DSRC Technology for Intelligent Transportation System

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***Abstract* – DSRC stands for Dedicated Short-Range Communications which is a wireless technology that integrates with Intelligent Transportation System to communicate between vehicle and roadside infrastructure units. DSRC has more advanced features compared to wireless technologies such as Wi-Fi, GSM, WiMAX, and etc. This paper summarizes the features, technical mechanism, and the applications of Dedicated Short-Range Communication in Intelligent Transportation Systems (ITS).**

Keywords - DSRC (Dedicated Short-Range Communications), ITS (Intelligent Transportation System), long distance RFID, OBE, RSE, V2I, V2V

1. INTRODUCTION

Dedicated Short-Range Communication Wireless technology is basically a long-range RFID based microwave wireless technology. The International Standardization Organization's (ISO) transport and control system unit is responsible for implementing and governing the standards for DSRC. USA 900 MHz, Japan ARIBSTDT75 and Europe ENV Series are the world DSRC standard camps. [1] Wireless Management congress has been advised to reserve 5.8 GHz frequency band to DSRC. With the assist of DSRC Wireless technology vehicle is capable of keeping connection other vehicles , in order to improve the road safety & driving experience.

2. TECHNICAL FEATURES

As a wireless communication technology, Dedicated short range technology is capable of operate at high-speed. Since DSRC can provide maximum transfer rate with minimum delay. This technology is capable of providing services in vehicle to infrastructure connection and vehicle to vehicle connection and many other communications services for transport systems such as Electronic Toll collection (ETC), intelligent parking systems and etc. . It can establish fast and high reliable connection in communication process. DSRC has more advanced features over GSM (Global System for Mobile Fidelity) and Wi-fi. Since DSRC has similar features and performance parameters as WiMAX and has less complication and cost it considered to be the more reliable wireless technology.

	DSRC	Wi-Fi	GSM	WiMAX
Delay	<50ms	Seconds	Seconds	/
Mobility	>60m/h	<5m/h	>60m/h	>60m/h
Data Transfer Rate	3-27 Mb/s	6-54 Mb/s	<2Mb/s	1-32 Mb/s
Communication Distance	<1000m	<100m	<10km	<15km
Communication Bandwidth	10MHz	20MHz	<3Mhz	<10MHz
Communication Band	5.86~ 5.925 GHz	2.4GHz, 5.2GHz	800MHz, 1.9GHz	2.5GHz
IEEE Standards	802.11P (WAVE)	802.11a	N/A	802.16e

Tab.1 Wireless Communication Technologies Comparison [2]

Federal communication congress of United States allocated 5.850 to 5.925 GHz band as patented frequency range for usage of Dedicated Short-Range Communication in Intelligent Transportation Systems. This frequency route has been divided into seven different channels. Initial channel has been allocated to V2V communication and Collison/accident avoidance while the last one is allocated to power and long-distance communication. The 4th channel in the center of band is allocated to broadcast message management instruction and control the systems. Rest of the channels out of seven channels are being used as service channels.

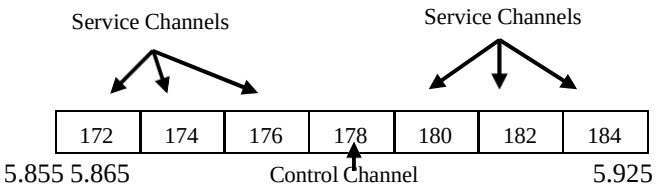


Figure 1: The DSRC communication channel allocation

IEEE 802.11a was based to develop the standard communication protocol. Then the bottom and middle protocols were developed. Followed by that IEEE 802.11 p protocol was established. This is used in rapid transportation to standard speed 5.98 KMHz for Vehicle-to-Infrastructure communication and Vehicle to Vehicle communication.[3]

3. COMMUNICATION AND TECHNICAL MECHANISM

Dedicated Short-Range communication technology mechanism basically consists of following three units.

