Optimization for Wireless Vehicular Network System in Urban Area

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Abstract. This paper aims to optimize the usefulness of the next generation vehicular network system so call WAVE (Wireless Access in Vehicle Environment) especially in urban areas that have heavy traffic density and high potential traffic accidents. The wireless vehicular technology is mainly based on DSRC (Dedicated Short Range Communication) technology defined by IEEE (Institute of Electrical and Electronics Engineers Inc.) and ETSI (European Telecommunication Standard Institute). The WAVE system is going to be used for safety and comport of vehicle mobility, for example, to avoid collision of car to car, car to other mobility and car to pedestrian and to reduce traffic congestion. In order to achieve those purposes, WAVE system is installed in vehicles as OBU (On Board Unit) and set at road side as RSU (Road Side Unit). Therefore, it is important how to set RSUs appropriate position. Authors analyze traffic condition and traffic accident condition of typical urban metropolitan area such as Tokyo and provide RSU setting guide from urban development point of view.

Keywords: DSRC, WAVE, IEEE802.11p, ITS, wireless vehicular network.

1 Introduction

The WAVE system is designed for ITS (Intelligent Transport System) which supports safety technology for automotive application. The next generation WAVE and or DSRC technology has being evaluated since 2007 when European Telecommunication Standard Institute has started TC-ITS (Technical Committee – Intelligent Transport System) group. There are several field trials especially European automotive committee such as Car to Car Communication Consortium (C2C-CC). There are also same activities in North America such as "IntelliDrive SM" [1] project under MOT (Ministry Of Transportation). In Asia especially in Japan, ETC (Electric Toll Correction) system has been well established since 1997 and try to expand this technology to ITS. The ETC market in Japan is 4.3 million units in 2011[2]. The ETC technology uses 5.8GHz frequency band. After 2010 when analog terrestrial services has been terminated, UHF (Ultra High Frequency) band especially 700MHz band has been open from 2011. Japanese MIC (Ministry of Internal Affairs and

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Communications) has assigned 9MHz bandwidth in 700MHz band for ITS, not only 5.8GHz band. In this paper, authors analyze existing metropolitan traffic conditions and accident conditions, and then provide appropriate RSU setting guidance in order to reduce traffic jams and traffic accidents efficiently. In this paper, RSU is defined WAVE base station of wireless vehicle network and it is used as vehicle to Infrastructure networks (V2I) application.

In Section 2, it describes analysis of metropolitan traffic accident statistics, provides relation between WAVE RSU setting allocation and WAVE system coverage. In section 3, it describes WAVE system setting plan and analysis of its coverage of the central part of Tokyo. In section 4, it describes WAVE system technology specification and technology advantage which covers issues in previous section which is low WAVE system coverage area. In section 5, it summarizes wireless vehicular communication optimization setting in urban area as guidance.

It is the first time to introduce WAVE system allocation in urban area by geographical methods i.e. GIS (Geographic Information System) in this paper.

2 Metropolitan Traffic Condition Analysis

2.1 Traffic Accident in Japan

According to the world statistics for traffic accident (year 2006, 2009)[3] from MIC (Ministry of Internal Affairs and Communications), Japan is 29th rank of fatal accident number per 100 thousand population. On the other hand, the rank of vehicular accident number per 100 million vehicle and kilo meter unit is number 5th. Therefore Japanese traffic accident level caused by cars is crucial.

Here is typical traffics accident statistics [4, 5] in Japan shown in Table 1 which shows top 10 prefectures' condition. According to Table 1, Aichi, Osaka and Tokyo are most careful area in Japan.

Table 1. Metropolitan traffic condition

Prefecture	Total	Fatal	Injured	Population	unified Total	unified Fatal	unified Indured
Aichi	49,651	235	61,576	7,427	669	3.16	829
Osaka	48,212	182	57,804	8,856	544	2.06	653
Tokyo	47,429	183	54,837	13,230	358	1.38	414
Fukuoka	43,178	161	56,670	5,085	849	3.17	1114
Kanagawa	37,049	179	44,135	9,067	409	1.97	487
Shizuoka	36,946	155	48,178	3,735	989	4.15	1290
Saitama	35,600	200	43,519	7,212	494	2.77	603
Hyogo	34,056	179	42,073	5,571	611	3.21	755
Chiba	22,931	175	28,558	6,195	370	2.82	461
Gunma	18,430	106	23,306	1,992	925	5.32	1170

Note: Unified data is based on 100 pollution.

2.2 Traffic Accident Tendency in Japan

Figure 1 shows the data[3] of traffic accidents classified by the transportation ways victims use. The result is shown in Fugure 1. The total number of traffic accidents is decreasing. However there are two major accident cases according to figure 1. They are accidents under vehicle driving and vehcile to pedestrian accidents during walking.

