International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Report ITU-R M.2228-1

(07/2015)

Advanced intelligent transport systems radiocommunications

M Series

Mobile, radiodetermination, amateur and related satellite services

International Telecommunication Union

Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

The regulatory and policy functions of the Radiocommunication Sector are performed by World and Regional Radiocommunication Conferences and Radiocommunication Assemblies supported by Study Groups.

Policy on Intellectual Property Right (IPR)

ITU-R policy on IPR is described in the Common Patent Policy for ITU-T/ITU-R/ISO/IEC referenced in Annex 1 of Resolution ITU-R 1. Forms to be used for the submission of patent statements and licensing declarations by patent holders are available from http://www.itu.int/ITU-R/go/patents/en where the Guidelines for Implementation of the Common Patent Policy for ITU-T/ITU-R/ISO/IEC and the ITU-R patent information database can also be found.

Series of ITU-R Reports

(Also available online at http://www.itu.int/publ/R-REP/en)

Series	Title
BO	Satellite delivery
BR	Recording for production, archival and play-out; film for television
BS	Broadcasting service (sound)
BT	Broadcasting service (television)
F	Fixed service
M	**Mobile, radiodetermination, amateur and related satellite services**
P	Radiowave propagation
RA	Radio astronomy
RS	Remote sensing systems
S	Fixed-satellite service
SA	Space applications and meteorology
SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	Spectrum management

Note*: This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

Electronic Publication
Geneva, 2015

REPORT ITU-R M.2228-1

Advanced intelligent transport systems radiocommunications

(Question ITU-R 205-5/5)

(2011-2015)

TABLE OF CONTENTS

Page

1 Background

Intelligent Transport Systems (ITS) are applied to services such as the provision of road traffic information and electronic toll collection, and deployed in many countries by using dedicated short-range communications (DSRC) or cellular phone systems. ITS have now become an important social infrastructure.

Several ITS relevant ITU-R Recommendations exist as listed below:

- ITU-R M.1890 Intelligent transport systems – Guidelines and objectives
- ITU-R M.1452 Millimetre wave radiocommunication systems for Intelligent Transport Systems applications
- ITU-R M.1453 Intelligent Transport Systems – dedicated short-range communications at 5.8 GHz
- ITU-R M.2084 Radio interface standards of vehicle-to-vehicle and vehicle-to-infrastructure communications for Intelligent Transport System applications.

Recommendation ITU-R M.1453, which supports a maximum data transmission rate of 4 Mbit/s, was limited to DSRC operations in the ISM band.

To extend beyond the existing Intelligent Transport System applications and to achieve traffic safety and reduce the environmental impact by the transportation sector, both R&D in and standardization of advanced Intelligent Transport System radiocommunications are expected, including not only roadside-to-vehicle communications but also vehicle-to-vehicle direct communications with a few hundred milliseconds or lower latency and with a few hundred metres or longer communication distance. To accommodate hundreds of vehicles in the communication range and to exchange their information in such a short latency, higher data rate wireless access technology is required for advanced Intelligent Transport System radiocommunications.

Studies and feasibility tests on advanced Intelligent Transport System radiocommunications have been actively conducted towards the realization of traffic safety and a reduction of the environmental impact.

As a result, recently, major progress has been made in R&D activities on advanced Intelligent Transport System radiocommunications in several regions including North America, Europe and Asia-Pacific Region. Therefore, it would be beneficial to share the information obtained for future harmonization and standardization.

Regarding standardization and information exchange, relevant discussions have been started in global standards collaboration (GSC) meeting. At the GSC-16 meeting, ITU-T, ETSI, TIA, TTA and ARIB presented their relevant activities. Furthermore, in the Asia-Pacific Region, issues relating to advanced Intelligent Transport System radiocommunications were discussed in a Task Group on ITS at the 11th meeting of APT Wireless Group (AWG-11).

2 Characteristics of advanced Intelligent Transport System radiocommunications

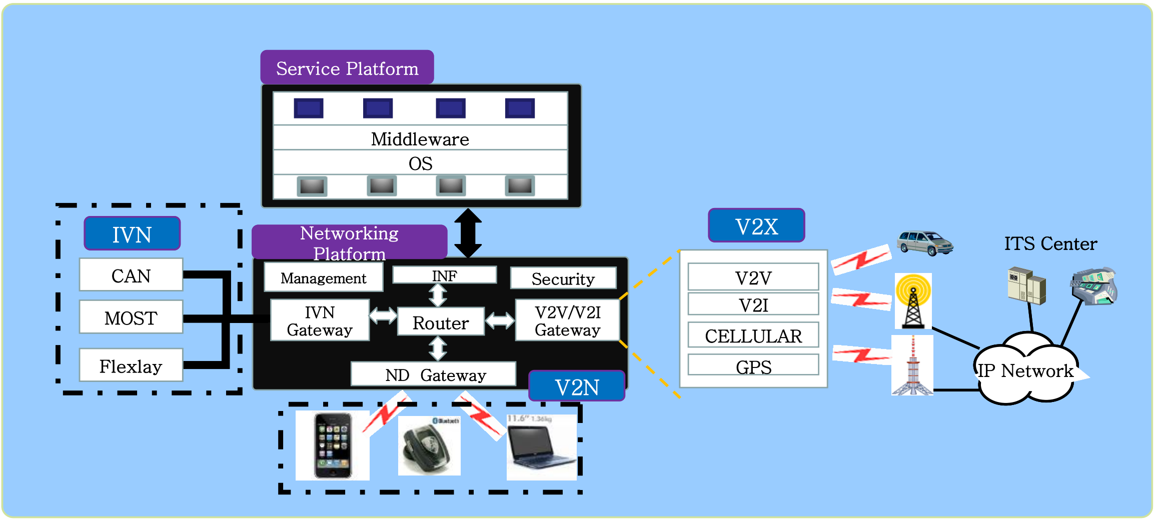
2.1 Terms and definitions

Advanced ITS have enhanced vehicular networking functionality to provide vehicle-to-vehicle communication (V2V), vehicle-to-infrastructure communication (V2I), in-vehicle network (IVN) and vehicle-to-nomadic devices (V2N). Enhanced vehicular networking functionality of advanced ITS also includes accurate location information with ID authentication and data encryption in the vehicle terminal. The vehicular networking is the basic requirement on the vehicle terminal for vehicle safety and new Intelligent Transport System applications. V2N allows hand-held devices to be used in vehicular environment as they are used in home and office environment.

Regarding radiocommunication aspects, advanced Intelligent Transport System radiocommunications support both V2V and V2I communications with improved performance in terms of radio coverage, packet data rate, packet size and latency.

FIGURE 1

Advanced ITS concept



2.2 Acronyms and abbreviations

APT	Asia-Pacific Telecommunity
ARIB	Association of Radio Industries and Businesses
ATIS	Alliance for Telecommunications Industry Solutions
AWG	APT Wireless Group
BAS	Broadcast Auxiliary Service
BPSK	Binary phase shift keying
CAM	Cooperative Awareness Messages
CCTV	Closed-circuit television
CSMA/CA	Carrier sense multiple access/collision avoidance
DEN	Decentralized Environmental Notification
ECC	Electronic Communications Committee
ECU	Electronic Control Unit
ETSI	European Telecommunications Standards Institute
FEC	Forward error correction
GPS	Global Positioning System
GSC	Global Standards Collaboration
ID	Identification
IEEE	Institute of Electrical and Electronics Engineers

ISE	Intersection safety equipment
ITS	Intelligent Transport Systems
IVN	In-vehicle network
LAN	Local area network
OFDM	Orthogonal frequency-division multiplexing
QAM	Quadrature amplitude modulation
OBD-II	On-board diagnostic system-II
QPSK	Quadrature phase shift keying
RF	Radio frequency
RSE	Roadside equipment
TIA	Telecommunications Industry Association
TTA	Telecommunication Technology Association
V2V	Vehicle-to-vehicle communication
V2I	Vehicle-to-infrastructure communication
V2N	Vehicle-to-nomadic device communication
VANET	Vehicular Ad hoc NETwork
WAVE	Wireless Access in Vehicular Environments
WSMP	WAVE Short Message Protocol

2.3 Technical characteristics

Technical characteristics of current and advanced ITS are described in the following table, respectively.

