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Advanced ITS Application for Natural Disaster Protection

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Abstract: This paper describes new ITS potential application for natural disaster protection. In general ITS application is mainly for safety and efficiency of transportation system such as collision avoidance in cross section, traffic jam avoidance by route guide and or jam information in advance. The specification of ITS in this paper has been defined by ES202 663/EN102 731 in Europe and IEEE802.11p/1609 in North America. There are also several projects for field trial test in worldwide too. After March 11th 2011 big earthquake in Japan, probing data has been recognized to be useful for understanding situation of natural disaster attack such as "Tsunami". One good example is to identify roads condition. The collected probing information from driving cars at stricken district shows survived roads and damaged roads. This kind of application is good usage not only normal safety traffic application. Therefore author tries to use ITS application for escape guidance for transportation from Tsunami and mass safety tools. In order to show effectiveness for this ITS natural disaster protection system, author takes detail investigation and analysis for several potential locations. One is identifying enough coverage for expecting damage area. Two is avoiding personal vehicles and use mass transportation for evacuation from stricken district. Three is using local communication system in case of limitation of public communication system such as cellular phone and out of power supply.

Keywords: WAVE, DSRC, IEEE802.11p, ITS.

I. INTRODUCTION

1.1 History of ITS specification

ITS (Intelligent Transport System) becomes near future safety technology for automotive application since 2007 when European Telecommunication Standard Institute has started TC ITS (Technical Committee – Intelligent Transport System) group[1]. There are several field trials especially European automotive committee such as Car to Car Communication Consortium (C2C-CC)[2]. And there are also same activities in North America as "IntelliDriveSM"[3] project under MOT (Ministry Of Transportation). In Asia especially in Japan, ETC system has been established since 1997 and try to use this technology for ITS. And UHF (Ultra High Frequency) band especially 700MHz band has been open from 2011 because of analog terrestrial service has been terminated. Japanese MIC (Ministry of Internal Affairs and Communications) has assigned 10MHz in 700MHz band for ITS, not only ETC 5.8GHz band [4]. Therefore there are two types of ITS standard potential system in Japan. In those standardization and field test projects, the main application is safety and efficiency traffic management such as anti-collision system by car to car communication, adaptive traffic signal control for avoidance of traffic jam by car to infrastructure communication for example.

1.2 Probe System

On the other hand, probing information system such as VICS (Vehicle Information and Communication System) in Japan has been started from 1994. It has used FM radio band for providing traffic information from center. The center collected traffic information from analysis traffic condition by vehicles with VICS as probing data. And it is also used camera information which has installed at highway and main traffic roads as assist system for recognition actual traffic condition by them. However VICS information is limited for prefectural area only, therefore it is difficult to providing traffic information in broad area among prefectures. After March 11th 2011, the probing information became important information because of well identifying roads condition after collecting probe information at stricken district. The traffic probe information indicated good roads and less probe information meant damaged or destroyed roads.

1.3 Target Application

In this paper, author try to use new ITS technology for natural disaster protection tool combined with probing mechanism of VICS. Author explained ITS standard harmonization and showed 700MHz ITS technology advantages in 2013[6], Vehicle wireless communication cell design in 2009 and 2010 [7][8]. All these papers are focused on normal vehicle wireless communication analysis for safety application. After March 11th 2011, Japan has detail analysis for future large potential earthquake disaster such as “Nankai Trough” especially pacific ocean area of Shizuoka, Mie, Osaka, Kochi, Nagoya prefectures [10]. In this paper, author took Shizuoka prefecture and Hamamatsu city and Kosai city as local detail study for ITS natural disaster protection research.

In section two, it is described ITS technology and ITS specification. In section three, it is described target application for ITS natural disaster protection and introduction of smart public transportation and smart bus stop concept. In section four, it is described potential natural disaster “Nankai Trough” Tsunami and shows damage forecast. In section five, it is described new ITS communication coverage for target area and shows effectiveness and challenges. Then summary is described in last.