- Roadside unit (RSE)
- On-Board Unit (OBU)
- Communication protocols

There are various types of equipments of OBU available. Most of the vehicles which run at high speeds are equipped with OBUs. RSUs are placed on shoulders of the roads. DSRC protocols has a layered architecture and it consists of three major layers containing data-link layer, application layer and physical layer (Figure 2) [4]. Again, the data link layer is divided into two layers relevant to their function : MAC (Medium Access control), LLC (Logical Link Layer). This simple protocol architecture is reason for its real-time features due to its low overhead in protocols OS which reduces the delays [5].

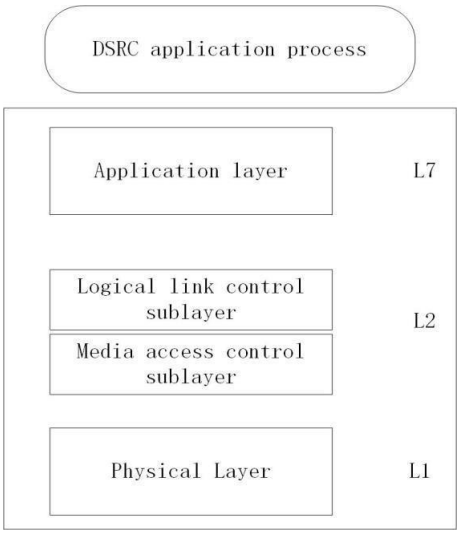


Figure 2 : DSRC Protocol Architecture

DSRC applied vehicles need be included with traffic monitoring, collision avoidance, adaptive cruise and etc.

Figure 3 illustrates a simple occurrence at an intersection. Since he development in urban areas, number of buildings and intersections are increased. Due to this, drivers cannot see through some places at intersections which may end up with occurrences of traffic accidents. Hence connections between vehicles and location sharing are needed to minimize occurrence of roadside accidents. Using this a warning message can be sent to the drivers if there is a chance of possible danger. By processing this information shared by other vehicle and surrounding infrastructure, vehicles and drivers can inspect and decide prior to making a turn.

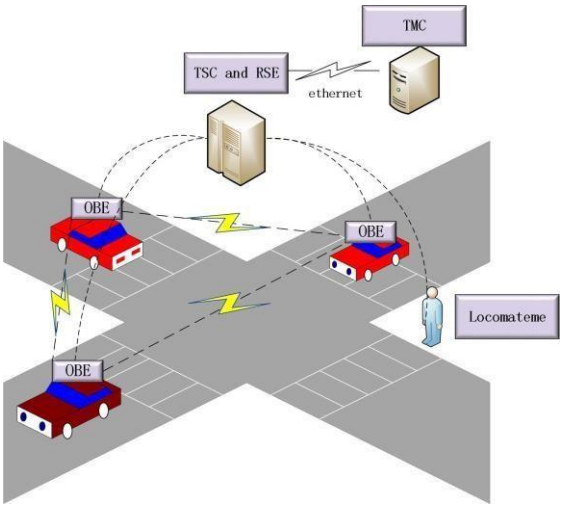


Figure 3 : DSRC Communication Model

Vehicle to Vehicle and Vehicle to Infrastructure communication can be operated via OBE unit installed in the vehicle. Inter-connected RSE and OBE exchange the traffic information frequently. RSE sends real-time SPaT (Real-Time Signal Phasing and Timing) information relevant to the intersection. OBE receives this information, and it processes the information to let the driver know whether they can make their movement or not. Moreover, if public transport vehicles are equipped with OBE units, the system prioritize to those vehicles which increases efficiency of public transportation.

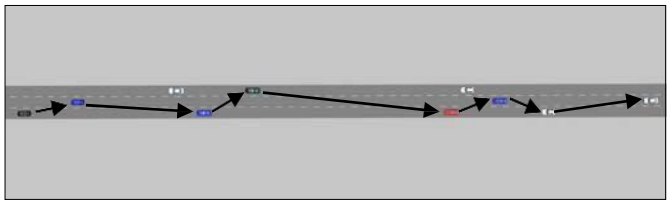
Network Model of Vehicle to Infrastructure (V2I) communications is grounded on single-HOC type communication and it is basically a communication mean between a fasten (fixed) equipment and a mobile equipment. This is widely applied in ETC and intelligent parking systems.