TABLE 1

Technical characteristics of ITS

Items	Current ITS	Advanced ITS
Vehicular networking	V2I	V2I, V2V, V2N
Radio performance	Radio coverage: Max. 100 m Data rate: ~ 4 Mbps Packet size: ~100 bytes	Radio coverage: Max. 1 000 m Data rate: Max. 27 Mbps Packet size: Max. 2 kbytes Latency: within 100 m/s

3 Requirements for advanced Intelligent Transport System radiocommunications

3.1 General system requirements

No.	Contents
1	Each vehicle must be individually identifiable.
2	Warning message related to vehicle safety such as vehicle crash, accident, etc. should be deliverable.

No.	Contents
3	Vehicle location information could be available.
4	The event occurrence time information of an accident should be able to transmit (broadcast) and receive.
5	Vehicle inter-communication should provide the functionality of transmitting and receiving messages in point-to-point communication as well as point-to-multi-point communication.
6	When needed, vehicle should be able to retransmit the received message to the nearby vehicles (multi-hop).
7	Vehicle should be able to collect the nearby vehicles' information when there is a request by driver or passengers.
8	Terminal should provide the ability to display the information (voice, message, video, etc.) to driver or passengers.
9	Terminal should provide the user interfaces (voice, keyboard, mouse, etc.) for various services.
10	Terminal should have external interfaces (USB, IDB1394, Bluetooth, etc.) for updating software and information.

3.2 Service requirements

3.2.1 Vehicle safety applications

3.2.1.1 Incident alert

A service that broadcasts monitoring messages of unexpected circumstances in front vehicles by means of vehicle communications.

3.2.1.2 Emergency vehicle entry warning

A service that broadcasts information about emergency vehicles such as their location, velocity, traffic lane in which they are moving, direction and destination by means of vehicle-to-vehicle communications in order to free their path for quicker response.

No.	Contents
1	Emergency vehicles should be able to transmit vehicle's moving direction information.
2	Vehicle should be able to collect the Vehicle Status Information (ex. location, velocity, acceleration direction, brake information, etc.).
3	The authentication methods for messages of unexpected incident information should be prepared.
4	The messages of unexpected incidents information should have priority.
5	Emergency vehicles should be able to broadcast the alarm message about their moving direction.
6	Emergency vehicles should be able to transmit the destination information.
7	When needed, vehicle should be able to broadcast the received alarm message to the nearby vehicles (multi-hop).
8	When needed, vehicle should be able to collect the information on road conditions and unforeseen circumstances.

3.2.2 Data communication services

3.2.2.1 Vehicle inter-communication service

A vehicle intercommunication service is that a data is transmitted and received by a point-to-point transmission among surrounding vehicles.

3.2.2.2 Group communication service

A group communication service is that a data is transmitted and received by a group transmission method among vehicles within a group.

No.	Contents
1	Link authentication should be supported for an individual communication.
2	Group ID and authentication should be supported for group communication.

4 Status of advanced Intelligent Transport System radiocommunications

4.1 Japan

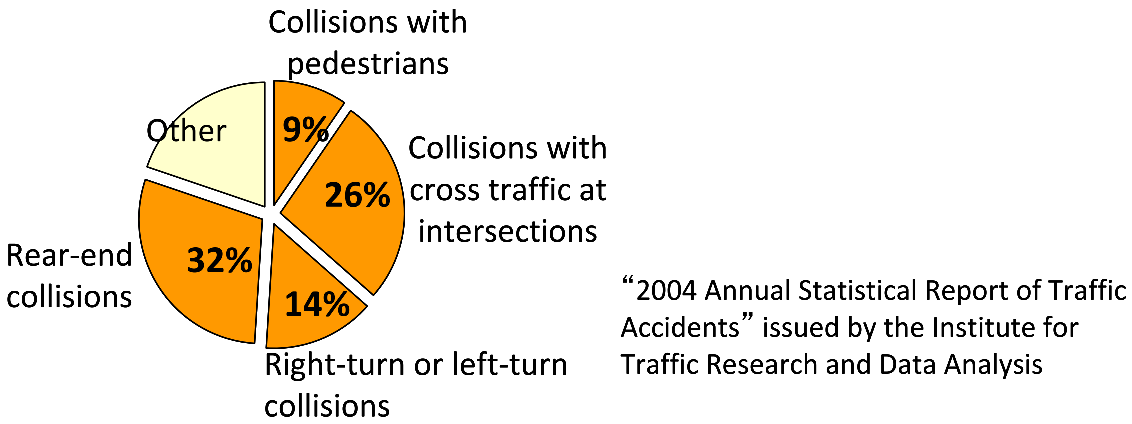
4.1.1 Applications

In Japan, realization of safe driving support systems has been studied extensively to reduce the number of traffic accidents. The 700 MHz radio-frequency band will be used for the safe driving support systems, since this frequency band is known for its good propagation characteristics in non-line-of-sight conditions such as behind buildings or large vehicles.

According to the "2004 annual statistical Report of traffic accidents" issued by the Institute for Traffic Research and Data Analysis in Japan, 80% of all traffic accidents fall into four accident types: rear-end collisions (32%), intersection collisions (26%), right-turn or left-turn collisions (14%), and collisions with pedestrians (9%).

FIGURE 2

Breakdown of traffic accidents by accident type



As much as the human factor behind traffic accidents is a concern, the Report reveals that "Failure to recognize a hazard in time," accounts for 70% of the total and, is the single leading cause compared to other causes such as "Errors in judgment" and "Errors in operation." Therefore, reduction of this

“Failure to recognize a hazard in time” should lead to a substantial reduction in traffic accidents. Safe driving support systems to prevent “Failure to recognize a hazard in time” are expected to be realized.

FIGURE 3

Breakdown of traffic accidents by human factor

To improve drivers’ recognition of potential hazardous situations, the safe driving support systems are supposed to consist of two types of systems: vehicle-to-vehicle communication systems that support safe driving by inter-vehicular radiocommunications at intersections with poor visibility, and roadside-to-vehicle communication systems that support safe driving by sending information (signal and regulatory information, etc.) from roadside units of traffic infrastructure to vehicles through radiocommunications.

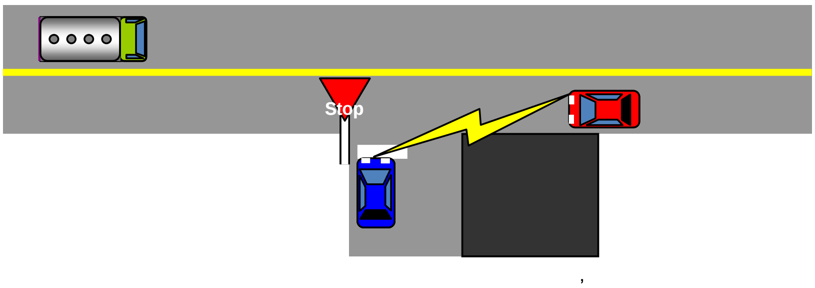
As the prioritized applications of safe driving support systems, such use cases as intersection collision avoidance, rear-end collision avoidance, right-turn/left-turn collision avoidance, emergency vehicle notification, provision of traffic signal information and regulatory information are considered and supported by using vehicle-to-vehicle and/or roadside-to-vehicle communications.

Examples of use cases are shown in the following three Figures.

Figure 4 shows a scene of intersection collision avoidance by vehicle-to-vehicle communications.

FIGURE 4

Intersection collision avoidance using vehicle-to-vehicle communications



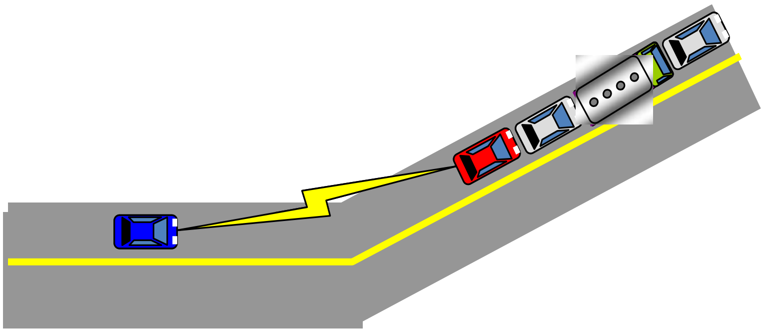
In Fig. 4, two vehicles, not visible to each other at the intersection, exchange information on their location, speed through vehicle-to-vehicle communications.

