DSRC Standardisation and Conformance Testing of DSRC / EFC Equipment

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Abstract

This paper focuses on the Dedicated Short-Range Communications (DSRC) Standards in Europe (CEN) and on world-wide international level (ISO) and Electronic Fee Collection (EFC) systems based on these standards, with regard to: motorway operator and driver (user) requirements, physical compatibility of the DSRC equipment, DSRC standard conformance testing, and countries in which commercial installations already exist / will exist in the near future.

1. Introduction

In order to increase the efficiency and safety of the traffic, new concepts and technologies for Road Traffic & Transport Telematics (RTTT) systems have been developed within the past years. In Europe, already in 1992, it became obvious, that standardisation efforts are required to harmonise the developments of the European industry with the main goal to support physical interoperability of the dedicated short-range communication (DSRC) equipment on which future RTTT applications were intended to be based upon. Therefore, within CEN/TC 278 working group 9 (WG9) on DSRC has been established to develop and specify the required standards in order to support a variety of RTTT applications. The most important applications were "Electronic Fee Collection (EFC) and Access Control", which were dealt with in CEN/TC278/WG1, while other applications like Traffic and Traveller Information (TTI), Public Transport, Fleet Management, Parking Management etc. were also considered in CEN/TC 278 from the beginning.

2. Dedicated Short-Range Communications (DSRC) Standards

The DSRC architecture has been developed according to the ISO-OSI layer model. But due to the real-time constraints a three layer approach has been chosen. The **Physical Layer** standard (CEN ENV (EN) 12253) provides the specification for the 5.8 GHz frequency band. Due to the fact, that only relatively short distances between the roadside equipment (RSE) and the on-board equipment (OBE) have to be covered, an approach of using very cost-effective semi-passive transponder technology has been chosen, in which the received signal from the roadside is used for uplink transmission by retransmitting it by the OBE after a frequency shift and encoding uplink data. This avoids the usage of local oscillators like in active transceivers and allows to produce battery powered OBE-tags at very low prices and small sizes. The default downlink/uplink data rates are 500 kbit/s and 250 kbit/s respectively.

The **Data Link Layer** (CEN ENV (EN) 12795) is built up by the Logical Link Control (LLC) and Medium Access Control (MAC) sub-layers. The LLC sub-layer has been adapted from the IEEE 8088.2 specifications for connection-less and connection-oriented services. The MAC sub-layer caters for efficient contention mechanisms to avoid and resolve data collisions in multi-lane environments.

The **Application Layer** (CEN ENV (EN) 12834) provides a service interface for the applications and specifies application multiplexing and a common initialisation mechanism for each communication process between the OBE and the RSE. In order to satisfy the requirements of various RTTT applications, these DSRC layer standards allow some options and different parameter settings.

To support interoperability for various RTTT application the parameter settings according to a chosen profile are specified in the **DSRC Profiles for RTTT Applications** (CEN ENV (EN) 13372) standard. On top of this architecture, application standards have been developed by the application-oriented working groups within CEN TC 278, e.g. for Electronic Fee Collection (EFC) and Traveller and Traffic Information (TTI).

The DSRC Standards have been approved with a high majority as CEN ENV standards.

<u>2.1 Status of DSRC Standardisation</u>:

#	Abbreviated Title	Date	Status	%
ENV 12253	DSRC Physical Layer at 5.8 GHz	Aug. 3,1997	**approved**	77
ENV 12795	DSRC Data Link Layer	June 13,1997	**approved**	85
ENV 12834	DSRC Application Layer	Sept. 1, 1997	**approved**	84
ENV 13372	DSRC Profiles for RTTT Applicat.	Dec. 3, 1998	**approved**	89
ETSI EN 300 674	ERM & Test methods for DSRC	Jan. 1999	**approved**	100
ITR on Registration	Internal Report on Registration	Sept. 1997	completed	n.a.
ITR on Infrared	DSRC Physical Layer Infrared	March 1999	completed	n.a.