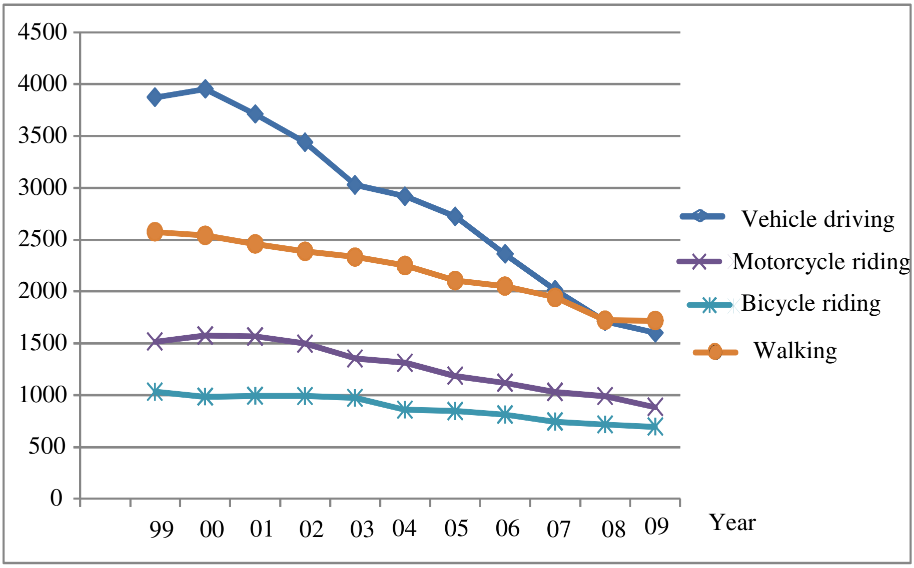

Fig. 1. Fatal accident case statistics

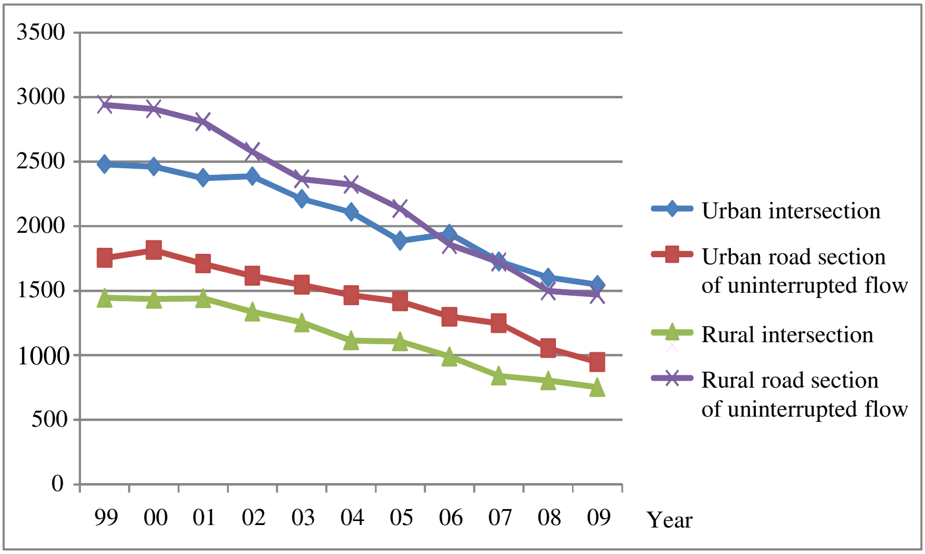

Fig. 2. Fatal accident geographical type statistics

Figure 2 shows statistics about where fatal accidents are happened. Accidents are mainly happened at intersection in urban area, and at road section of uninterrupted flow in rural area. It is celar reason for each locations for traffic accidents. There is much traffic and pedestrians at intersection in urban and it is most likely crowede area in urban. There are mis-driving in rural area such as over speed limit driving.

2.3 Tokyo Metropolitan Traffic Condition Parameters

Accdoring to section 2.1, authors choose the Tokyo area for case study as most popultaed city in Japan. The Table 2 shows Tokyo traffic density calculation process based on road traffic census data. According to the Table 2, traffic density of Tokyo becomes 115 vehicle / km^2.

Table 2. Tokyo Traffic Density (Year 2010)

	Unit	Source (formula)	Ave. Japan	Tokyo	Note
a)Ave. traffic no.	No./24h	[6]	22482	33710	
b) Day ave. traffic no.	No./12h	[6]	16331	22442	
c)Day traffic Ratio	%	b) / a)	72.6	66.5	
d) Ave, velocity	Km / h	[6]	37.7	18.7	Velocity at congested
e)Year moving distance	km	[7]	9807	8336	
f) Day moving distance	Km / day	e) / 365	26.8	22.8	24 hours
g) Day use hour	h	f) x c) / d)	0.52	0.66	day time 12 hors
h) Vehicle use ratio	%	g) / 12 hour	4.33	5.50	
i) Vehicle density	No./km2	[8] / [9]	209	2095	
j)Traffic density	No./km2	h) x i)	9.1	115	

In Table 2, authors analyse Tokyo traffic conditon based on road traffic census from MLIT (Ministry of Land, Infrastructure and Transport) year 2010[10,11]. From this result of analysis, denisty of Tokyo 23 wards is caluculated by propotion to population as in Table 3.