Thus, the drivers can receive alert messages in case of a hazardous situation.

Figure 5 corresponds to another use case and shows a scene of rear-end collision avoidance using vehicle-to-vehicle communications.

FIGURE 5

Rear-end collision avoidance using vehicle-to-vehicle communications

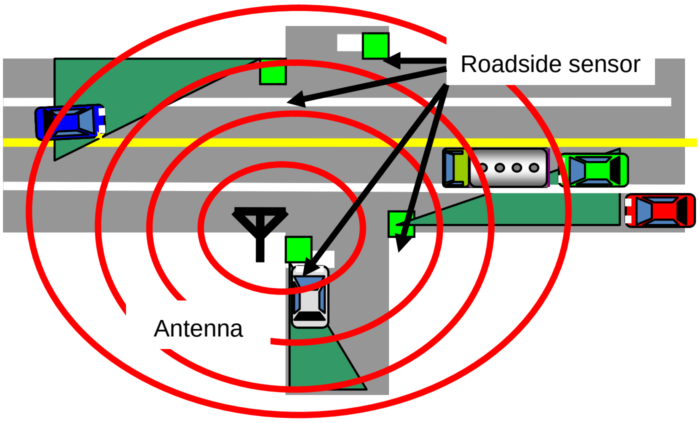


In Fig. 5, a vehicle approaching the tail end of a traffic jam, obtains information on the location, speed of vehicles ahead using vehicle-to-vehicle communications. Thus the driver can anticipate a traffic jam in advance.

Figure 6 shows a scene of intersection collision avoidance using roadside-to-vehicle communications.

FIGURE 6

Intersection collision avoidance using roadside-to-vehicle communications



In Fig. 6, roadside sensors at an intersection detect vehicles that cross or turn at the intersection and share this information amongst the vehicles approaching the intersection using roadside-to-vehicle communications.

4.1.2 Technical characteristics

This section provides examples of technical characteristic for the advanced Intelligent Transport System radiocommunications.

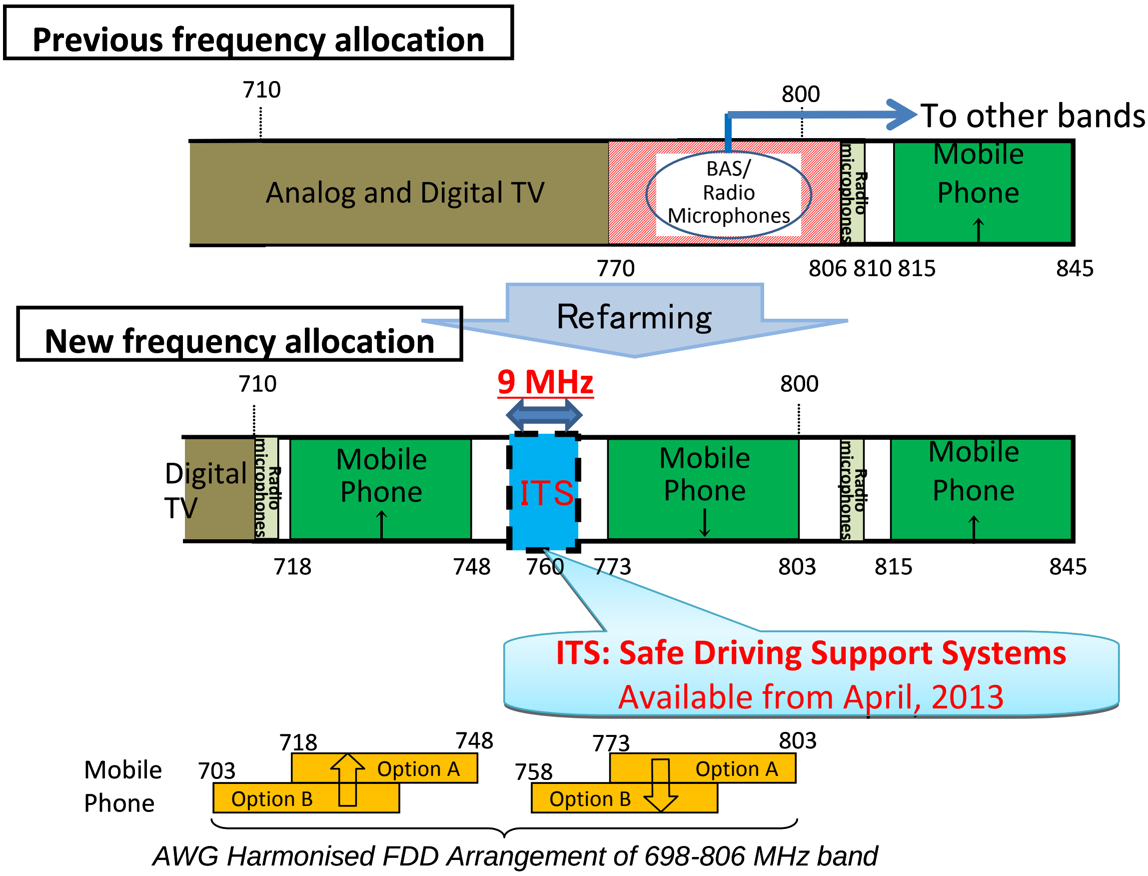
In Japan, for the use of the safe driving support systems, a part of the 700 MHz band (755.5-764.5 MHz) has been assigned in a new spectrum allocation on a primary basis in the digital dividend band as shown in Fig. 7. This Figure also shows a Harmonised FDD Arrangement of 698-806 MHz band[1]. Japan adopted “Option A” as shown in the Figure.

---

1 http://www.apt.int/AWG-RECS-REPS (APT-AWF-REP-14_APT_Report_Harmonized_Freq_Arrangement.doc).

FIGURE 7

700 MHz band frequency allocation for ITS in Japan



BAS: Broadcast Auxiliary Service

The technical characteristic of vehicle-to-vehicle and roadside-to-vehicle communications for safe driving support systems are shown in Table 2.

TABLE 2

Characteristics of the transmission scheme

Item	Technical characteristic
Operating frequency range	755.5-764.5 MHz (single channel)
Occupied bandwidth	Less than 9 MHz
Modulation scheme	BPSK OFDM/QPSK OFDM/16QAM OFDM
Error correction	Convolution FEC R = 1/2, 3/4
Data transmission rate	3 Mbit/s, 4.5 Mbit/s, 6 Mbit/s, 9 Mbit/s, 12 Mbit/s, 18 Mbit/s
Media access control	CSMA/CA

Table 2 shows basic specifications of ARIB standard; ARIB STD-T109[2], 700 MHz band Intelligent Transport Systems (ITS) which has been developed in February 2012, based on "ITS Forum

[2] ARIB standard; ARIB STD-T109, 700MHz band Intelligent Transport Systems (http://www.arib.or.jp/english/html/overview/doc/5-STD-T109v1_2-E1.pdf).

RC-006"[3] issued by the ITS Info-communications Forum as an experimental guideline for feasibility tests in Japan.

A 9 MHz channel width in the 700 MHz radio frequency band will be used for the safe driving support systems.