<u>Conclusions</u>:

- All three DSRC Layers (1, 2, 7) and DSRC Profiles are approved as ENV Standards
- All three DSRC Layers (1, 2, 7) and DSRC Profiles are ready for the CEN EN Standards Commenting Process
- ETSI EN 300 674 on Electromagnetic Radio Matters (ERM) and Test methods for DSRC is approved as EN (European Norm) Standard

3. Conversion of CEN DSRC ENV into EN Standards

The process of conversion of the CEN DSRC ENVs into EN Standards started with the establishment of the "STAR" Project under the ISIS Program of EC / DG III in January 1999. Within a year, i.e. in January 2000, a set of documents have been forwarded to Joint CEN / TC 278 / WG9 & ETSI / ERM / RP08 / TG2 "Dedicated Short Range Communications". In parallel, a commenting process with the involvement of CEN TC 278 "Road Transport and Traffic Telematics" has been started after the CEN TC 278 Plenary Meeting in Sept. 1999, with the deadline of Jan. 15, 2000.

It was important to the author (C.-H. Rokitansky, Convenor of CEN / TC 278 / WG9 and project co-ordinator of the "STAR" Project) that already in the "STAR" Project, which consisted of the 6 major European DSRC 5.8 GHz manufactures representatives of the motorway operators (France (TIS2), Netherlands (Rekening Rijden), Norway (autopass), Switzerland (LSVA), etc.) were invited as guests to comment to the proposed refinements of the DSRC ENV Standards, taking their user requirements into account. This involvement of motorway operators was even intensified in the continuing work of CEN / TC 278 / WG9 (since Jan. 2000), in which several representatives from the motorway operators and future users from France, Netherlands, Norway, Portugal, Spain, Switzerland, etc. participated with experts in WG9.

At this time (July / August 2000) the Draft CEN DSRC EN Standards are being completed and will be launched in the public inquiry for CEN voting in September 2000. This set of standards, in which, according to the CEN rules, the comments from both the DSRC manufactures but also the future DSRC users (motorway operators, road authorities, etc.) have been intensively investigated and after a comment harmonisation and resolution process agreed, with the result, that now, the Draft CEN DSRC EN Standards have been streamlined by deletion of unnecessary options contained in the ENV Standards, have been improved with regard to some formulations to avoid ambiguity, and an enhanced functionality by the addition of some important features (e.g. chaining concept, etc.). The authors are confident that these CEN DSRC EN Standards will satisfy the user needs for the variety of applications for which they were designed. It is important to mention, that aspects, like physical characteristics, limited communication zones (it's D**<u>S</u>**RC !), proper system design concepts, careful configurations and nearby installations are taken into account in current / future operational systems based on DSRC.

4. Evaluation of Draft DSRC EN Standards

4.1 Interference considerations in a DSRC communication environment

A typical application for DSRC is automatic fee collection in a free flow multilane environment, often requiring security operations on an *integrated chip card* (ICC) and using transponders inside the vehicle. In order to efficiently use the limited communication zone, usually one downlink transmitter is active per lane. Co-channel interference is reduced by using different frequency channels on adjacent lanes.

In case of slow ICC being used, it may be necessary to install a two or even three gantry system. For the standardisation this opens the questions of interference between gantries, and uplink-to-uplink interference has been identified as most critical by some standardisation parties.

4.2 Investigation of the interference level

Therefore a need arises to investigate the impact of interference on the system. The most exact way to do this is field trial testing under realistic conditions. Field trials are, however, difficult to perform and evaluate and costly to conduct. An other way to investigate the impact is to simulate the system using a detailed computer model.

