DSRC – NEW PRINCIPLES AND IMPLEMENTATIONS IN ITS ROMANIA

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ABSTRACT

Cities around the world are suffering from severe traffic congestion resulting in economic losses via delayed time, fuel consumption, traffic accidents, air pollution and traffic noise. An efficient wireless technology used in the road-to-vehicle radio communication can help reducing this negative effects and improve traffic parameters. Active **DSRC** is one of the most reliable road-to-vehicle communication methods available in the market today, since it has wide communication area and high-speed communication and is the most suitable for non-stop toll collection system, especially for multi-lane free-flow toll collection system, where vehicles can pass the toll gantry without reducing speed. The Active **DSRC** also supports other **ITS** applications related to road-to-vehicle communication applications that need high speed communication, and can improve public transportation, help to reduce air pollution, NOx and CO2, and road noise via a decline in traffic.

INTRODUCTION

Cities around the world are suffering from severe traffic congestion resulting in economic losses via delayed time, fuel consumption, traffic accidents, air pollution and traffic noise. **DSRC** is a new wireless technology that can reduce traffic congestions, accidents avoidance and improve traffic parameters.

ACTIVE DSRC IN ITS

Active **DSRC** is the road-to-vehicle radio communication method, and it is based on the international standard as specified by Annex 1 on Recommendation ITU-R M.1453. The main features of Active **DSRC** are high reliability and large capacity. It can provide very high level of accuracy for the road-to-vehicle communication, without any lowering by weather conditions. As actually proved in the highways where is implemented (e.g. Japan), the communication error rate of Active **DSRC** is less than one in every 100 thousands transactions.

Thus, Active **DSRC** is one of the most reliable road-to-vehicle communication methods available in the market today. Also, Active **DSRC** has the large capacity for road-to-vehicle communication, since it has wide communication area and high-speed communication. This enables the roadside equipment to interactively transmit and receive large volumes of data with multiple vehicles. Thus, the Active **DSRC** is the most suitable for non-stop toll collection system, especially for multi-lane free-flow toll collection system, where vehicles can pass the toll gantry without reducing speed.

One Active **DSRC** antenna can cover up to three free-flow lanes. Moreover, Active **DSRC** can be the base of wide applicability for future **ITS** services.

Because of Active DSRC and smart card adoption, flexibility becomes the most important selling point of **ETC** regarding the payment method, it can adapt to both pre-paid system and post-paid system. Also, it can meet requirements for tollgate-type toll collection, as well as free-flow type toll collection, and so it can be installed either at toll plaza and/or main lane gantry. Furthermore, since its adoption of a smart card, it can be used for Touch-and-Go system. So, it can correspond flexibly to each development stage of toll collection scheme. For example, when traffic volume is low, such as rural area, it is not necessary to install **ETC** system, but, for closed system toll road, one must install the same toll collection system at both ends, regardless of traffic volume. So, with **ETC** system, one can install **ETC** system at urban area, where traffic volume is high, and use Touch-and Go system at rural area, where traffic volume is low. By this way, the introduction cost of **ETC** can be reduced drastically. Moreover, introduction of Global **ETC** can enable appropriate apportionment of toll revenue among different toll road operators. It is also possible to offer various type of discount rate system, such as mileage discount, nighttime discount, etc. [1] Further more we present examples of what **DSRC** can provide for transportation applications.