According to Table 3, the estimated traffic density of Tokyo 23 wards becomes 303 vehicle / km^2.

Table 3. Estimated traffic density of Tokyo 23 wards

	Area square	Population	Density	Density Ratio	Traffic density by ratio
	km2	man	Man / km2		No. / km2
Tokyo	2103	12,686,067	6,032	1.000	115
Tokyo 23 wards	538	8,575,228	15,939	2.642	303
Central 3 wards	42.16	215,433	5,109	0.846	97

2.4 Spatial Distribution of Traffic Density in Tokyo

In previous section, authors show high traffic density of Tokyo 23 wards from the data analysis. And in this section, authors make more detail a traffic condition analysis of these areas spatially. By using person trip information[12] authors show the trafic density of Tokyo 23 wards person trip. It si shown in Figure 3. Accodring to Figue 3, Tokyo central 3 wards (Chuo-ku, Chiyoda-ku and Minato-ku) have high value.

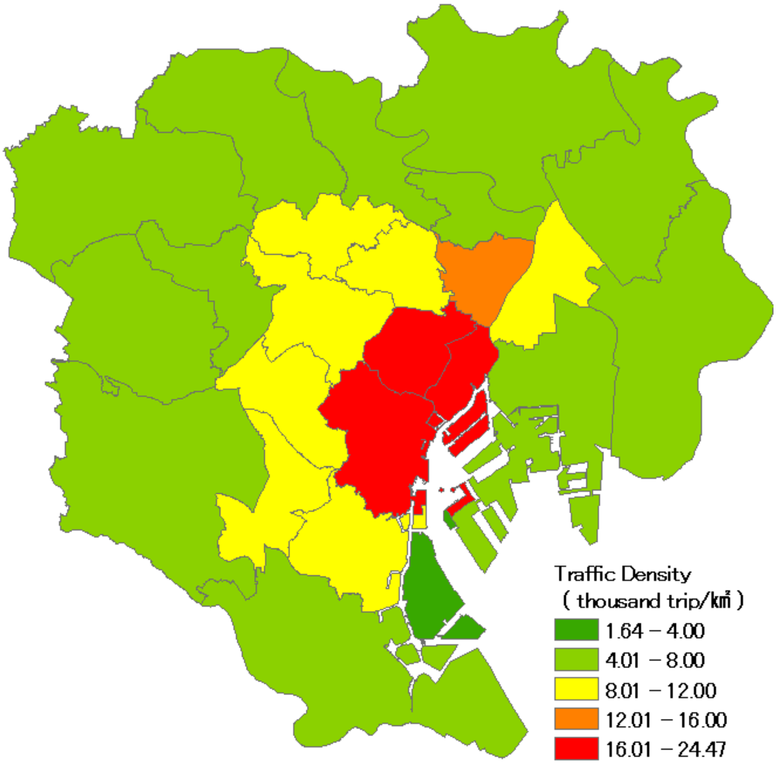

Fig. 3. Tokyo traffic condtion based on person trip

From the figure3, traffic desnity becomes higher towards the center of Tokyo. The main reason of this is that the density of road network in central Tokyo is also higher than other areas. Generally speaking, there are more traffic accidents in the areas that have many roads. Therefore high traffic desity analysis is important for the effectiveness of WAVE RSU setting.

2.5 Tokyo 23 Wards RSU Setting and Coverage Analysis

In this section, authors analyze RSUs setting and coverage of Tokyo 23 wards based on the result of previous sections.

Authors choose cross section points of major roads in Tokyo 23 wards as the first WAVE RSU setting location because there are major accidental areas at urban intersections from Figure 2. In Figure 4, it shows the location of major intersections with WAVE RSUs setting. The target location for RSUs setting is intersections along with major roads such as national and Tokyo public roads because there are more pedestrians and vehicles than other narrower roads. The buffer from each RSU means WAVE system wireless communication range which is used experienced 274 meters from ITS Forum RC-007 document[13]. In this paper, WAVE system is used Japanese 700MHz frequency which is defined ARIB (Association of Radio Industries and Businesses) STD-T109.

Fig. 4. WAVE RSU setting in Tokyo 23 wards [14]

In terms of WAVE RSU coverage, authors use geographical coverage as the ratio of roads that are covered by the buferrs from RSUs.The calculated ratio is based on the length of each road, and result is aggragated by each area. So the caluculation formula of RSU geographical coverage is as follows;

[RSU buffer geographical coverage] =

[Road length which covered by RSU in each area] / [Total road length in each area] ----- (1)

The coverage condition in Tokyo 23 wards shows in Figure 5.