Network model of Vehicle-to-Vehicle communication is built upon on multiple-HOC communication and it is a communication mean between two mobile objects regardless

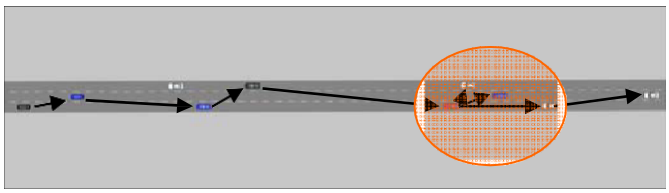
of their movement. V2V is basically used in tasks such as barrier detection, highway management and initiative avoidance.

3.1 Vehicle to Vehicle communication mechanism

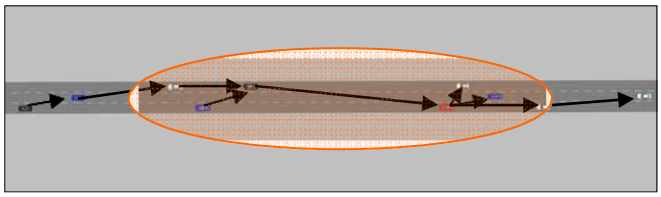
V2V communication mechanism can be divided to three major geocast schemes : topologically scoped broadcast, geographical broadcast and geographical unicast. (Figure 4) Geographical unicast delivers packet among pair of nodes through several wireless hops. If a node wants to pass a unicast message, firstly it locates target. Secondly it sends data packets for the node that located nearby to the target. Geographical broadcast basically floods the region to dispense data packets in identified geographical regions by the packets. This flooding technique used in V2V is improved to overcome the wireless add hos issues such as broadcast storms by simply using packet numbering technique. Topologically scoped broadcast rebroadcast the data packets to source to destination nodes which are located in n-hop neighborhood. Topologically scoped broadcast has a special technique called single hop broadcast which sends periodic messages [6]. (Figure 4)



1) Geographic Unicast



2) GeographicBroadcast



3) Topologically - scoped

Figure 4 : Three Geocast Schemes

3.2 Communication Mechanism of V2I

On-Board unit holds the vehicle – infrastructure connection alive unit even though when the vehicle is moving. It does disconnect connection with the present unit after leaving the radio frequency range and then it deos seek a new infrastructure unit to connect. As soon as a new unit is located, on-board unit automatically links with the new infrastructure unit. Switch preparation, Switch reregister & reassociation stage are three major steps in this switching process. The infrastructure searching process can be categorized as active searching and passive searching. In active searching OBU actively sends a request message to infrastructure unit and infrastructure unit sends a feedback message with network topology information. In passive searching infrastructure unit sends a message to OBU to ask for network topology information passively. [7]

3.3 Network Architecture of DSRC

Number roadside accidents is massively increasing day by day. So as a solution, Dedicated Short-Range Communication technology will be vastly applied as a safety mechanism in every car manufactured and every road in future. The network model gets differ from system to system. This paper discusses the network model architecture of Vehicle Infrastructure Integration. Geographical routing and IPv6 protocol integration have developed over the time. This integration makes it possible to vehicle to use all the current internet protocol-based applications and to use multi-hop communication to connect to internet or connect to internet directly.

The traffic management, road development department and other government institutes send the traffic information to drivers to the infrastructural components through Ethernet technology. Most of the business organizations are capable to broadcast this information for public - infrastructural components through Ethernet technology. Then this information is received by the OBD of the vehicle and the drivers can use this information as for their preference.