II. ITS DEFINITION AND SPECIFICATION

2.1 ITS definition

In terms of ITS technology, there are several potential technologies such as VICS in Japan, OnStar®[11] by General Motors, Ford Sync®[12] by Ford Motors, CarWings®[13] by Nissan and etc. In this paper, new ITS technology is Wireless Access in Vehicle Environment (WAVE) and or Dedicated Short Range Communication (DSRC), which is defined by ES202 663/EN102 731[14] in Europe and IEEE802.11p/1609 [15] in North America. Author also takes Japanese WAVE potential target specification which is Association of Radio Industries and Businesses (ARIB) RC-005, RC-006 ITS standard proposal.[16] These ITS standards are shown in Table 1.

Table 1. New ITS standards

	Japan		USA	EU
	DSRC	700MHz	(DSRC)	(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 10MHzx1ch	■CCH ■SCH 10MHzx7ch (20MHz option)	■CCH ■SCH 10MHzx3ch
Frequency Band	5.8GHz	700MHz	5.9GHz	5.9GHz

2.2 ITS specification features

According Table 1, there are several features as follows;

1) Frequency: 5.9GHz is assigned in North America and Europe. Similar 5.8GHz is assigned in Japan. And 700MHz is also assigned after analog terrestrial service termination in 2012.

2) Number of channels: There are two types of channels, CCH (Control Channel) and SCH (Service Channel) with 10MHz bandwidth. The North America bands are one CCH and six SCHs and Europe bands are one CCH and two SCHs. In Japan, there is only one CCH in 700MHz but dedicated channel usage for 5.8GHz.

3) Access type: They are common CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) except 5.8GHz DSRC.

4) Upper layer protocol: North America and Europe standards are common based on IEEE1609 specification. Japanese standards are independent.

The SCH is necessary to use non-safety ITS application such as natural disaster protection application in this paper. Therefore author takes Japanese 700MHz potential specification, North America and Europe WAVE specifications.

III. TARGET APPLICATIONS

3.1 Technology Features

The main target application of this paper is ITS natural disaster protection and this is the first time to propose WAVE system. The reasons why author takes WAVE system for natural disaster protection application are as follows;

1) Real time communication: It is important to provide and receive real time information under emergency situation not only collision protection.

2) High speed data access: The visual image information is also important to understand critical condition such as damage information of roads and environment information.

3) Local independency: The system needs local operation capability especially under destroy of infrastructure. It is easy to understand at natural disaster condition for limited access of cellular phone system, local power service shutdown.

4) Ad-hoc communication: The ad-hoc communication capability becomes also important under infrastructure damage condition. It is necessary to be autonomous communication system.

5) Flexibility data access: It is allowed to use data flexibility access in order to transfer different type of information, i.e. text data, aural information, image and video information, graphical information etc.

3.2 System for ITS natural disaster protection

The ITS natural disaster protection application is used those above WAVE technology features. The WAVE system is expected to be implemented into all vehicles in future and infrastructures such as traffic signal lights, cross section, and major congested roads highways. Therefore author takes local public transportation such as bus because bus system has regular course and mass human transportation capability. Therefore author takes bus stops as for local base station of WAVE system which covers wide range area for roads and good for distance among stops in order to exchange information. This concept is WAVE smart bus transportation and smart bus stops which brings road condition and passengers get-on and get-off information from buses, and certain environment condition information, bus location and drivers and other passenger condition information through bus stops. The concept image is shown in Figure 1.