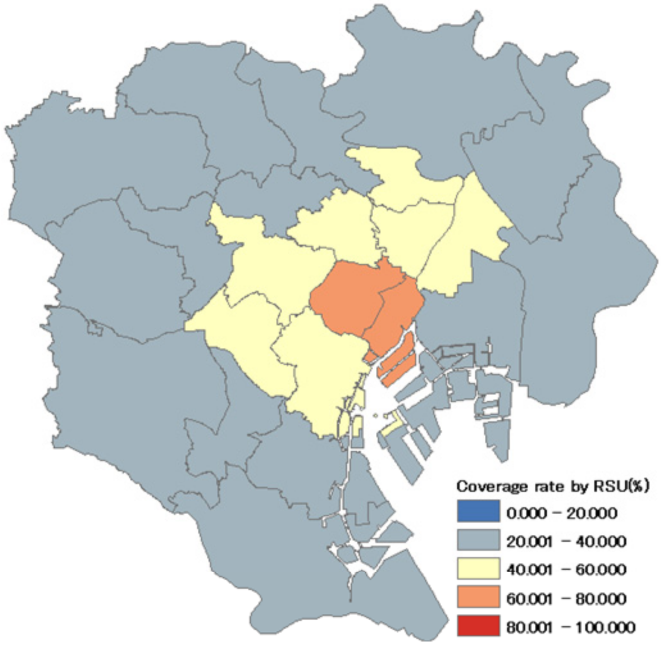

Fig. 5. RSU coverage of Tokyo 23 wards

According to Figure 5, central areas of Tokyo are well covered by RSU and the coverage rate of other areas is lower than that of central areas. However it is reasonable RSU setting compared by traffic condition in Figure 3 and coverage condition in Figure 5.

3 Detail Metropolitan Case Study

According to section 2, Tokyo central three wards have many traffic accidents because of their high traffic density. Authors also show effectiveness of WAVE RSUs by setting major intersection of roads.

However the detail of roads network of each area is different. So there may be deviation of RSU coverage rate and it may not be enough for some regions to set RSU at the major intersections, if focus on the each area on fineer scall. So we have to consider additional countermeasures in such regions.

In this section, authors focus on the road network in Tokyo central 3 wards area(i.e. Chiyoda-ku, Chuo-ku and Minato-ku) whose traffic density are higher than other areas of Tokyo.The aim of this section is to take more detail about WAVE RSU setting plan.

3.1 WAVE System Setting Plan

The Figure 6 shows RSU setting in Tokyo central 3 wards.

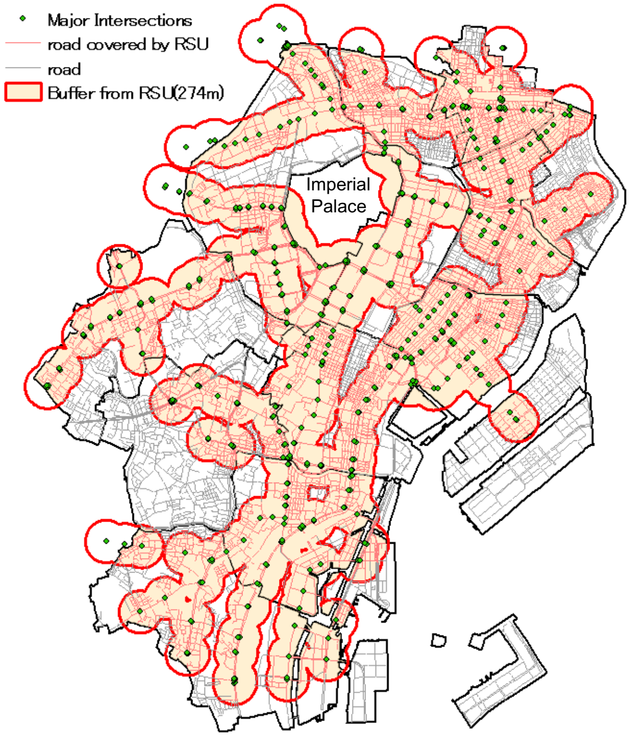

Fig. 6. WAVE RSU setting plan in Tokyo central 3 wards

In terms of WAVE RSU system coverage, it is used as same as calculation formula (1) in section 2.4.

The Figure 7 shows the WAVE RSU coverage of Tokyo central 3 wards.