Toll stations can collect the information when the driver drives the vehicle to the toll station based on vehicle to infrastructure communication. This is achieved by the communication between infrastructure unit installed in the toll and On-Board computer installed in the car. In this process the customs' information will be searched from the database by the system and then it records the toll information. If an accident occurs warning information is broadcasted to other vehicles based via V2V communication among vehicles. This information also is being shared among different regions if needed . [8]

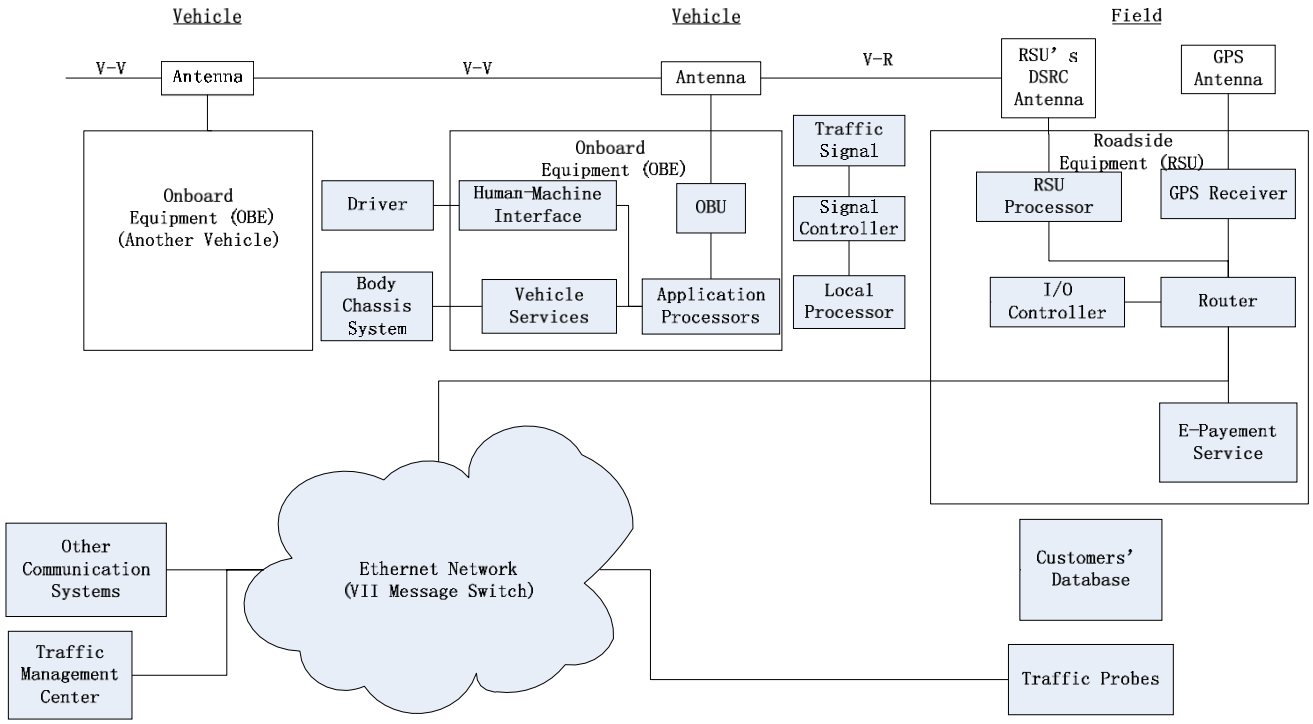


Figure 4 : Network architecture of DSRC

4.V2V VEHICLE TO VEHICLE COMMUNICATION APPICATIONS

4.a Enhanced Traffic Security

V2V communication technology is vastly applied to secure the traffic environment. Most of the fatal accidents could be avoided using V2V communication. By using V2V, sensitive warning information is passed among a vehicles. The sensors installed on the front of the car can detect the barriers to avoid collisions. Furthermore, these sensors can also detect conditions on curvy roads to assist driver to control vehicle easily. [9] Figure 5 shows and example of traffic condition in a highway. Car A is broken down and stopped due to a mechanical failure, Huge truck behind the Car A can see the incident but Car B cannot see it. This could lead to Car B to collide into traffic. But since the V2V communication is present Car A can send a message to upstream vehicles nearby. Then the OBU unit installed in Car B can obtain the message from Car A on time and driver can brake the car in a safe distance in order to avoid the accident.