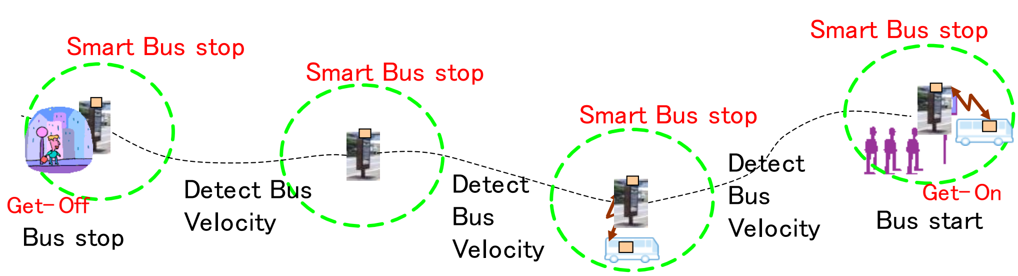

Figure 1. Smart bus and Smart bus stop.

The field trial test scene is shown in China for this system in Figure 2. The ITS center gets bus position and inside bus view from buses which approach to the bus stops and transfer environment information from certain bus stops to the bus drivers through ITS center. In this field trail test, author demonstrated video data from cross section to bus through ITS center and inside bus view transferred from bus to ITS center.[17]

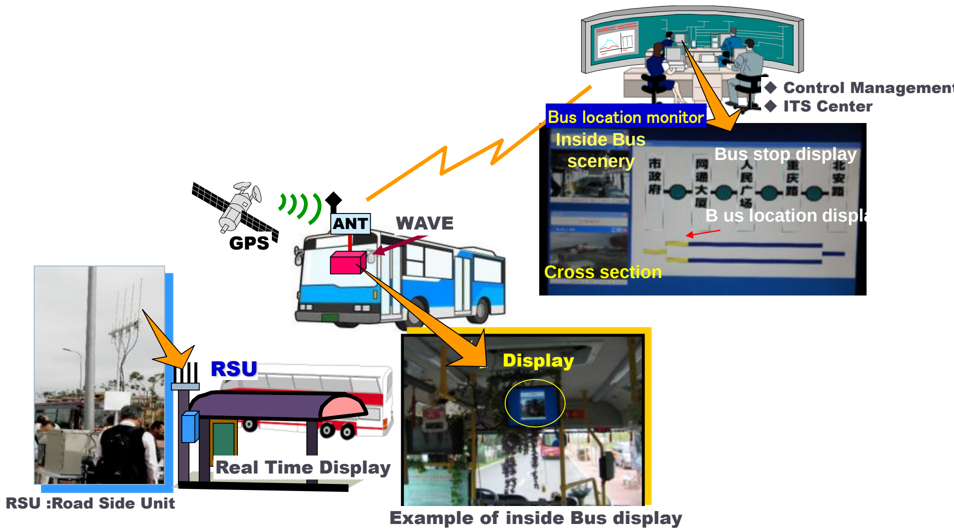

Figure 2. ITS bus field trial test scene.

The system concept of smart bus stop and smart bus shows in Figure 3. The smart bus stop and smart bus communicate by WAVE system after reaching bus stop communication area and Bus management center controls bus distribution and check bus location through bus stops.

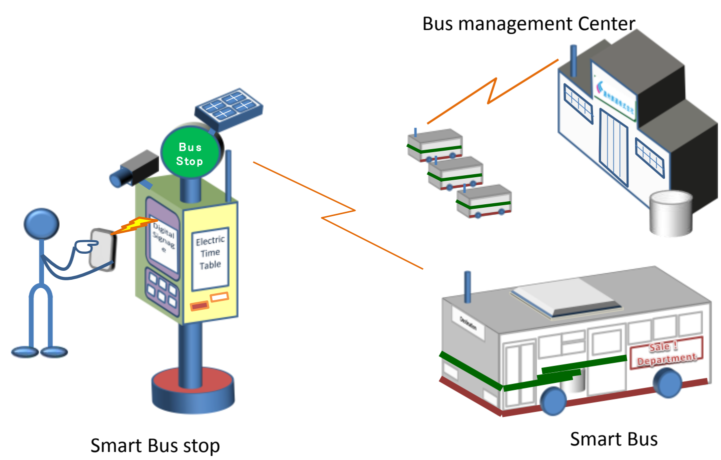

Figure 3. Smart bus and Smart bus stop system concept.