Data transmission rate is variable based on the selection of Modulation scheme and coding rate (R) as follows:

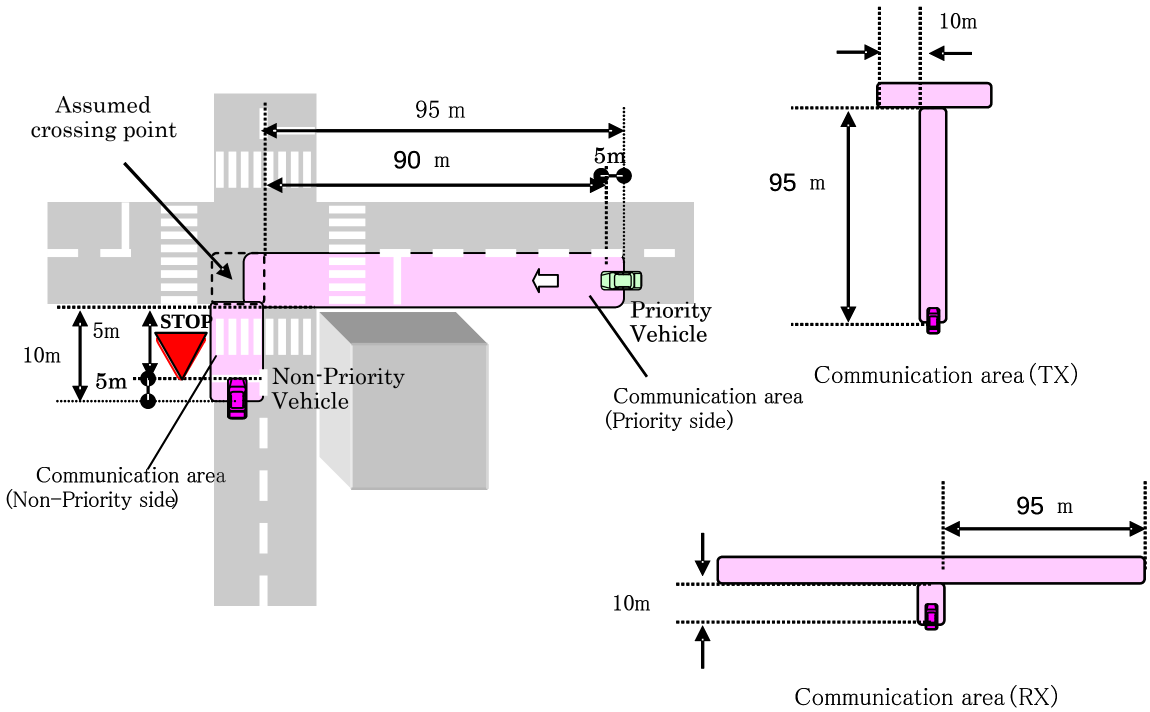
– 3 Mbit/s (BPSK OFDM, R = 1/2), 4.5 Mbit/s (BPSK OFDM, R = 3/4);
– 6 Mbit/s (QPSK OFDM/, R = 1/2), 9 Mbit/s (QPSK OFDM, R = 3/4);
– 12 Mbit/s (16QAM OFDM, R = 1/2), 18 Mbit/s (16QAM OFDM, R = 3/4).

The single channel accommodates both vehicle-to-vehicle and roadside-to-vehicle communications based on CSMA/CA media access control.

A 700 MHz radio frequency band will be used for the safe driving support systems. In particular, this frequency band is considered appropriate for communications in the use case of intersection collisions avoidance as shown in Fig. 8.

FIGURE 8

Communication areas for intersection collision avoidance using vehicle-to-vehicle communications (V2V)



In some safety applications, information from roadside units is considered more reliable than on-board information, therefore, roadside-to-vehicle communications shall be allocated

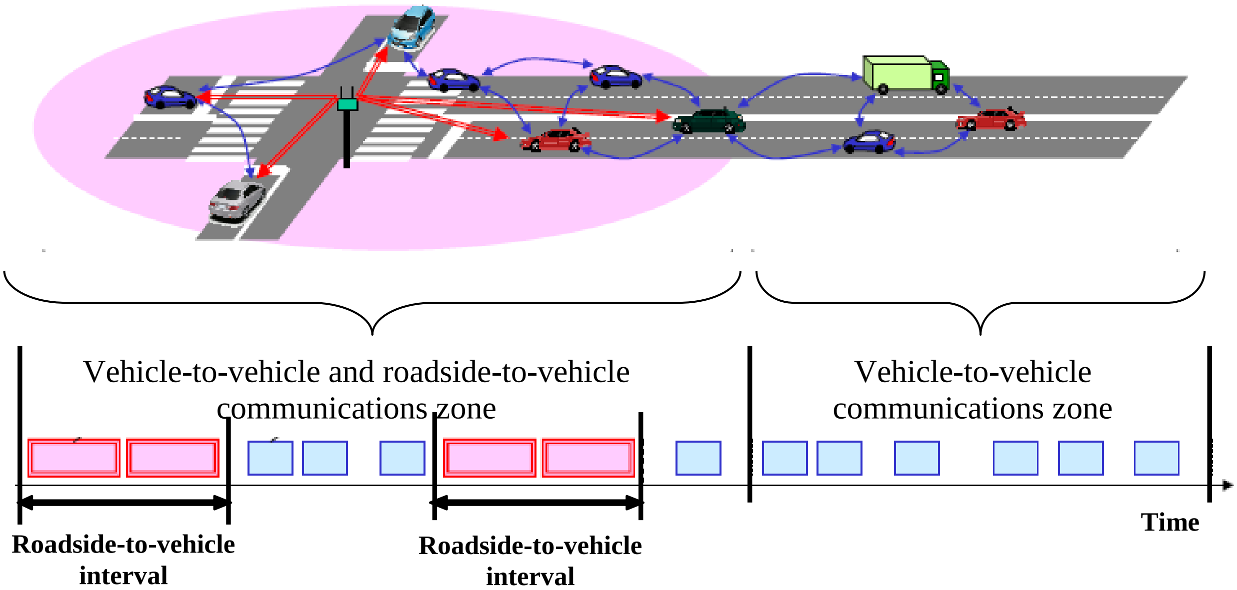
[3] Experimental Guideline for Vehicle Communications System using 700 MHz-Band (http://www.itsforum.gr.jp/Public/J7Database/p35/ITSFORUMRC006engV1_0.pdf).

an appropriate time-slot to ensure the communication band using roadside-to-vehicle interval shown in Fig. 9.

The time division mechanism is studied in ITS Info-communications Forum and ITS Radio System Committee in the Telecommunications Council in Japan.

FIGURE 9

Vehicle-to-vehicle and roadside-to-vehicle time division access



4.2 Korea (Republic of)

4.2.1 Applications

Advanced Intelligent Transport System radiocommunications provides new vehicle communication based applications. Radar systems also provide traffic information for safety applications.

Vehicle information service provides vehicle diagnosis and traffic information by using V2I and IVN interworking. The ECU information can be monitored by connecting OBD-II interface equipment and processed in vehicle terminal. Vehicle terminal will store the vehicle data such as vehicle speed, time, direction, acceleration or de-acceleration, CO_2 emission, etc. Vehicle information is transmitted to the server via V2I communication. Server will generate real time traffic information from the raw vehicle data. Figure 10 shows vehicle information based service concept.

FIGURE 10

Vehicle information service

IP Video streaming service will provide CCTV image or streaming data to vehicle terminal. CCTV is installed on roadside and its video streaming data is sent to the server to monitor road situation. The CCTV information will be sent to the vehicle terminal on driver's request. CCTV data will provide information to the driver on road and traffic conditions in the driving direction. Figure 11 shows IP Video streaming service.

FIGURE 11

IP video streaming service

Intersection safety service will provide intersection road situation to the driver. Intersection situation information is attained by using CCTV, radar sensor, traffic signal to reduce traffic accidents at the intersection. The intersection situation information will be processed on the intersection safety equipment (ISE) which is connected to IP cameras and traffic signal. ISE will have intersection image, traffic signal and pedestrians, which will be transmitted to vehicle terminal through RSE. Figure 12 shows intersection safety service.