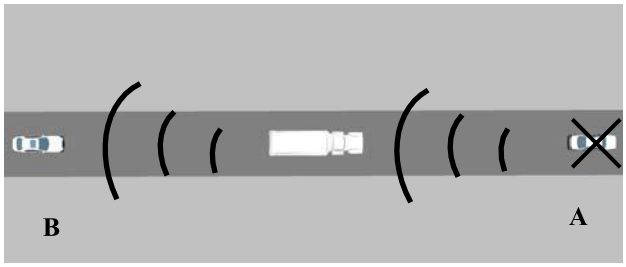


Figure 5: Avoidance of the barrier

4.b Enhanced Intelligent Traffic Management

This application is immensely responsible for Emergency vehicle management, highway fleet management, safe overtaking and etc. The emergency vehicles are able to run in V2V green channels when an emergence happens. Figure 6 illustrate how a fleet management is done. Car A & Car B are driven on high-speed lane. Car C wants to exit the current lane enter to the high-speed lane. Prior to changing lanes, car C sends a warning message with lane changing request information to Car A and B. Then Car A and B can keep a safe distance amongst two vehicles so that Vehicle C can change enter into high-speed lane safely.

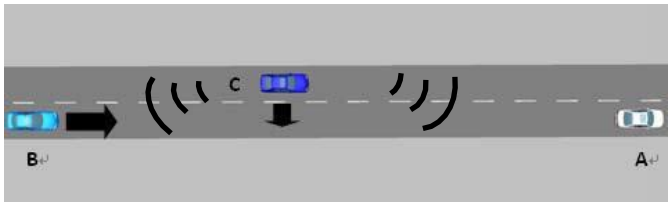


Figure 6 : Lane Management of Highway

4.c Improved Real-Time Traffic Information Broadcast

Most of the drivers cannot get reliable real-time traffic information via mobile phones. DSRC technology is capable of broadcasting most reliable and accurate real-time traffic information to the drivers. [10] When a vehicle accident

occurs, GPS devices installed on other vehicles nearby can detect the traffic and transmit the traffic information to other vehicles which are not at scene. So, the drivers in those vehicles can take most reliable route avoid the traffic and save time. This can also be helped transmit the accident information to authorities such as police department, fire brigade, hospitals and etc.

4.d Co-operative Adaptive Cruise Control

Using V2V vehicle cruise control can operate more efficiently. To avoid road accidents. Using car sensor integrated with vehicles OBE unit vehicles can communicate with each other to obtain information such as the speed of vehicle in the front and obstacle in the road to maintain a safe gap between vehicle when a vehicle is operating under cruise control. Also, RSE units can broadcast the weather information and traffic information to OBE unit to maintain a secure speed when the cruise control is active.

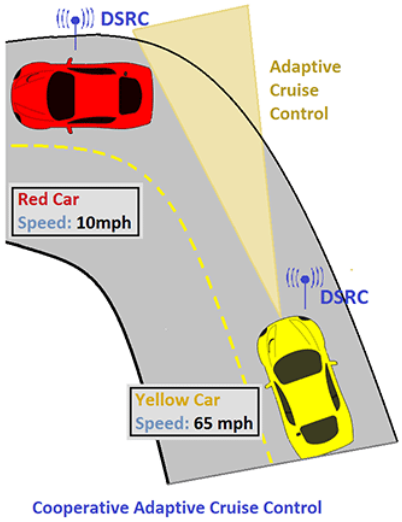


Figure 7 : V2V integrated with adaptive cruise control

5. V2I Vehicle to Infrastructure Communication Applications

5.a Enhanced Toll Service

Toll gates at the highways widely use DSRC technology. Additionally, DSRC can be used in parking lots, gas stations and etc. . RSU units should be placed within slightly nearby to the ticketing machines at exit and entrance gates where the ticket cost is calculated on hour basis. In filling stations, roadside units should be installed in close proximity to the station. These infrastructure units can collect and store the customers' data in databases. Figure 8 illustrates how a toll gate integrates with DSRC technology.