IV. POTENTIAL TSUNAMI OF "NANKAI TROUGH" NATURAL DISASTER

4.1 Tsunami damage of "Nankai Trough"

After East Japan big earthquake disaster on March 11th 2011, Japanese Cabinet Office has investigated and get simulation results for future similar class of high potential earthquake "Nankai Trough" area. The Figure 4 shows most affective area of Tsunami damage simulation results from Cabinet Office. According to the Figure 4, Pacific Ocean coast side of Chubu, Kinki and Shikoku area will have heavy damage of Tsunami of "Nankai Trough". The most depth of Tsunami will be more than 30 meters from surface of land.

"Nankai Trough" will be expecting to he happened in near future according to Japanese Cabinet Office. Therefore all those Tsunami damage expecting area has started to prepare how to reduce damage by government of each reason.

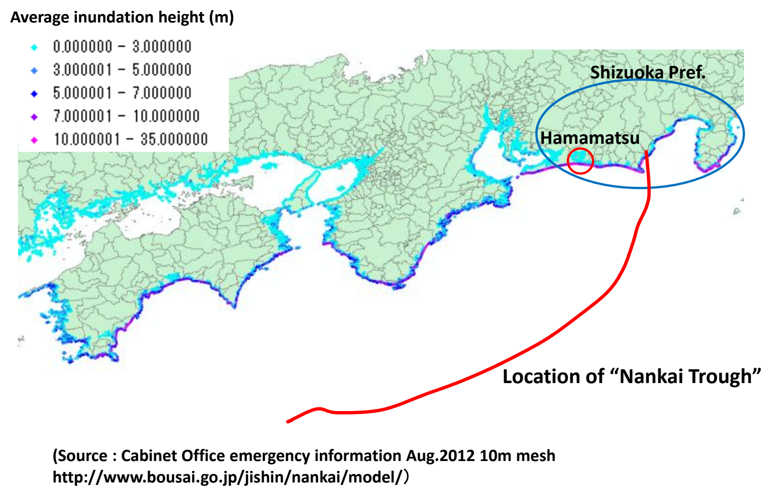

Figure 4. Tsunami disaster simulation results of "Nankai Trough" earthquake.

4.2 Local city condition

Author picks up one of most damage area where it has inundation height and populated city from Figure 5 results. This is Hamamatsu city where there is 820 thousand population, top level automotive manufacturing, and top level of agriculture shipment in Shizuoka prefecture.

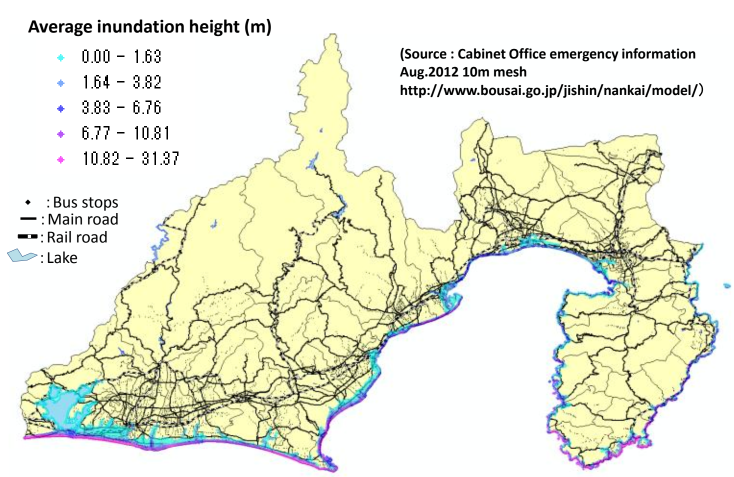

Figure 5. Shizuoka Prefecture and main bus stops position.

Figure 6. Hamamatsu city Tsunami and main bus stops position.

The Figure 5 shows more detail Tsunami damage simulation results with local bus stops position. And the Figure 6 shows Hamamatsu city Tsunami damage simulation results with local bus stops position.