4.3 Modelling of the communication system

At the chair of communication networks (*ComNets*), the tool CAVIAR ***C****ommunication of* ***A****utomoti****v****es Simulator for the* ***I****nvestigation of* ***A****pplications and* ***R****eliability*) has been developed, comprising a vehicle mobility model providing traffic with a realistic vehicle flow and distance distribution, a communication protocol and a detailed channel model. Special attention has been paid to the design and implementation of the channel model, taking care of a detailed propagation modelling (ray tracing techniques taking into account reflections on objects with different material specific reflection coefficients, polarisation is taken into account) to determine the influence of multi-path propagation in DSRC specific scenarios. The scenario descriptions comprise the following items:

- antenna characteristics
- characteristics of transmitting/receiving vehicle (shape, materials, position of OBE, etc.)
- characteristics of mobile vehicles in the neighbourhood of the active vehicle (position in relation to active vehicle, shapes and materials, etc.)
- characteristics of fixed installations (e.g. booths or other road-side installations)
- additional frequency dependent attenuation due to steam or other absorbing gasses in the air

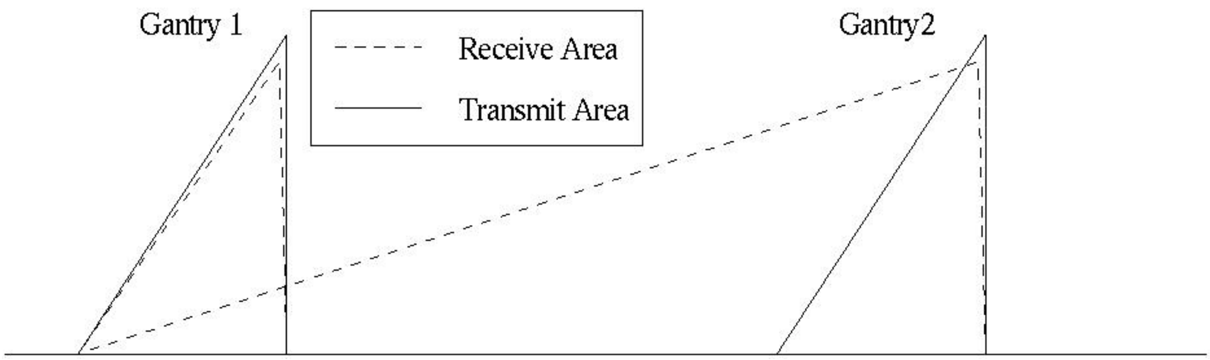

Fig. 4-1: Setup of the simulated system

4.4 Description of the simulation scenario

A scenario with two gantries was simulated (see Fig. 4-1). At both gantries, spaced 22 meters, an electronic fee collection transaction was performed. The antenna of the OBU (*on-board unit*) were modelled as isotropic antenna, the receive power level of the fixed antenna was modelled as ramp, rising by 50 dB over 5 meters and then keeping its value.

Three different OBU populations were tested: A system in which all OBUs had the same conversion gain, one in which half the OBUs had a higher conversion gain, and one in which again the gain was equal, but the power transmitted from the OBUs was limited to a fixed value. In addition, a fourth reference simulation was run with the application only running on the second gantry and thus being free of interference. The resulting curves are labelled Norm, Mix, Lim, and One in the following graphs.

4.5 Evaluation Results

The most interesting point of the investigation was the influence of interference on the application performance. In Fig. 4-2 and Fig. 4-3, the fraction of OBUs that has not completed its transaction is plotted over the available communication distance. With increasing amplification the OBUs manage to complete their transaction earlier due to the better uplink signals, but the OBU population plays a minor role.

The number of transmissions affected by interference also decreases with increasing gain (see Fig. 4-2), and differences between OBU populations only show at high conversion gains (see Fig.4-3 and Fig. 4-6).