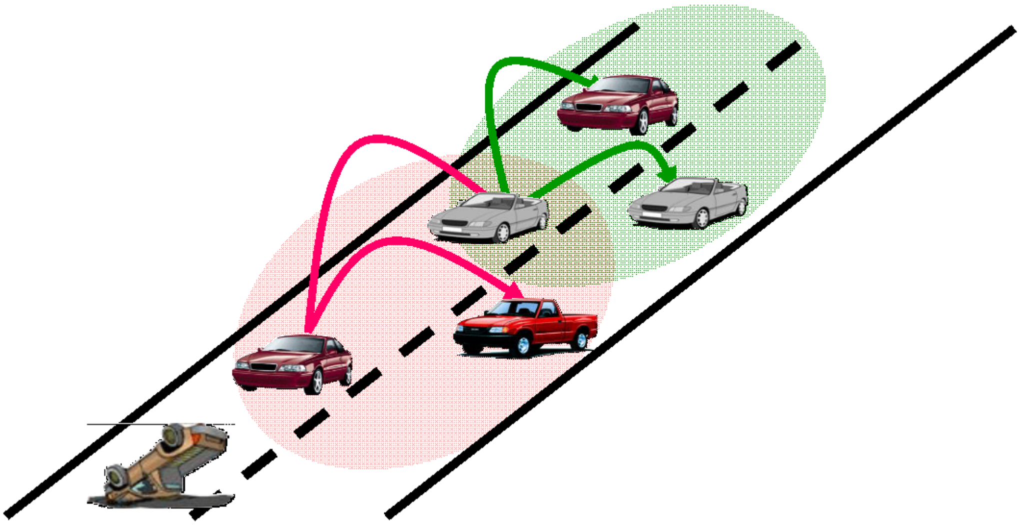
FIGURE 12

Intersection safety service

Unexpected situation warning service will inform the driver about car accident, road construction and dangerous situation. Unexpected situation can be reported as warning packet in periodic broadcasting. For example, warning packet can be generated by pushing the emergency switch. It can be also automatically generated in the vehicle terminal in case of sudden stop by pressing on the brake. This warning packet would help preventing traffic accident. Figure 13 shows unexpected situation broadcasting service.

FIGURE 13

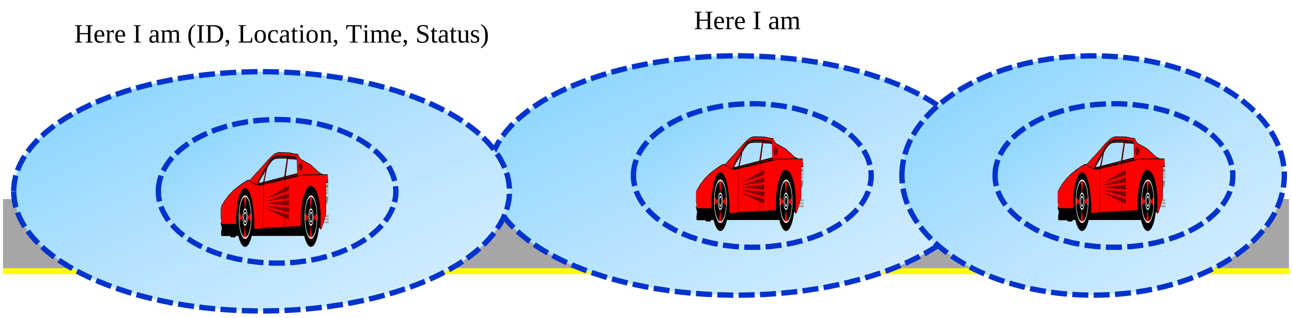
Unexpected situation broadcasting service



Vehicle anti-collision service provides pre-crash protection by broadcasting vehicle's information to the adjacent vehicle, the message is called "Here I am" message. Vehicle information includes its identification, location and driving status. This service needs accurate location information, signal signature and data encryption. Figure 14 shows vehicle anti-collision service.

FIGURE 14

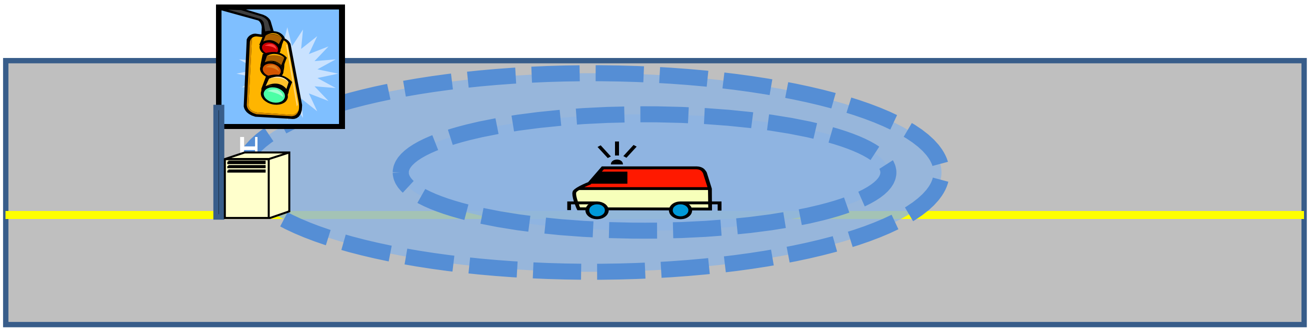
Anti-collision warning service



Emergency vehicle signal pre-emption service provides signal priority to ambulance and fire truck when they enter an intersection area. The emergency vehicle flickers emergency light and broadcasts packet message to inform other vehicles that it is approaching. RSE receives the packet and turns the traffic lights in order for the emergency vehicle to pass through the intersection without stopping. Figure 15 shows emergency vehicle signal pre-emption service.

FIGURE 15

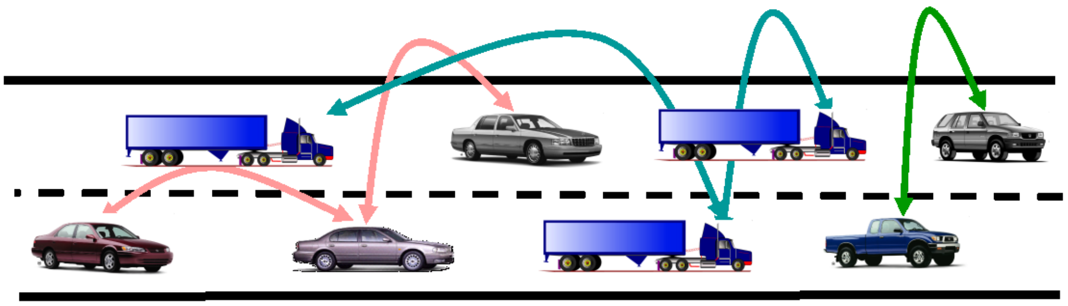
Emergency vehicle signal pre-emption service



Group communication service provides multi-hop communication among vehicles. Each vehicle has its own ID and supports group communication by unicasting. Group communication uses IP communication protocol and includes message, voice and image information. Thus it can be used for police, fire station, emergency and military applications. Figure 16 shows group communication service.

FIGURE 16

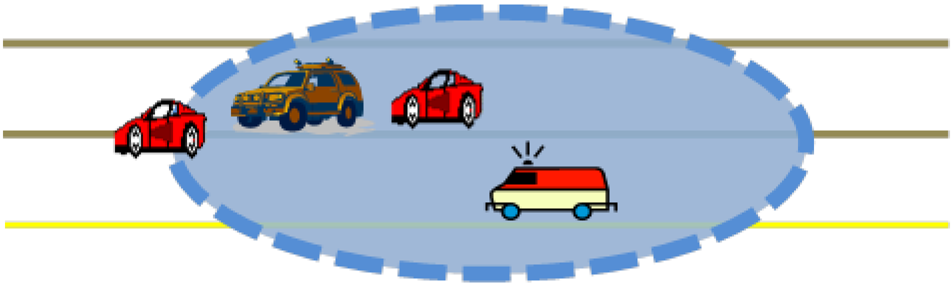
Group communication service



Emergency vehicle approach warning service provides alarm to vehicles to clear front road for ambulance and fire truck when they are approaching those vehicles. The emergency vehicle flickers emergency light and broadcasts packet message to inform other vehicles that it is approaching. The vehicles receiving the information change the lane to pass emergency vehicle without blocking. Figure 17 shows emergency vehicle approach warning service.