V. ITS Coverage Analysis and Challenges

5.1 ITS communication coverage

According to Hamamatsu city bus stops location of Figure 6, coverage ratio of target area is calculated by the following steps. It is shown in Figure 7.

1) Calculate all each bus stop distance

2) Analyze of variance for minimum distance from all each bus stop distance

3) Count total number of bus stop under certain minimum distance

4) Get existence ration from the number of bus stop by analysis of variance, then this existence ratio is equivalent of coverage percent for target area.

The ITS communication coverage here means ITS radio communication available area by WAVE technology.

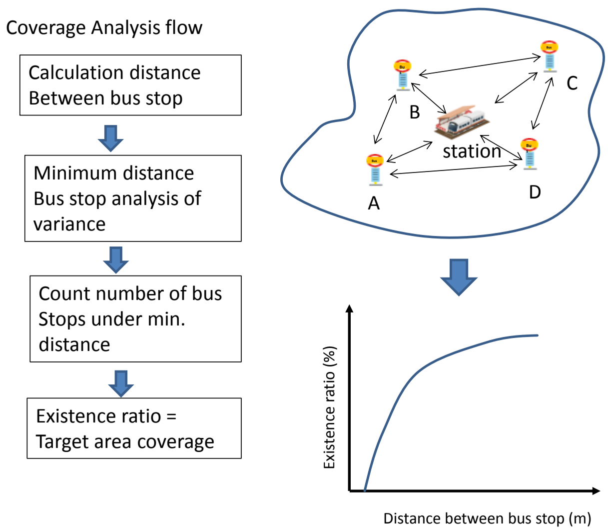

Figure 7. Smart Bus stop coverage analysis.

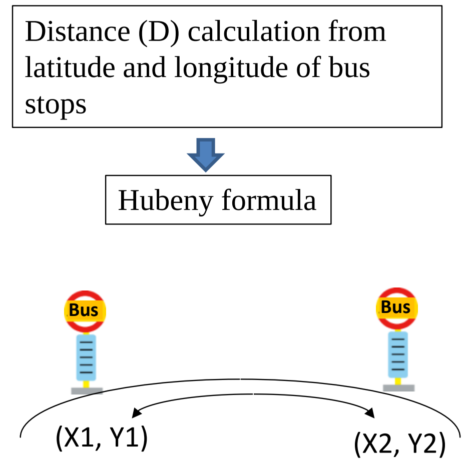

Figure 8. Hubeny formula idea.

The Hubeny formula is idea of considering for round shape of earth in order to calculate distance between two places from grid shape. This is illustrated in Figure 8.

5.2 Distance between bus stops

There is Hubeny formula to calculate distance of two places of grid chart. The distance (D) between tow bus stops is calculated by following;[19]

$$D = \sqrt{(M \times dP)^2 + (N \times \cos(P) \times dR)^2}$$

M: Meridian radius of curvature
N: Prime vertical radius of curvature

$$M = \frac{6334834}{\sqrt{((1-0.006674 \times \sin(P)^2)^3}}$$

$$N = \frac{6377397}{\sqrt{(1-0.006674 \times \sin(P)^2}}$$

P: Average of two position latitude

$$P = \frac{(Y1+Y2)\times\pi}{180\times 2}$$

dP: Differential of two position latitude
dR: Differential of tow position longitude

$$dP = \frac{(Y1 - Y2) \times \pi}{180}$$
$$dR = \frac{(X1 - X2) \times \pi}{180}$$

dP: Differential of two position latitude
dR: Differential of tow position longitude

$$dP = \frac{(Y1 - Y2) \times \pi}{180}$$
$$dR = \frac{(X1 - X2) \times \pi}{180}$$

5.3 Target area ITS communication coverage

In this section, there are two case studies for target area coverage. The first target is Hamamatsu Japanese Railway (JR) station which is main station of Hamamatsu city. And the other one is Takatsuka JR station because of heavy damage of Tsunami according to Figure 6. And there are also three cases distances from each station, i.e. 1km, 2km and 3km. The location and target area coverage are of Hamamatsu station and Takatsuka station is shown in Figure 9, 10 and Figure 11, 12.