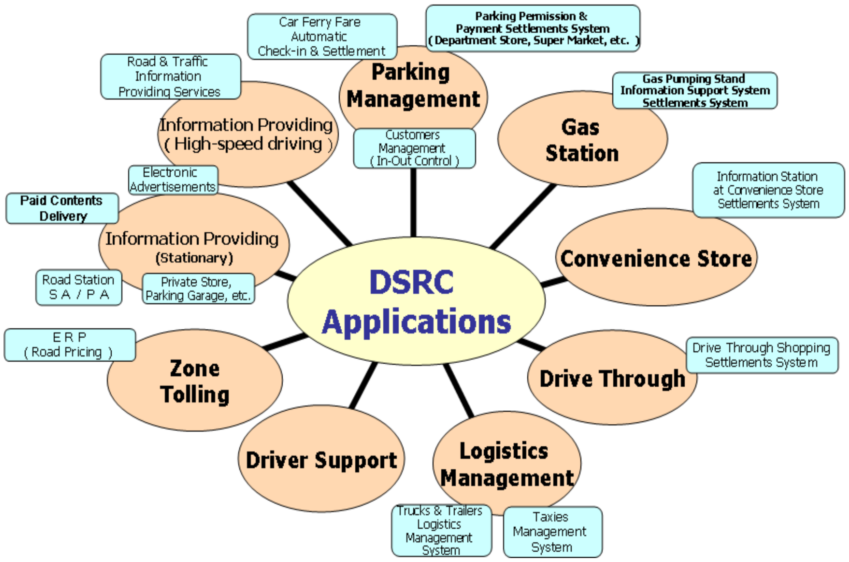

Figure 1. DSRC Multiple Applications [2]

PRINCIPLES OF OPERATION OF THE FREE FLOW SYSTEM

The vehicle detection and tracking module shall be the core component of the free flow system. As a general rule, the tolling systems are required to provide a maximum accuracy in collection of revenues but even more critical is to ensure that no wrong assignments of transactions to vehicles can occur, as such errors may have a very negative impact on the public perception of the scheme (for instance enforcing a vehicle with a right **OBU** must be strictly avoided).

Following these crucial requirements, the vehicle detection and tracking algorithms should be carefully designed and tested in simulated and real environments.. Vehicles may be in any position across the road and may change lane anywhere in the toll charging area. The complexity increases by the fact that traffic jams may occur at the charging points and therefore the system shall be able to track properly the vehicles even in “stop and go” situations.

The principle of operation of the vehicle detection module is based on perpendicular scanning of the road, from which the transversal position (y axis) of the vehicles is directly measured. A pair of parallel laser scanners is installed above the lanes. By measuring the travel time between the scanning plans, the speed of the vehicles can be deduced and hence the x position at each moment.
Once an **OBU** is read, an algorithm assigns it to the proper vehicle depending on the known x and y coordinates associated to each vehicle. In case of uncertainty between two contiguous vehicles, the x and y coordinates of the **OBU** measured by the **DSRC RSU** are used to decide which of them the actual holder of the **OBU** read is.

As the DSRC interrogators have a very directional lobe, the overlapping zone of the contiguous lobes is set up to be as reduced as possible, minimizing the probability of cross-readings and therefore the cases of uncertainty. If a vehicle crosses the scanning plans without any valid **OBU** being associated to it, a violation is generated and the front and rear pictures are stored and linked to the passage

The DSRC communication can be viewed as consisting about four phases:

- Idle phase
- Initialization phase

- Transaction phase
- Optional tracking phase

In the *idle phase*, every Interrogator synchronously transmits a **BST** (Beacon Service Table) in its own communication zone. The **BST** tells any approaching **OBU** what services are provided, and how communication from the **OBU** should be performed. Each communication zone normally uses its own communication frequency to avoid frequency interference, but the content of the transmitted **BST** are exactly equal. Synchronization and **BST** content are controlled by a **DSRC** Controller. **BST** transmission takes place periodically in the idle phase, e.g. every 10 milliseconds. Once an **OBU** enters a communication zone, it responds with a request to transfer its capabilities. If communication zones overlap, the request may be received by one or more Interrogators. The Interrogators calculate a speed estimate based on the Doppler frequency on the received **OBU** signals. The requests are then routed to the election process, which decides how to handle the requests. Depending on the speed of the **OBU**, the time since first contact with the **OBU** and other factors, the election process may either decide to elect one of the communication zones for further communication, or it may postpone communication to make sure the **OBU** has entered far enough into the communication zone to be able to detect any zone overlap. In the latter case, the **OBU** again responds with a request after the next **BST**. The election process estimates a transversal position (y axis, across the road) based on the relative signal strength when an **OBU** is in an overlap zone. The election process also estimates a longitudinal position (x axis) based on the time of first contact and the estimated **OBU** speed. When a communication zone is elected for further communication, the communication zone with most optimal signal conditions is normally elected.