FIGURE 17

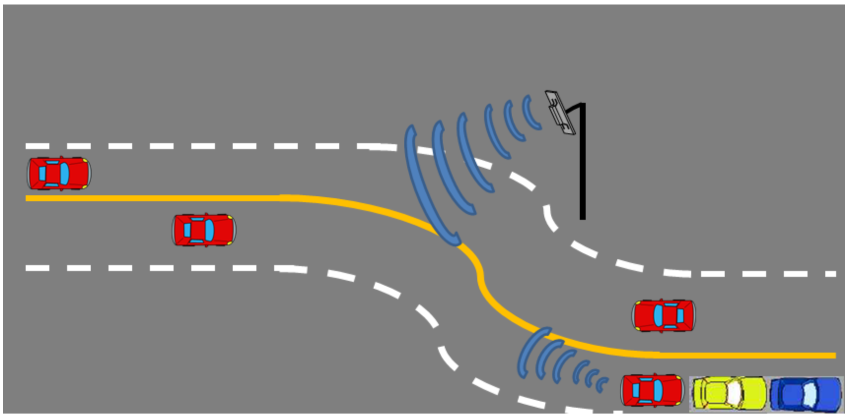
Emergency vehicle approaching warning service



Congestion/Curve warning service enables drivers in the approaching vehicles to receive congestion or road works information in advance, then it assists drivers to decrease the speed for safe driving roadside equipment or a vehicle to other vehicles to deliver the warning or alert information at the hard curve, entering/outgoing point of tunnel or accident occurred places. Drivers can proceed cautiously at the end of a traffic jam, by obtaining information on the location, speed of vehicles ahead using vehicle-to-vehicle communications. Thus the driver can anticipate a traffic jam in advance. Figure 18 shows safe driving assistant service.

FIGURE 18

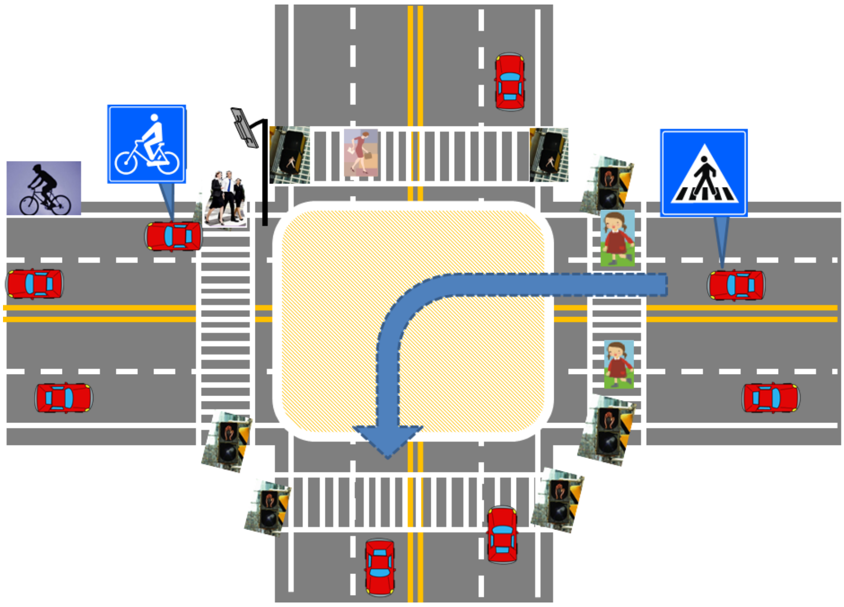
Congestion warning service



Pedestrian/bicyclist warning service enables drivers to receive warning messages about the detected pedestrians or bicyclists in the vicinity from radar or video sensors in the vehicle. This service would be served at the intersection with or without the traffic signal. If pedestrians or bicyclists are equipped with communication modules or wearable devices, they could be alerted of approaching vehicles for safe walking or crossing. It would be bidirectional communications. The vehicle will warn automatically to pedestrians or bicyclists without human intervention. Figure 19 shows the pedestrian warning service.

FIGURE 19

Pedestrian warning service



Smart tolling service enables non-stop passing without the tollbooth. This service provides high speed electronic toll collection services in multiple lanes. Vehicles installed tolling system can pass tolling area at the same speed without stops and delay to pay the toll fee. Figure 20 shows smart tolling service.

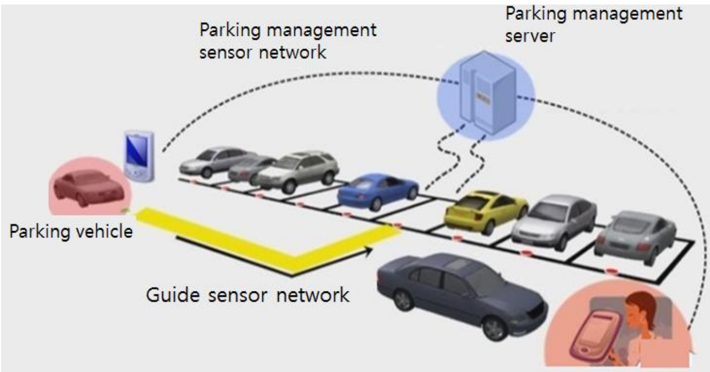
FIGURE 20

Smart tolling service

Auto valet parking service enables unmanned vehicle to park in the predetermined area. Parking management server, which manages the parking space with database of parking space, guides the parking vehicle to available parking space. Parking vehicle has parked automatically through guided sensor networks. Figure 21 shows auto valet parking service.

FIGURE 21

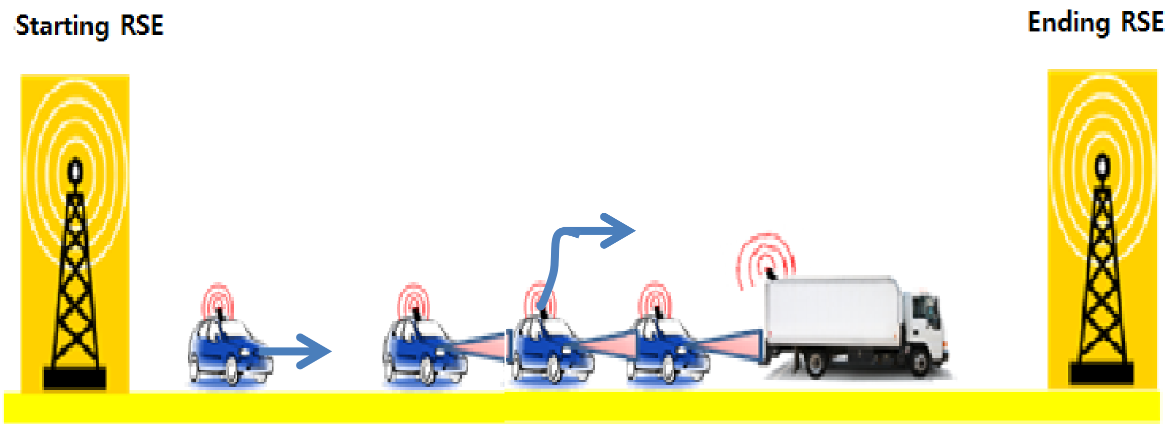
Auto valet parking



Cooperative driving service enables to drive a couple of following vehicles without drivers by leading vehicle or drivers in vehicles to make free without heavy workload during cooperative driving by forming a group so called platoons. As the number of vehicles can be flexible in the group, this service can build a long one with join function of newly entering vehicle to the group and a shorter one with leave function of leaving vehicle from the group. This service encourages to safe driving with steady speed and supports helpful for energy saving also. Figure 22 shows cooperative driving service.

FIGURE 22

Cooperative driving service



4.2.2 Technical characteristics

The advanced ITS radiocommunications system has to consider the described V2V/V2I communication and its service requirements and WAVE standard for international harmonization. In V2V application, it is required to consider the low packet latency because the life time of safety message is useful in the order of 100 m/s. Also it requires highly activated radio channel when many vehicles activate radio channel simultaneously. In V2I applications, it needs to adopt the long packet transmission which includes short message, map information and image information to be order of 2 kbytes in packet size in high mobility condition. Thus the advanced Intelligent Transport System radiocommunications have the following features as shown in Table 3.