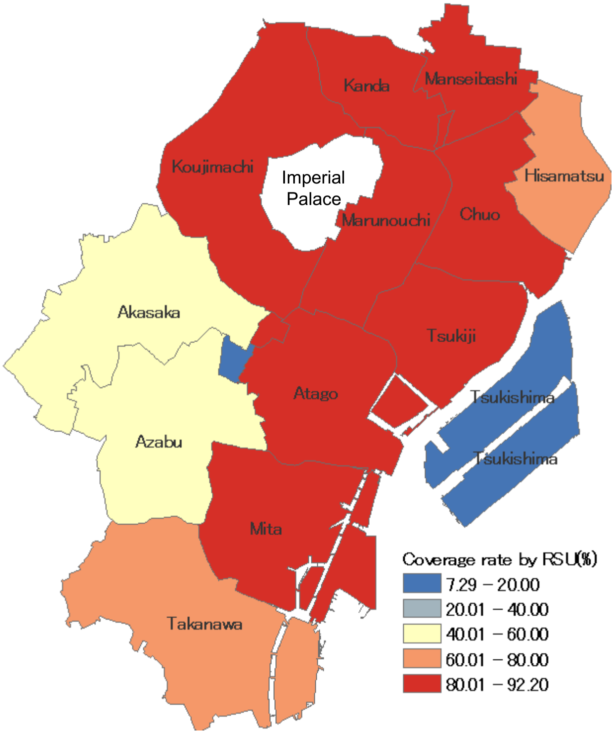

Fig. 7. WAVE RSU geographical coverage

3.2 Tokyo Central 3 Wards Traffic Accident

The Figure 8 shows traffic accident distribution of Tokyo central three wards. The number of accident is normalized by the total length of roads in each area. The data[15] authors use is the statistics of traffic accidents in Tokyo central three wards from the Metropolitan Police Department 2011.

Here is issue about RSU coverage from comparison between Figure 7 and Figure 8. There is one area Azabu in Minato-ku where it is not well covered by WAVE RSU even though the area is higher accitdental area from Figure 8. Therefore it is necessary to consider how to cover lower WAVE RSU coverage area where it is higher potential traffic accident area. This geographical limitation is caused by urban road systems i.e. the distribution of roads, intersections, traffic signals etc. Authors provide countermeassures for this issues in the next section.

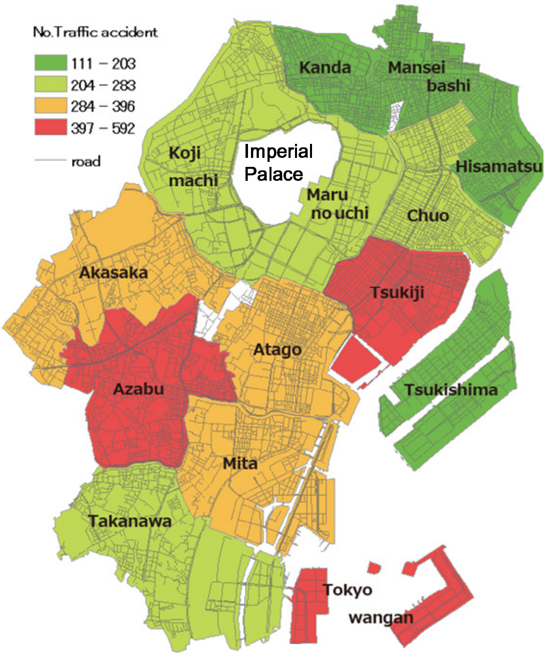

Fig. 8. Traffic accident distribution in Tokyo central three wards

4 Proper WAVE Selection under Low RSU Coverage Area

4.1 Vehicle Communication Comparison

There are several wireless communication technology such as 3GPP of cellular network, high speed data network like LTE (Long term Evolution) and or WiMAX (Worldwide Interoperability for Microwave Access). Tsuboi has studied vehicle related wireless communication network comparison among 3GPP cellular network, WiMAX and WAVE. The results were as follows[16];

- WAVE technology (700MHz and 5.9GHz) has covered high data rate communication above 10Mbps in case of less than 1,000 vehicle per 1km^2 , which is actual traffic condition (refer to Table 3).
  (Vehicle density and Data rate analysis is shown in Figure 9.)
- 3GPP and WiMAX have more than 1,000 vehicle communication coverage within their cells.
  (Vehicle density and Number of vehicle analysis is shown in Figure 10)

