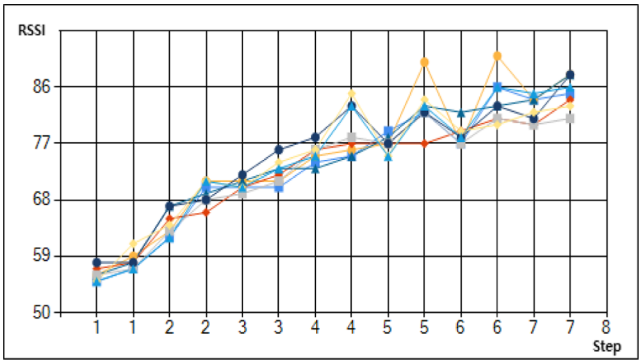


Fig. 8. Changes in the RSSI value according to the step interval (4 m).

VI. CONCLUSIONS

In this paper, we propose an intelligent edge network technique, which is a connection and information process environment between road infrastructures, using intelligent road infrastructure according to the recently developed C-ITS environment. In addition, based on the proposed intelligent edge network, a recognition system for the traffic situation developed to recognize traffic flows and unexpected accidents. To this end, we implemented a transportation system that uses IoT devices to collect and provide traffic information, intelligent edge networks to connect the IoT devices, and traffic flow and recognition services to monitor traffic accidents.

To verify the stability and efficiency of the intelligent edge network, we conducted an analysis of the construction result. The data transmission rate, data transmission time, and recovery time of the network failure were set as experimental parameters. As a comparative object, a mesh network based on the existing RSSI constructed in the same experimental environment, and the experimental object and the proposed intelligent edge network compared and analyzed.

The results of the analysis showed the data transmission rate in the intelligent edge network was 97.48%. The data transmission time was 215 ms, and the recovery time of network failure was 49,983 ms. In the case of the proposed intelligent edge network, the experimental results of the data transmission rate, data transmission time, and network failure were compared to those of the target network, which showed stable and improved results on average. The existing RSSI-based mesh network showed some experimental results in which the data were superior but changed significantly; in contrast, the proposed intelligent edge network showed relatively sufficient data. This shows that the intelligent edge network proposed in this paper provides a stable environment.

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