TABLE 3

Technical characteristics

Item	Technical characteristic
RF frequency	5.855-5.925 GHz (Pilot system)
RF channel bandwidth	10 MHz
RF Transmit power	23 dBm
Modulation type	OFDM(BPSK, QPSK, 16QAM, Option : 64QAM)
Data rate	3, 4.5, 6, 9, 12, 18 Mbit/s, Option : 24, 27 Mbit/s
MAC	CSMA/CA, Option: Time Slot based CSMA/CA
Networking	IPv4/IPv6, VMP(WSMP compatible)
Multi-hop	Location information based routing

4.2.3 TTA Standards related to advanced Intelligent Transport System radiocommunications

In the Republic of Korea, Telecommunication Technology Association (TTA) established five standards for advanced Intelligent Transport System radiocommunications. The detailed information of these standards is shown in Table 4.

TABLE 4

TTA standards related to advanced ITS radiocommunications

Standard No.	Standard title	Summary	Issued date
TTAK.KO-06.0175/R1	Vehicle communication system Stage 1: Requirements	The standard describes mainly some services are supported by the multi-hop vehicle communications such as the warning service and group communication service. And it also describes general requirements and performance requirements of vehicle communication systems for information service and the group communications service, etc.	2013.12
TTAK.KO-06.0193/R1	Vehicle communication system Stage 2: Architecture	The standard describes mainly architecture and components of vehicle communications system which supports vehicle communication services such as the warning service and group communication service. As to the main contents, this standard defines the structure of the inter-vehicle communication system describing the hierarchical layers comprised the system architecture. And it also describes general architecture with the of vehicle-to-infrastructure communication systems for information service, etc.	2013.12

TABLE 4 (*end*)

Standard No.	Standard title	Summary	Issued date
TTAK.KO-06.0216/R1	Vehicle communication system Stage 3: PHY/MAC	The standard describes specifications of physical (PHY) and medium access control layer (MAC) for vehicle-to-vehicle communication systems. This standard is based on IEEE P802.11p™ which modifies IEEE P802.11™-2007 standard. The detailed description of IEEE P802.11p™ is not specified in this standard. This document only deals with new technologies for vehicle-to-vehicle communication systems which are not covered in IEEE 802.11p™. The other technical contents which are not specified in this standard follow IEEE 802.11p™.	2013.12
TTAK.KO-06.0234/R1	Vehicle Communication System State 3: Networking	The standard describes specifications of networking layer for multi-hop vehicle communication systems. This standard is based on IEEE P1609™ (WAVE) and IEEE P802.11p™ standards. The detailed description of IEEE P1609.3™ is not specified in this standard. This document only deals with new technologies for vehicle-to-vehicle multi-hop communication systems which are not covered in IEEE P1609.3™. The other technical contents which are not specified in this standard follow IEEE P1609.3™.	2013.12
TTAK.KO-06.0379	Join and leave messages and procedures for cooperative driving	This standard is to specify the message formats and communication protocol for cooperative driving systems which support high mobility (maximum speed with 200 km/h) and short latency; these cooperative driving systems provide traffic information, and safety services.	2014.12

4.3 Europe

4.3.1 Standardization

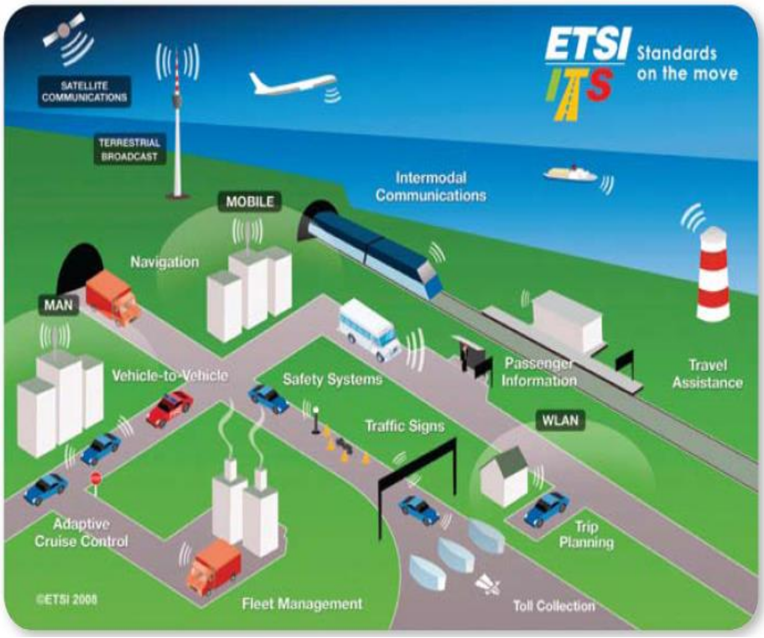
With regard to cooperative systems that include car-to-car, car-to-infrastructure, infrastructure-to car and infrastructure-to-infrastructure communications it has been necessary to identify a new frequency band that is able to cope with the requirements of the envisaged safety critical applications implying low latency and time-critical capabilities.

The ECC Decision of 14 March 2008 (ECC/DEC/(08)01) on the harmonized use of the 5 875-5 925 MHz frequency band for ITS stimulated an initiative to further develop ITS in Europe. Hereby the radio spectrum in the 5 875-5 905 MHz frequency is reserved for safety-related applications of ITS in Europe. Relevant parameters for the use of this band are covered by the European Commission Decision 2008/671/EC.

The European Commission (EC) issued the Mandate M/453 and invited the European standardization organizations to prepare a coherent set of standards.

FIGURE 23

Overview of ITS in ETSI



The European standardization organizations CEN and ETSI have accepted the mandate and they agreed to jointly develop a list of minimum set of standards for interoperability and other identified standards and technical specifications to support cooperative ITS services.

The standardization activities focus on:

– Basic set of applications (ETSI TR 102 638), e.g.:
  - Cooperative Awareness (ETSI TS 102 637-2)
  - Decentralized Environmental Notification (ETSI TS 102 637-3)
– Geonetworking (multi-hop communications, ETSI TS 102 636)
– Secure and Privacy-Preserving Vehicular Communication (ETSI TS 102 731)
– European profile standard based on IEEE 802.11p (ETSI ES 202 663)
– Congestion Control and Harmonized Channel Specifications (ETSI TS 102687, ETSI TS 102 724).

Furthermore the work of the Car-to-Car Communication Consortium and ISO/CALM is considered as well as the outcome of public funded projects (e.g. COMeSafety2, DRIVE C2X).

4.3.2 Applications

The ITS standardization in Europe defines a system that is able to support a variety of applications. Therefore a basic set of applications has been specified in ETSI TR 102 638[4] and the standardization takes into account their requirements.

[4] The description of this chapter is mainly taken from ETSI TR 102 638 v1.1.1 (2009-06).

TABLE 5

Basic set of applications definition

Applications class	Application	Use case
Active road safety	Driving assistance – Cooperative awareness	Emergency vehicle warning
		Slow vehicle indication
		Intersection collision warning
		Motorcycle approaching indication
	Driving assistance – Road Hazard Warning	Emergency electronic brake lights
		Wrong way driving warning
		Stationary vehicle – accident
		Stationary vehicle – vehicle problem
		Traffic condition warning
		Signal violation warning
		Roadwork warning
		Collision risk warning
		Decentralized floating car data – Hazardous location
		Decentralized floating car data – Precipitations
		Decentralized floating car data – Road adhesion
		Decentralized floating car data – Visibility
		Decentralized floating car data – Wind
Cooperative traffic efficiency	Speed management	Regulatory/contextual speed limits notification
		Traffic light optimal speed advisory
	Cooperative navigation	Traffic information and recommended itinerary
		Enhanced route guidance and navigation
		Limited access warning and detour notification
		In-vehicle signage
Cooperative local services	Location based services	Point of interest notification
		Automatic access control and parking management
		ITS local electronic commerce
		Media downloading
Global internet services	Communities services	Insurance and financial services
		Fleet management
		Loading zone management
	ITS station life cycle management	Vehicle software/data provisioning and update
		Vehicle and RSU data calibration.