The *transaction phase* takes place in one communication zone only. This makes possible to perform simultaneous and independent communication in several communication zones. The transaction phase is normally completed in a few tens of milliseconds, minimizing the risk of an **OBU** moving out of one communication zone and into another. Information from the **OBU** determines what **DSRC** protocol variants and subscription types the **OBU** supports. The **DSRC** Controller selects the appropriate application for the transaction phase. In general, during the transaction phase identification information is read from the **OBU**, the validity of the transit is checked by e.g. subscription status in the road-side integrators databases, and a receipt is written back to the **OBU**. Optionally, the **OBU** is also instructed to beep depending on the subscription status. [3]

WHY DSRC? TECHNICAL DESCRIPTIONS

Currently, there are three primary technologies for urban road pricing: **DSRC**, **GPS**/Cellular network, and Camera **ANPR** (Automated Number Plate Recognition). The following Table 1 shows comparison of three basic technologies. DSRC is good for operation in urban area because of very high accuracy, minimized enforcement, flexible charging scheme, and prepaid by IC Card, and low operation cost.

Table 1 Comparison of three primary technologies

Base technology ***Items***	**GPS/ Cellular Network**	**DSRC**	**Camera ANPR**
RSE	Broad Band station	**DSRC** fixed station	Camera fixed station
OBU	Broad Band adopter **GPS** receiver	**DSRC**	(non)
Enforcement	Fixed station Stationary Patrol car	Fixed station	Fixed station Stationary Clearing number plate Patrol car

Accuracy (error rate)		Location error: Urban 20m Traveling error rate Urban 1.9%, Suburb 0.4%	Transaction error: 10^{-6}	**OCR** error: 0.13%
Weak point		There is necessary to improve accuracy, and admissible error of application must be considered.	**RSE** is required for each charging point.	**RSE** is required for each charging point.
Payment		Center account or On board (**IC** card) account	Center account or On board (**IC** card) account	Center account
Cost	***RSE Investment***	High	Very high	High
	Operation	Very high for enforcement	Reasonable	Very high for enforcement
	OBU	Very high	Little high	n/a

In addition to the comparison above, road side equipment should be designed to harmonize with urban scenery, and each charging point must be clear to see for drivers. Therefore, the number of gantry equipment should be small as much as possible. Many urban roads are two-way type which has no separator. Therefore, the system must be designed not to charge on-coming vehicles by mistake. Urban roads have complicated structure compared with expressways. There are roads under skyway, underground roads, bridges and roads in urban canyons. Therefore, the system should work accurately under any road structures.

WHY ACTIVE DSRC IN ITS?

There are two **DSRC** method, active method and passive method.

Active DSRC: The **OBU** incorporates **RF** (radio frequency) oscillator.
Passive DSRC: The **OBU** does not have an internal oscillator, the **OBU** reflect the modulated **CW** (continuous wave) from **RSE** mixed with sub-carrier.

The following table 2 shows comparison of **DSRC** specification of three major areas. Because the **OBU** has a **RF** oscillator, Active-**DSRC** can realize flexible communication zone from narrow area to wide area (max. 30m). Thus Active-**DSRC** characters realize real-time **IC** card access in the communication area as well as other **ITS** applications.

Table 2. Comparison of Primary DSRC technologies

Region / ***Item***	**Europe**	**Asia**	**North America**
1.International Standard	ITU-R M.1453-2 (Layer-1)		None
	ISO 15628 (Layer-2,7)		ISO 21215 (CALM M5)
2. Regional standard	[CEN Standard] -ENV 12253(L-1)	ARIB-STD-T75 (Japan) TTAS06-00625 (Korea)	ASTM E2158-01