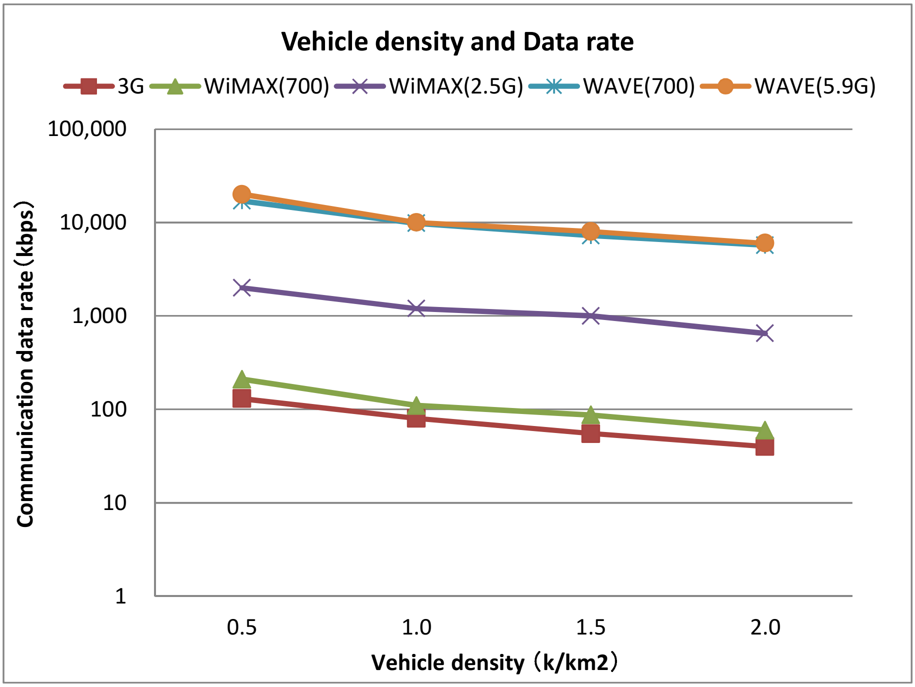

Fig. 9. Vehicle density and Communication data rate

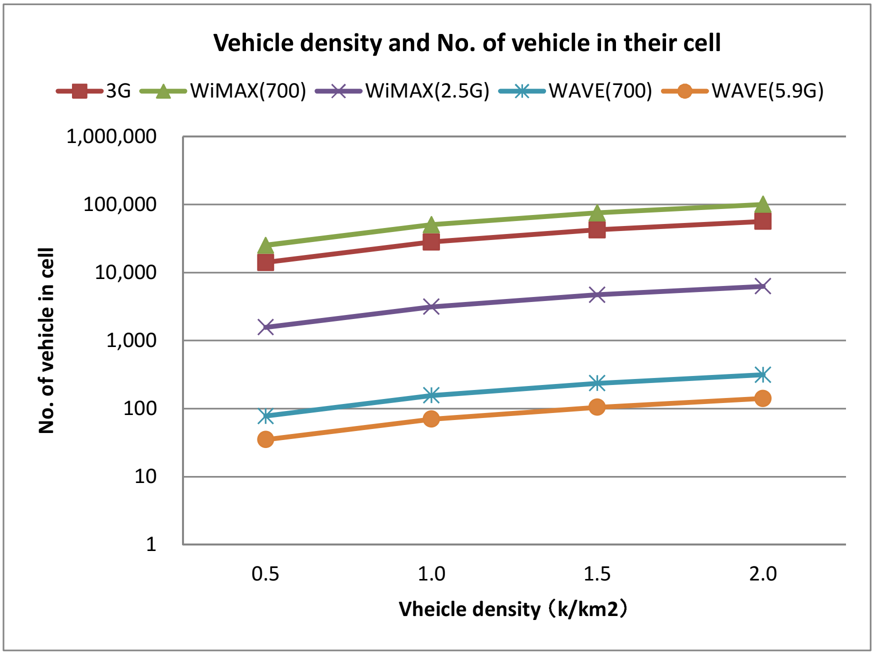

Fig. 10. Vehicle density and Number of Vehicle in cell

According to this analysis, WAVE technology has communication data rate advantage compared with 3GPP and WiMAX broadband wireless communication technology, especially it is sufficient to support multimedia application such as moving picture transmission. The moving picture is good communication tools for drivers because of drivers know real situation of traffic condition rather than just warning message. Among these wireless access technologies, the latency is key factor especially for safety application such as anti-collision. The latency of WAVE is less than 10 msec based on our measurement[17]. But the latency of 3GPP is more than 100 msec and that of LTE is around 10 msec[18].

However in terms of supporting number of vehicles in their cell, 3GPP and WiMAX have advantage than WAVE. According to Table 3 in this paper, the Tokyo 23 wards vehicle density is 303. But WAVE 700MHz system covers 80 vehicle in cell with 15Mbps data rate transmission condition. Therefore when 700MHz WAVE system covers 303 vehicles in its cell, it is necessary to calculate how much the data rate is. In WAVE system, the total data is less than 1,000 byte per packet and data is shown in Table 4 in ARIB STD-T109 specification.

Table 4. WAVE data structure

Type of data	Contents	Length（Byte）
Service	Power level, modulation type, standard	2
MAC control	MAC control, ppacket counter between OBU and R	24
Link management	Netork management information	8
Data	Feee data	Lx
FSC	Error correction	4
Pad	Data length adaptation	2
Total		40+Lx

The data rate is calculated by Table 5 under Table 4 WAVE data structure condition. In Table 5, it is used typical WAVE parameters such as bandwidth 9MHz, interval transmission 100 msec. When number of vehicle is 303, then data transmission is calculated 12.31 Mbps.

In section 4.1, WAVE technology is more sufficient for supporting multimedia data transmission such as moving picture and it also covers high density of vehicle density in metropolitan compared with other vehicle related wireless communication system.