1) Hamamatsu Station:

According to the previous Hubeny formula calculation among all bus station distance, the each target area coverage results are shown in Figure 11. And 90% coverage distance between bus stops are as follows;

- 1 km: 123m
- 2 km: 115m
- 3 km: 118m

All conditions are covered by WAVE communication range, which is 274m between Road side unit and Vehicle and 185m between vehicle to vehicle.[18]

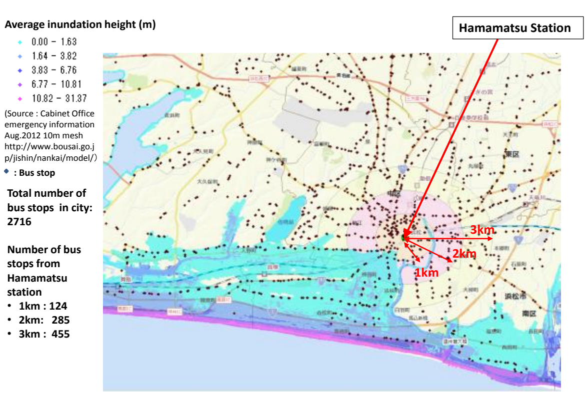

Figure 9. Location of Hamamatsu station.

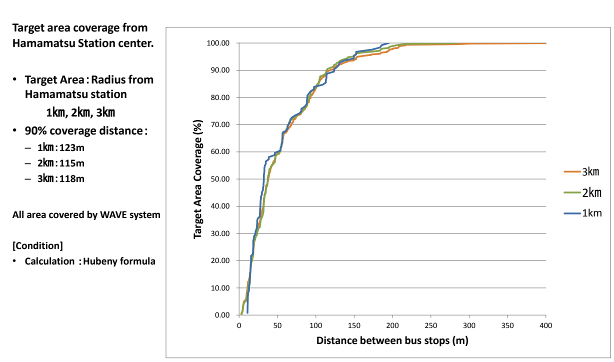

Figure 10. Target area coverage of Hamamatsu station.

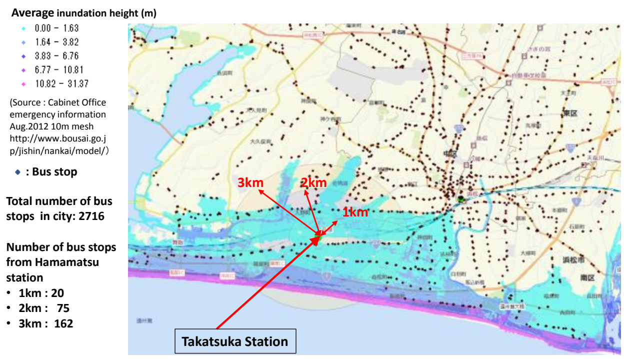

Figure 11. Location of Takatsuka station.

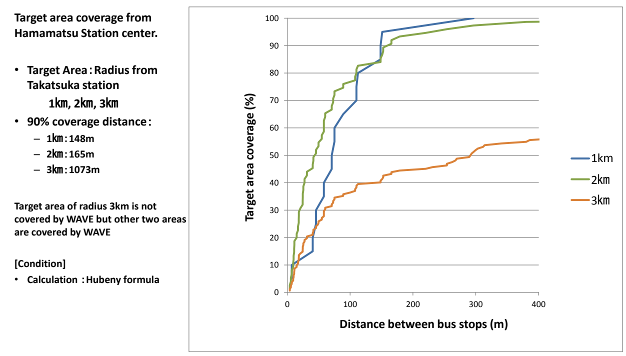

Figure 12. Target area coverage of Takatsuka station.