		-ENV 12795(L-2) -ENV 12834(L-7)	GB/T20851-2007 (China)	ASTM E2213-03 IEEE 802.11p, 1609 (WAVE soon come)
3.Communication method		Passive	Active	Passive/Active Active (WAVE)
4. Radio Frequency		5.8GHz	5.8GHz	915MHz 5.9GHz(WAVE)
5.Data Rate	***Down***	500Kbps	1Mbps 4Mbps (Japan)	500Kbps 2 ~ 27Mbps (WAVE)
	Up	250Kbps	1Mbps 4Mbps (Japan)	500Kbps 2 ~ 27Mbps (WAVE)
6. Communication Range (Foot print)		Up to 5m	4m for Single-lane 16m for Multi-lane 30m for ITS Applications	10m 1Km (WAVE)
7. Adopted Countries		European Countries, etc.	Japan, Korea, (China)	USA, Canada

The Active **DSRC** consist of roadside antenna and **OBUs** and both equipment interactive each other with electro-wave transmission simultaneously at high speed. This feature realizes high reliability, wide-area communication, scalability toward other secured settlement via contactless **IC** card in **OBUs** and scalability toward other **ITS** applications. High reliability in any traffic and weather condition is essential condition to support the multi-lane and free-flow operation in the urban area. The traffic flow on the urban road is complicated and diversified compared with that on expressways. The system is required to detect any traffic pattern on open road. Wide-area communication enables the system need less the roadside antenna and keeps the system more simple.

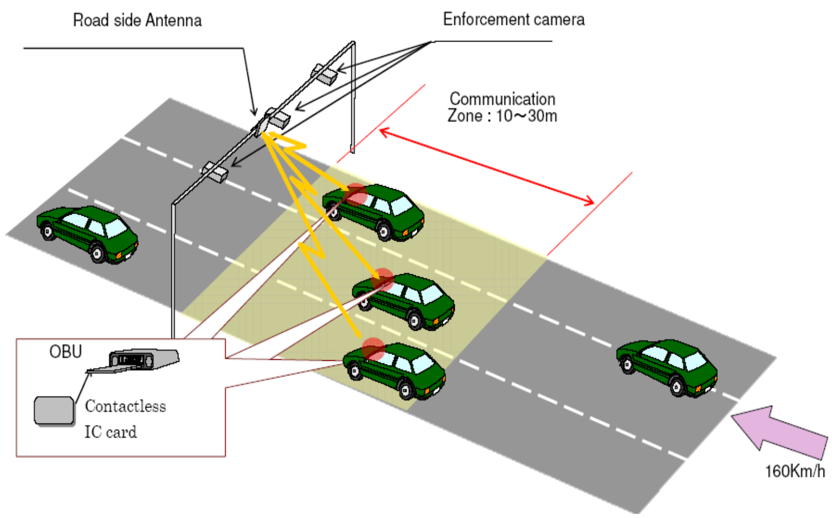

Figure 2   DSRC Free-Flow Road Pricing system

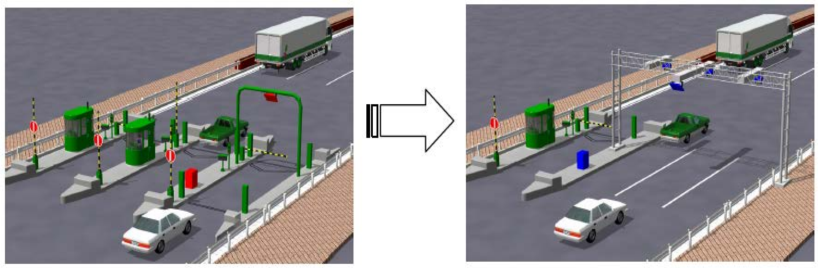

Figure 3 Example of DSRC implementation (single lane toll plaza to multi-lane free-flow toll plaza)

The Active **DSRC** also supports other **ITS** applications related to road-to-vehicle communication applications that need high speed communication, such as Traffic and Travel Information, Collision avoidance at intersection and confluence, Commercial Vehicle Operation. [4]

CONCLUSIONS

Active **DSRC** can improve public transportation, and will help to reduce air pollution, NOx and CO2, and road noise via a decline in traffic.

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