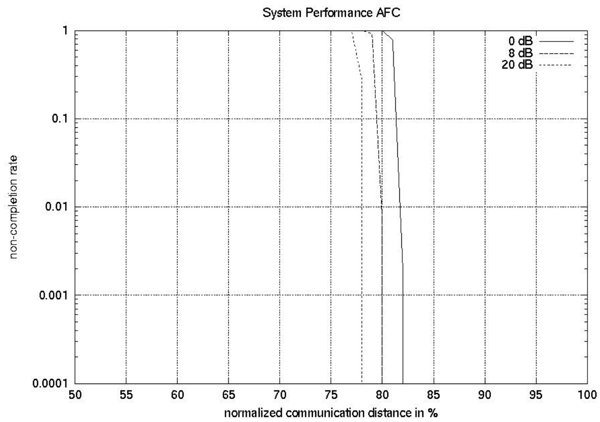

Fig. 4-2: Performance for different conversion gains populations

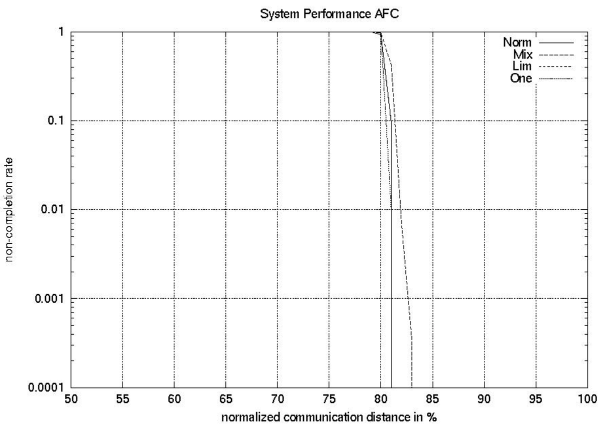

Fig. 4-3: Performance for different OBU populations

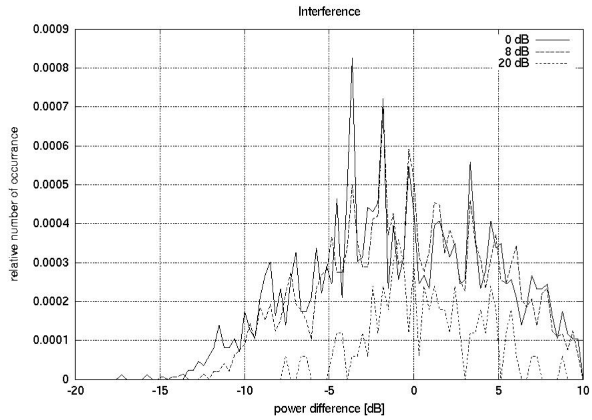

Fig. 4-4: Interference for different OBU gains

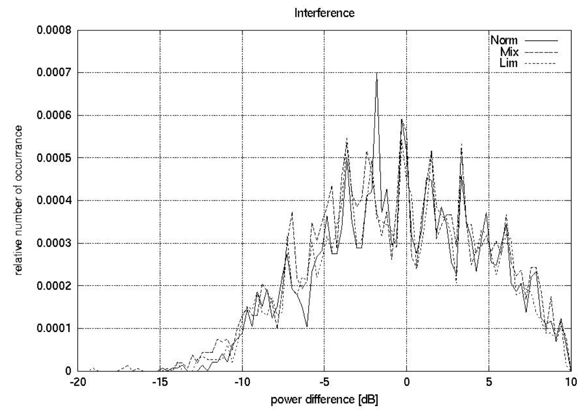

Fig. 4-5: Interference at an OBU conversion gain of 3 dB for different populations

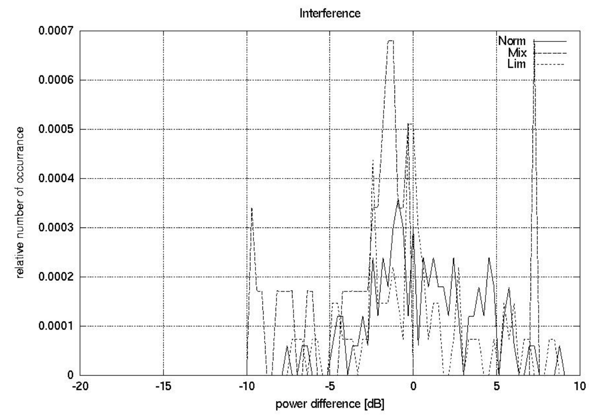

Fig. 4-6: Interference at an OBU conversion gain of 20 dB for different populations

This investigation shows that the problem of interference is less severe than expected. Differences in the interference behaviour of OBU populations can be observed, but even in dense traffic, interference situations occur so seldom that the system performance suffers only marginally.