2) Takatsuka Station:

In case of Takatsuka station, the results of target area coverage by calculation of Hubeny formula are shown in Figure 12.

And 90% coverage bus stop distance for each 1km, 2km and 3km radius condition from Takatsuka station are as follows;

- 1km: 148m
- 2km: 165m
- 3km: 1073m

Two conditions of results are covered by WAVE system but 3km radius condition is not able to be covered by current WAVE specification. Therefore it is necessary to take some countermeasures. One is to allow more radio transmission power output beyond 33dBm in case of emergency situation. The other is to have more bus stops and or other WAVE base station location. In general bus business is tough condition; therefore it is not easy to expand to set more bus stops without any special economic condition.

3) Improvement Takatsuka station coverage

In terms of 3km radius from Takatsuka station, it is necessary to have more WAVE station setting not only bus station but also other potential such as gas station. The location of Takatsuka station including gas station is shown in Figure 13.

After including gas station as additional WAVE base station, the result of target area coverage is shown in Figure 14. And 90 % coverage distance between WAVE base stations are as follows for each 1km, 2km and 3km radius distance from Takatsuka station.

- 1 km: 150m
- 2 km: 152m
- 3 km: 165m

In this case, all conditions are covered by WAVE communication range.

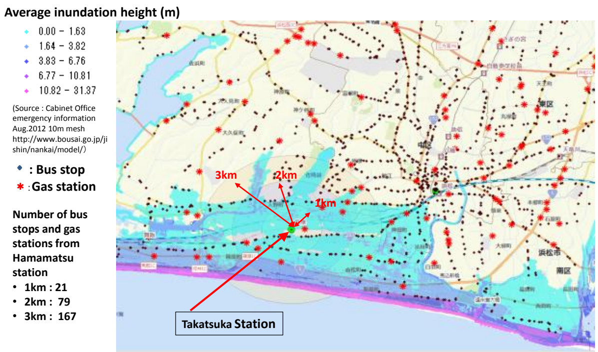

Figure 13. Takatsuka station with gas station.

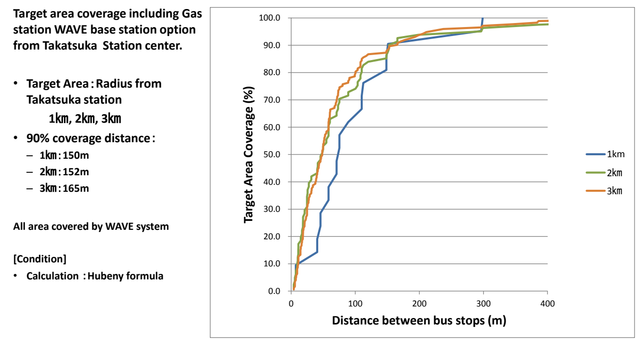

Figure 14. Coverage of Takatsuka station with gas station.

VI. SUMMARY

In this paper, it is the first time to expand ITS application for natural disaster protection tools for wireless communication system with using public transportation system such as bus and bus stop. Author shows the potential wireless communication system with WAVE system and creates "smart bus stops" with WAVE base system implementation. And this smart bus and bus stops concept can cover target area wireless communication system for especially expecting the next big earthquake disaster area "Nankai Trough" in Shizuoka prefecture. Author analyses one of big damage potential city where it is Hamamatsu city and target areas are two major Hamamatsu and Takatsuka station center point area of 1km, 2km and 3km radius distance. Author shows the effectiveness of smart bus and smart bus stop concept as WAVE application for natural disaster protection in terms of wireless communication system and shows sometimes other potential WAVE base station setting effectiveness for not enough wireless communication coverage, Takatsuka station in this paper with additional gas station WAVE base station.

In terms of more practical natural disaster protection, it is necessary to deploy protection system such as traffic jam guidance by analysis of traffic jam congestion by natural disaster evacuation, ad-hoc communication and hand-over mechanism of wireless communication system. All these other disaster protection technology will be covered by further study and real field trials.

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