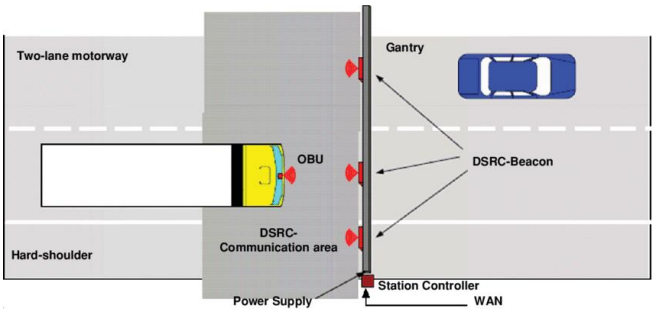


Figure 8 : Usage of DSRC at Toll Gates

5.b Advanced Vehicle Management

V2I communication technology can be applied in systems that are performing vehicle management tasks to monitor and control the in and out movements in vehicles. This facility is mostly configured in factories, warehouses, and residences to prevent unauthorized non-registered vehicles trespassing the area, record electronic data history of vehicles. This improves the efficiency in the entry and exit process and also provides automated security. This also can be used to manage parking lots by processing information as number of cars parked at present to avoid blocks in parking lots and to help drivers to find free parking slots. In this way car drivers can save both of their time and fuel.

5.c Smart Traffic Lights

Vehicle to infrastructure communication can be also used with traffic lights to make them self-adaptive. Other than changing lights on specific intervals V2I integrated traffic lights can change lights based on present traffic conditions since sometime changing lights on preprogrammed times cannot be much efficient. Smart traffic lights can communicate with OBE and RES units and process the current traffic information to make decisions on changing lights. Using these units traffic lights can obtain information such as number of cars waiting in the line, weather conditions and etc. Using this information traffic lights can calculate times and operate lights at a higher efficiency level to maintain the road traffic. Also, these lights prevent running over a red light when pedestrian crosswalk is activated.

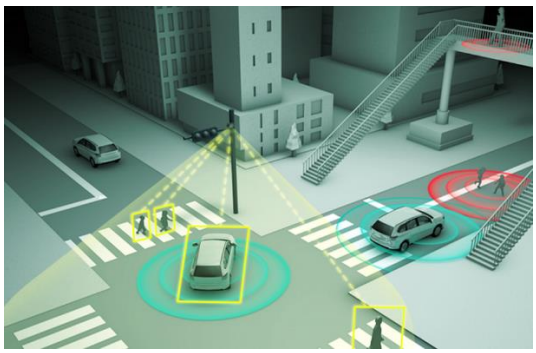


Figure 9 : Smart Traffic Lights

6. SUMMARY AND OUTLOOK

Features of Dedicated Short Range is suitable for high-speed data movement. Hence the DSRC does have extensive capabilities in applications of Intelligent transportation Systems and can be vastly used develop transportations services to its maximum potential.

DSRC is vastly applied in ITS Systems due to its reliable, stable, fast & real-time data transmission capabilities. With these features DSRC is capable of being applied in multi priority, collision avoidance, transit priority, which will be benefited in reducing traffic jams, reducing roadside accidents, developing public transport and etc.[11]

Nevertheless, DSRC technology consists of some security problems when using as an application in ITS. It is still vulnerable to cyber attacks likewise the other wireless technologies. Hence if the security mechanism is breached, attackers can malfunction the system unit which could caused to numerous problems. Also, the demand and popularity of the technology could affect the performance applications in ITS. Technology's longevity depends on its reliability and security.

If only few vehicles have onboard units installed, this technology is less effective since it cannot avoid most of the accidents and monitor traffic. On the other hand, these smaller number of onboard units installed vehicles can be a threat to other vehicles due to its traffic flow disturbance. So, the proprietary should be overcome.

DSRC is in bit of a spectrum battle with technology called U-NII where wireless carriers want to open lot more Wi-Fi to expand the data transfer in mobile phones which operates in same 5.9 GHz band. Most automakers hesitate to share this wireless band since it can lead to malfunctions in vehicles.

To operate DSRC systems, most infrastructure units need upgrades in signal and control centers which could lead to break municipalities.

This DSRC technology in ITS can be used as a basic application to develop more advanced vehicle to infrastructure and vehicle to vehicle communication. With these developments DSRC technology can be used as one of the most reliable application in Intelligent transportation Systems. Experts in the technology development should carry out more research and develop DSRC in ITS applications to build a safe, reliable, and secure environment for the automotive industry.

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