5. Formal specification and DSRC Standard Conformance Testing

In order to guarantee compatible DSRC equipment of different manufacturers, DSRC ENV standard conformance tests and well defined type approval procedures are required. Within the European Commission 4th Framework VASCO project, conformance testing tools using a DSRC reference beacon have been developed and tests on DSRC ENV compliance have been carried out. Within the "STAR" project, these conformance testing tools have been further improved, and are currently continued in co-operation with an independent accredited institute. These DSRC ENV standard conformance tests are important to DSRC/EFC manufacturers, motorway operators and road authorities, as well as car manufacturers.

5.1 Formal specification of the DSRC protocol using SDL

Standard communication protocols are often specified using formal description techniques, such as SDL (Specification and Description Language), which is recommended by the ITU/CCITT [ITU_Z.100/110]. Furthermore the usage of SDL enables an hardware-independent transfer of specifications onto various platforms.

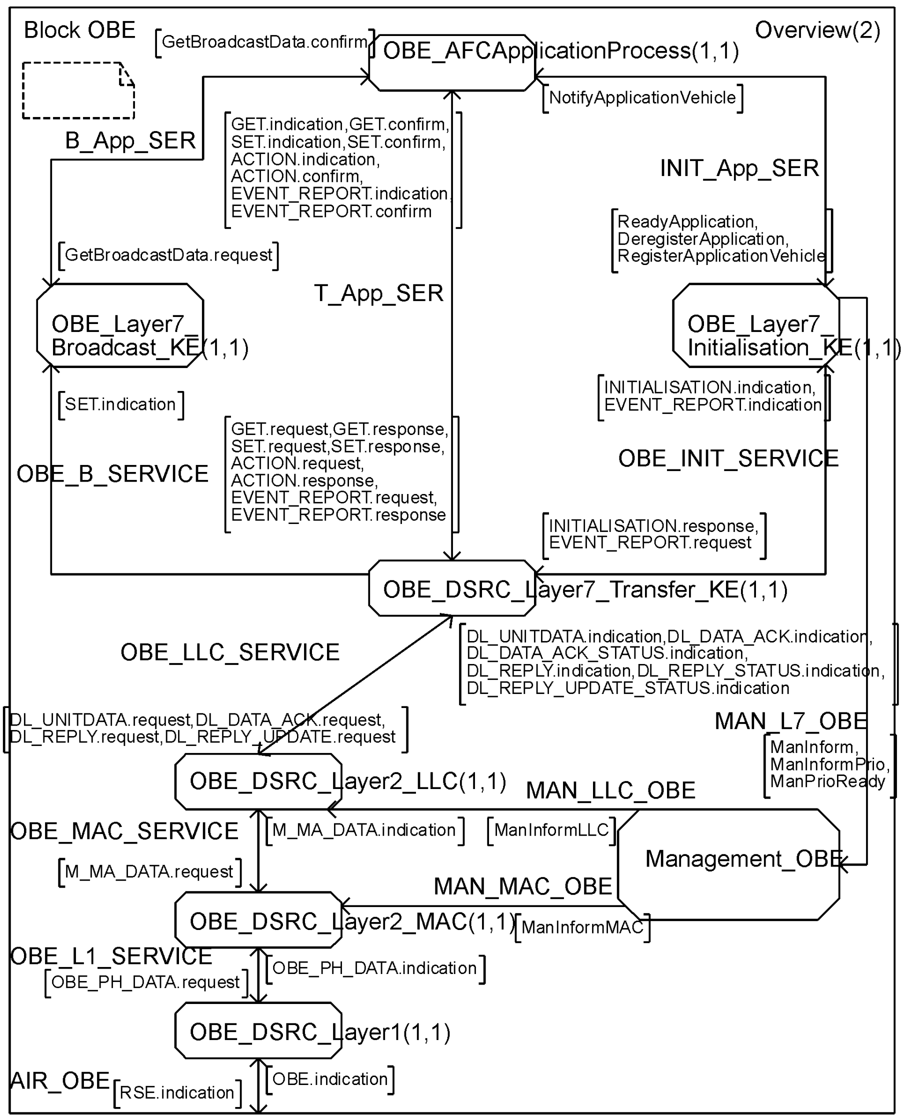

Fig. 5-1 SDL system diagram of DSRC protocol stack

It is even possible to use the same SDL specifications for later implementations on the target hardware.