Table 5. WAVE data rate calculation

Symbol	Contents	Unit	Value	Reference
D1	No. of Vehicle	number	303	
D2	Data	byte	508	＝Lx
D3	Interval of transmission	msec	100	
D4	Transmission rate	Mbps	12.31	D1*D2/D3
D5	Effciency of frequency	bit/Hz	1.368	
D6	Bandwidth	MHz	9.00	D4/D5

4.2 WAVE Technology Comparison

Here is current WAVE technology specification comparison which is shown in Table 6. There are two types Japanese ITS standards, North America IEEE standard, and European ITS standard ETSI. The IEEE standard is IEEE802.11p-2010/IEEE1609 and ETSI standard is ETSI ES202 663/EN102 731. IEEE and ETSI have quaterly technical meetings for harmonization each other. Therefore there is not so much differnces between them. For example, there were three channels which are one CCH and two SCHs in ETSI until 2010. But there are seven channels as total now.

Table 6. WAVE technology comparison

	Japan DSRC	Japan 700MHz	USA (DSRC)	EU (DSRC)
Application Layer	**application** **ETC**	**application** **Anti-collision**	**application** ●**Anti-collision** ●**High speed data**	**application** ●**Anti-collision** ●**High speed data**
Upper Layer Protocol	**DSRC Protocol**	**Dedicated (current)**	**Application mng.** IEEE1609 **UDP/TCP, IPv6 WSMP (non-IP) LLC**	**Application mng.**
Access typ.	**TDM/FDD**	**CSMA/CA**	**CSMA／CA** 802.11p	
Modulation	**QPSK**	**OFDM (BPSK/QPSK/16QAM)**		
No. of channel	5MHzx7ch x2(up/down)	■CCH 9MHzx1ch	■CCH ■SCH 10MHzx7ch (20MHz option)	■CCH ■SCH 10MHzx7ch
Frequency Band	5.8GHz	700MHz	5.9GHz	5.9GHz

4.3 700MHz WAVE Technology Advantage

In section 3, there is a issue about WAVE RSU low coverage area such as Azabu in Tokyo central three wards. In terms of main traffic accidents in urban area, they are most vehcile to vehicle collision and vehcile to pedestrian in Table 1. Therefore it is important to how to cover those main traffic accidents by WAVE system not only by RSUs but also WAVE OBUs which are installed in vehicles. This WAVE OBUs are expected to perform prevent collisions by the vehcile to vehicle (V2V) commuication essentially. In this section, authors explain effectiveness about this V2V commuication system in order to support WAVE RSU low coverage area as vehcile to infrastrucrue (V2I).

The reason why authors take 700MHz WAVE rather than 5.8GHz DSRC is 700MHz WAVE communication range advantage. The range difference between 700MHz band and 5.8GHz band is around 8 time obtained by the free space propagation loss using its direct wave electic power i.e. Friss formula equation[19].

Therefore 700MHz WAVE is more capable for vehicle to vehicle communication under less RSU setting location like Azabu in this case.

In terms of wireless communication range compalison, Tsuboi[20] has analized braking distance under wet asphalt pavement road condition by comparison among 5.8 GHz, 2.4GHz and 700MHz freaquency band WAVE/DSRC system. The Figure 11 shows the shimulation results of braking disnatnce comparison at the corner of metropolitan area which shows the image of the town in Figure 12[21]. The illustration of Figure 12 is typical metropolitan cross pont which is srounding by higher buldings. Therefore drivers who drive in those area is hard to know the condition of traffic behind the buildings.

In Figure 11, there are three different type of frequency bands of WAVE system. The line graph shows the acceptance braking disatnce for each WAVE system. The acceptance braking distance here is the distance in which one vehicle from the street driving can stop after when the vehicle receives a approaching signal from the other driving vehicle of the cross road. The bar graph shows running distance which one vehicle is able to stop when driver starts breaking vehicle. When the line graph is above the bar, it means that the vehicle can stop before the other vehicle comes into the corner of the cross point. There is no collision in this condition. On the other hand, when the line is under bar, it means there is possibility of collison between vehciles. This road condition if Figure 11 is wet asphalt pavement. According to Figure 11, it is clear that there is no potential collision under 60km per hour vehicle velocity with 700MHz WAVE system. It shows that 700MHz WAVE system has communication range advantage for NLOS (non Line of sight) communication against 2.4GHz and 5.8GHz WAVE system. This advantage becomes valid for anti-collision at low