The applications are divided into three classes:

– **Cooperative road safety**

The primary objective of applications in the active road safety class is the improvement of road safety. However, it is recognized that in improving road safety they may offer secondary benefits which are not directly associated with road safety.

– **Cooperative traffic efficiency**

The primary objective of applications in the traffic management class is the improvement of traffic fluidity. However it is recognized that in improving traffic management they may offer secondary benefits not directly associated with traffic management.

– Cooperative local services and global internet services

Applications in the cooperative local services and global internet services classes advertise and provide on-demand information to passing vehicles on either a commercial or non-commercial basis. These services may include Infotainment, comfort and vehicle or service life cycle management. Cooperative local services are provided from within the Intelligent Transport System network infrastructure. Global internet services are acquired from providers in the wider internet.

The following scenarios are examples (from ETSI TR 102 638):

FIGURE 24

The motorcycle warning use case scenario has been demonstrated at the CAR 2 CAR Communication Consortium (C2C- CC) Forum from 22-23 October, 2008 in Dudenhofen, Germany

FIGURE 25

Road work warning (Cooperative road safety)

FIGURE 26

Traffic light optimal speed advisory use case scenario (cooperative traffic efficiency)

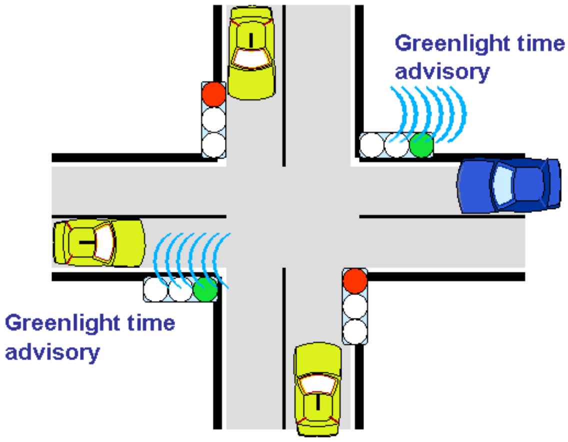
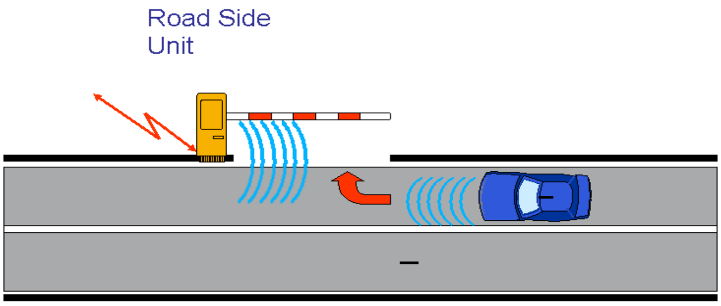


FIGURE 27

Automatic access control/parking access use case scenario (cooperative local service)



4.3.3 Technical characteristics

ITS in Europe is based on the European profile standard based for IEEE 802.11p as described in ETSI ES 202 663. The set of protocols and parameters that are defined in that document are called ITS-G5 operating in the frequency ranges:

– ITS-G5A: 5,875 GHz to 5,905 GHz dedicated to ITS for safety related applications.

– ITS-G5B: 5,855 GHz to 5,875 GHz dedicated to ITS non- safety applications.

– ITS-G5C: 5,470 GHz to 5,725 GHz.

The technical characteristics for ITS-G5A and ITS-G5B are summarized in Table 6.

TABLE 6

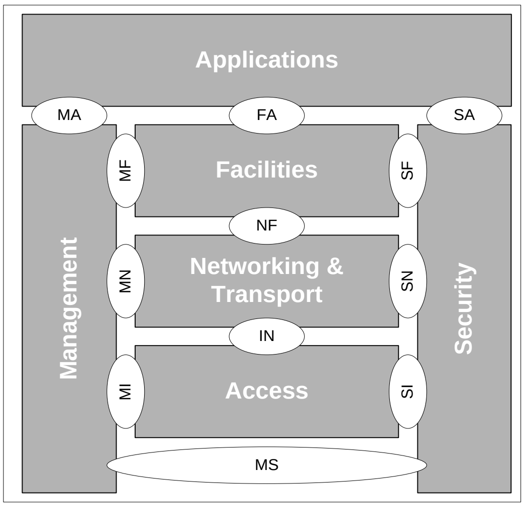
Characteristics of the transmission scheme

		Centre frequency	**Name**	**Tx power limit (EIRP)**	**Default data rate**
Channels	ITS-G5A	5 900 MHz	G5CC – control channel	33 dBm	6 Mbit/s
		5 890 MHz	G5SC2 – service channel 2	23 dBm	12 Mbit/s
		5 880 MHz	G5SC1 – service channel 1	33 dBm	6 Mbit/s
	ITS-G5B	5 870 MHz	G5SC3 – service channel 3	23 dBm	6 Mbit/s
		5 860 MHz	G5SC4 – service channel 4	0 dBm	6 Mbit/s
Channel bandwidth	10 MHz				
Modulation scheme	OFDM with channel access CSMA/CA (see IEEE 802.11p)				
Available data rates	3/4.5/6/9/12/18/24/27 Mbit/s				

The communications architecture is shown in Fig. 28.

FIGURE 28

ITS station reference architecture (from ETSI EN 302 665)



The main features of the ITS stations using ITS-G5 are:

– **Access layer**

Based on IEEE 802.11p, supplemented with a powerful "Decentralized Congestion Control" (DCC) as described in ETSI TS 102 687. The DCC uses channel load measurements to restrict transmissions such that the overall channel load is below a given threshold.

ITS stations are forced to always listen to the control channel it not transmitting. Consequently for using a service channel a second transceiver (dual channel concept) or a multi-channel receiver is needed.

– **Networking & transport**

Besides standard functionalities for unicast and broadcast transmission, this layer includes geocast functionalities, i.e. a geographic area (circle, ellipse, rectangle) can be addressed that exceeds the usual communication range. In that cast multihop communications are used.

– **Facilities**

Support of the applications by providing commonly used functions. The “Cooperative Awareness” basic service (ETSI TS 102 637-2) establishes the so-called vehicular ad-hoc network (VANET) by quasi-periodical transmissions of Cooperative Awareness Messages (CAM) on the control channel. Event messages like hazard warnings are wrapped into “Decentralized Environmental Notification” (DEN) messages (ETSI TS 102 637-3).

– **Security**

Security in VANETs care for secure and privacy preserving communication in ITS environments. It describes facilities for credential and identity management, privacy and anonymity, integrity protection, authentication and authorization (ETSI TS 102 731).

– **Management**

Management functionalities for configuration and cross layer issues.

– **Applications**

Cooperative road safety, Traffic efficiency and cooperative local services and global internet services.

NOTE – The ITS station communications architecture also describes how the ITS stations are integrated into the internet using other media like standard RLAN (e.g. operating in ITS-G5C) or mobile communications (e.g. UMTS). This is used for connecting to “central ITS stations”.

5 References

[1] APT/AWG/REP-18, APT Report on "Usage of Intelligent Transportation Systems in APT Countries", 2011.03.

[2] TTAK.KO-06.0175/R1, Vehicle Communication System Stage 1: Requirements, 2013.12.

[3] TTAK.KO-06.0193/R1, Vehicle Communication System Stage 2: Architecture, 2013.12.

[4] TTAK.KO-06.0216/R1, Vehicle Communication System Stage 3: PHY/MAC, 2013.12.

[5] TTAK.KO-06.0234/R1, Vehicle Communication System State 3: Networking, 2013.12.

[6] TTAK.KO-06.0242/R1, Vehicle Communication System Stage 3: Application Protocol Interface, 2013.12.

[7] IEEE Std P802.11p-2010, Telecommunications and information exchange between systems-Local and Metropolitan networks-Specific requirements-Part II: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications-Wireless Access in Vehicular Environments, 2010.

[8] IEEE 1609, Family of Standards for Wireless Access in Vehicular Environments (WAVE).

[9] TTAK.KO-06.00379, Join and Leave Messages and Procedures for Cooperative Driving, 2014.12.