Therefore the first step of the testing of the DSRC Standard was the detailed SDL specification of all three DSRC protocol layers. Fig. 5-1 shows the overview SDL diagram of the SDL specification of the DSRC protocols including an application for electronic fee collection according to the A1 EFC application specification and the application interface definition specified by the project team 02 [CEN_PT02] of the CEN/TC278/WG1. The SDL specification was used as a reference specification to develop conformance tests for the time period when no real DSRC hardware was available.

5.2 Conformance Testing using TTCN

As mentioned before, to ensure that any system works according to a given specification, it is necessary to specify tests. That means, that the SDL specification of the DSRC protocol has to be tested regarding conformance to the DSRC standard. This task was performed by specification of an abstract test suite (ATS). The ISO standard IS 9646 explained in [OSI_Conf] respectively defined in CCITT recommendations describes the OSI conformance testing methodology and framework for protocol requirements. The used notation for the definition of protocol conformance tests according to this recommendations is TTCN (Tree and Tabular Combined Notation). A TTCN test suite describes the communication between a test system and an implementation under test (IUT) at specific control points (points of control and observation, PCO) without consideration of the specific Implementation of the IUT. The test system transmits abstract service primitives (ASP) or protocol data units (PDU) via the PCO to the implementation under test and receives the reaction of the IUT. This reaction will be compared with the expected reaction and the result of the test will be decided.

Therefore an abstract test suite was developed with regard to the document of the project team 04 of CEN/TC278/WG1 [CEN_PT04], which describes the test procedures for DSRC equipment and the A1 EFC application specification. The representation of the implemented ATS follows the ISO standard mentioned above.

For the implementation of the ATS a distributed single embedded test method (DSE) was selected as shown in Fig. 5-2.

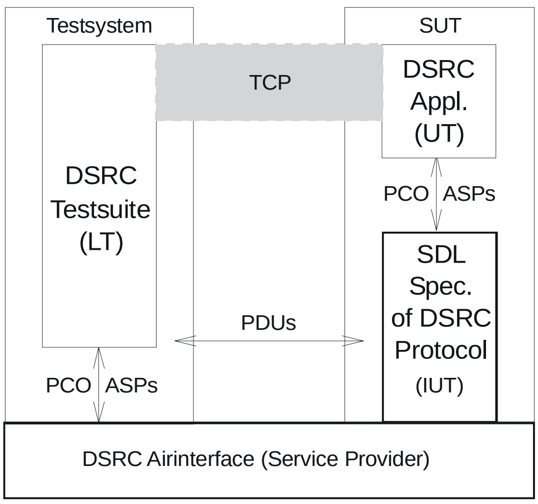

Fig. 5-2 Conformance test approach based on the distributed test method

That means each protocol layer was tested as an IUT separately with a upper tester (UT) and a lower tester (LT). These testers are connected with test co-ordination procedures. The upper tester is able to send ASPs to the IUT. Then the LT receives the reaction released by the ATS of the UT and can assess it. The LT is also able to initiate tests by transmitting PDUs via ASPs to the IUT. Fig. 5-3 shows the basic interconnection test specified in TTCN.

After having real DSRC equipment available this DSRC equipment was tested with the developed ATS regarding DSRC conformance. In the past these tests were carried out for several DSRC manufacturers in various European research projects.

For the realisation of this task Bosch and RWTH/ComNets have developed a reference beacon controlled by the ATS. The implementation of the ATS transmits in a continuous loop conformance tests specified in TTCN to the controller of the reference beacon. The controller is represented by a PC which contains the real time functionality of the medium access control layer of the DSRC protocol. The PC sends the received tests from the workstation to the reference beacon and the beacon passes these onto the DSRC on-board-units via the air interface. The answer from the on board units will be sent the same way back to the workstation where the evaluation of the test results will take place (Fig. 5-4).