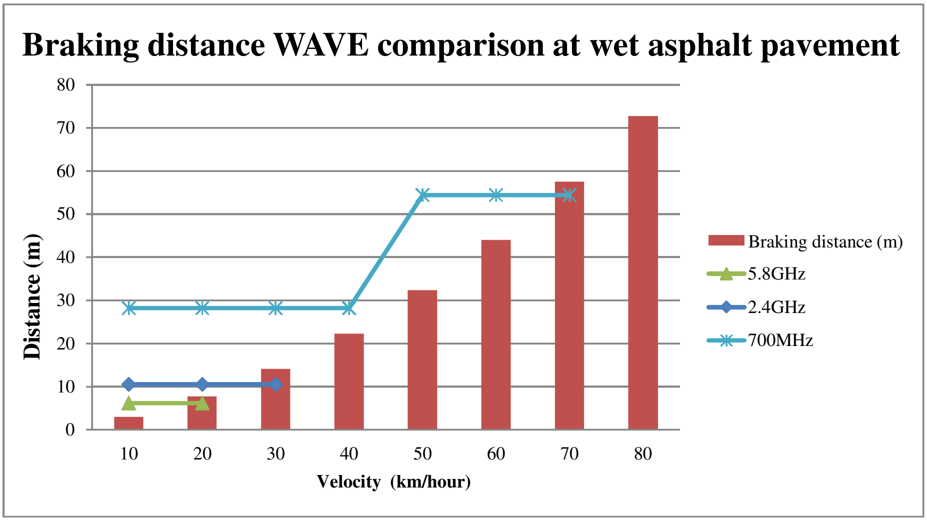

Fig. 11. Validation of 16QAM WAVE

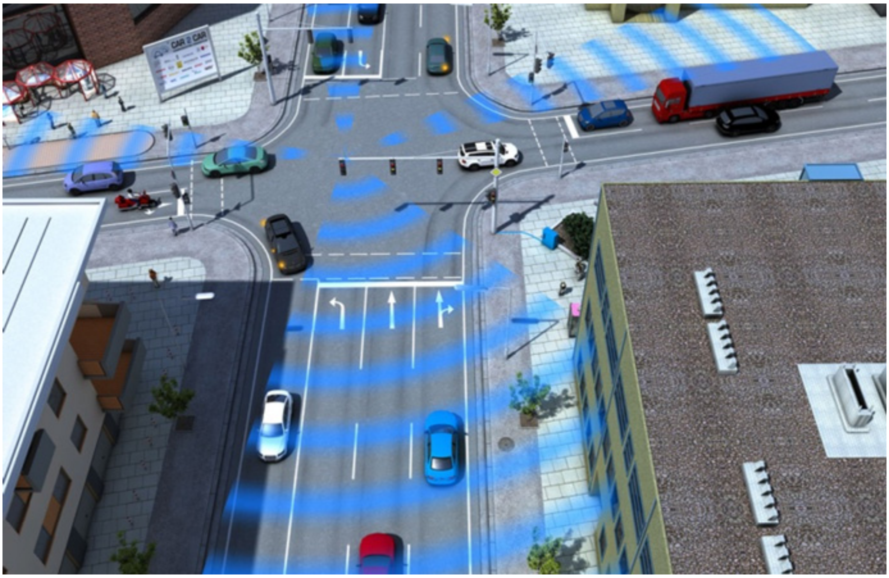

Fig. 12. Image of typical cross point of metropolitan

coverage by RSU in urban area such as Azabu in Figure 7. According to the actual traffic accidents statistics of Azabu[14,22], there are 461 of vehicle to vehicle collision accidents in total 592 traffic accidents in 2012. And there are 125 of vehicle to pedestrian accidents, and 6 accidents of indivisual vehicle. Therefore traffic safety system has to cover traffic accidents caused by vehicle to vehicle collision in those locations especially the place where there are less intersection points which means no WAVE RSUs beuase of less intersection condition. Therefore 700MHz WAVE system of V2V compensates V2I for safety application in such metropolitan area.

5 Summary

Authors provide the result of analysis about next generation WAVE RSU setting plan for reducing the traffic accidents in metropolitan area by GIS methods. Authors pick up Tokyo metorplotain area as a case study of traffic condition analysis and show evidence of RSU coverage there. As the summary, the utilization of WAVE RSU setting in urban area is as follows;

1) Effective settting area of WAVE RSU is cross section point in urban for safety application
   The cross section points of urban is most accidental area especially in Tokyo Japan.
2) 700MHz WAVE RSU (V2I) is effective for traffic safety application under current traffic condition in Tokyo by analysing traffic density for each area.

3) In case of low coverage area of RSUs, 700MHz frequency band WAVE system is effective by using vehicle to vehicle (V2V) communication application. 700MHz WAVE system has wireless communication range advantage compared with other WAVE system such as 5.8/5.9GHz frequency band DSRC technology.

Author take the first step for WAVE RSU setting opitimization by allocating RSU at cross points in metroplitan. And authors show that cross point section by setting of WAVE RSUs is effective for safety application especially in metoropolitan area such as Tokyo Japan. However there are also several issues of setting place for RSU in future because each location is different condition by historical develoment of towns in general. The next generation 700MHz WAVE system becomes good candidate system in future ITS application.

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