Test Case Dynamic Behaviour					
Test Case Name : BST_send_and_receive **Group :** BITs/ **Purpose :** Test to check the addressing mechanism and to decide whether or not to run further tests **Configuration :** **Default :** **Comments :** The OBE should go from sleep mode to wake up mode					
Nr	**Label**	**Behaviour Description**	**Constraints Ref**	**Verdict**	**Comments**
1		+Calculate_FCS(OBEi_BST)			
2		!Oi START Rec	OBEi_BST		
3		?Ri (LiAd := RSEind.Link_Address)	RSEi_VST	(P)	
4		+Validity_of_Frame			
5		+Send_private			
6		?OTHERWISE		(F)	
7		?TIMEOUT Rec		(F)	
Detailed Comments :					

Fig. 5-3 DSRC Basic Interconnection Test in TTCN format

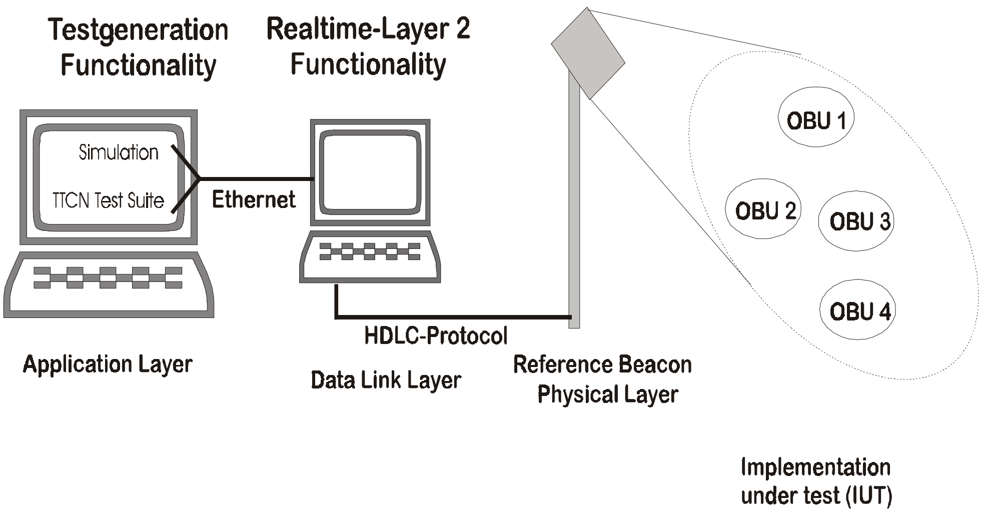

Fig. 5-4 Laboratory test scenario of VASCO project

6. ISO TC 204 WG15 "Short-Range Communication" Standardisation

Although the ISO / TC 204 "Traffic and Intelligent Control Systems (TICS)" / WG15 "Short-Range Communications" Working Group has been established already in 1994, the standardisation of DSRC on an international level has started more intensively only since 1997. While initially the work focused on all layers (DSRC Physical Layer, Data Link Layer and Application Layer) it became soon evident, that different systems in different regions around the world are either already in operation or at least in a test phase, such that harmonisation on the Physical Layer and on the Data Link Layer (due to its dependency on some parameters on the lower Physical Layer) are difficult / impossible to achieve (see Fig. 6-1). Therefore, since 1998, work concentrated on the specification of the Draft ISO "DSRC Application Layer". This Draft ISO "DSRC Application Layer" was based initially on the CEN ENV

"DSRC Application Layer", but the requirements and comments from the regions: Europe, Japan and North (South) America have been taken into account in the further development under the editorship of DSRC Application Layer expert(s) from Japan. In turn, this commonly specified Draft ISO "DSRC Application Layer" has formed the basis for the Draft CEN EN "DSRC Application Layer". Recently, it was agreed in ISO / TC 204 / WG15 to consider whether this Draft CEN EN "DSRC Application Layer" (after it's completion) could also be a basis for an Committee Draft on the "DSRC Application Layer" to ISO / TC 204.

Region	Europe	Asia/N.Pacific	N. America
Application Layer	**ISO "DSRC Application Layer" CD 15628 (including L2 Services) in comments resolution process and towards DIS (based on Draft CEN EN 12834 t.b.c.)**		
Data Link Layer (LLC)	CEN ENV 12795	LLC Japan	LLC (US)
Data Link Layer (MAC) (non-exclusive list)	CEN ENV 12795	MAC Japan	MAC (US)
Physical Layer (non-exclusive list)	CEN ENV 12253 5.8 GHz Transponder	5.8 GHz active Transceiver	Currently **915** MHz, intended 5.9 GHz Transponder/Transceiver

Fig. 6-1: DSRC Architecture as currently considered by ISO / TC 204 / WG15

In 1999, the additional work item "DSRC Resource Manager" has been agreed to be carried out by ISO / TC 204 / WG15 under US subgroup convenor-ship. This work item, which makes good progress, will ensure, that DSRC based applications, requiring services by the "DSRC Application Layer" and system resources, are supported in an appropriate, efficient and user-friendly way.

7. Commercial CEN DSRC based EFC Installations (current / near future)

CEN DSRC ENV based EFC systems are currently spreading within but even outside Europe:

Europe:

Austria: Eco-Point System is based on CEN DSRC ENVs (currently 65.000 on-board tags, 60 single-lane and 9 multi-lane roadside installations); Tolling for trucks is in preparation.

Denmark: 5.8 GHz DSRC-based EFC system installed on the Great Belt Toll Bridge; another DSRC-based system will be installed on the bridge to between Copenhagen and Malmö.

France: A nationwide EFC system (TIS) is already in operation. By mid 2000 fully CEN DSRC compliant EFC will be available: 2 manufacturers have orders for 1800 beacons; 1 manufacturer has an order for 100,000 OBUs; interoperability tests, based on ISO 14906 with Layers 1, 2 and 7; commercial project involving 8 operators

Island: DSRC-based EFC system installed on Bridge and Tunnel outside Reykjavik (10.000 OBUs).

Netherlands: Two consortia (Q-Free / Siemens+Combitech) are current candidates for a multi-lane road pricing / access system on several motorways.

Norway: Norway has decided to replace its existing EFC system with 5.8 GHz hardware.

Switzerland: A DSRC-based EFC system (namely a distance-related heavy vehicle fee), will become operational in 2001.

UK: Road Traffic Adviser project is about to install 70 beacons on M4/M25/M23 motorway; infrastructure linked to traffic control centres; Dept. of Transport to commission a common charging application using interoperable DSRC. DSRC-based Park & Ride / EFC-System is currently evaluated in Bristol / Leicester (6 stations, 600 OBUs).

<u>Australia</u>: CEN DSRC ENVs were adopted as national standards in Australia in April 1998; CEN DSRC ENV based EFC system in operation on Melbourne City Ring (multi-lane system, 600.000 OBUs); CEN DSRC ENV based EFC system will become operational in Sydney (10 lanes, 150.000 OBUs).

<u>South America</u>:

<u>Brazil</u>: CEN based DSRC /EFC Systems are currently installed in the San Paolo area; recently a decision has been reported, to extend these systems also to other regions in Brazil.

Considerations to use CEN DSRC EN(V) Standards apply for several additional European and non-European countries.

8. Conclusions

This paper focused on systems based on the CEN Dedicated Short-Range Communications (DSRC) ENV Standards and their conversion into CEN EN Standards. The authors are quite confident that these CEN DSRC EN Standards will satisfy the user needs for the variety of applications for which they were designed. It is important to mention, that aspects, like physical characteristics, limited communication zones (it's D**<u>S</u>**RC !), proper system design concepts, careful configurations and nearby installations are taken into account in current / future operational systems based on DSRC. The results of investigations on some DSRC Physical Layer parameters having an impact on possible interference of nearby installations resulted in the conclusion, that differences in the interference behaviour of OBU populations can be observed, but even in dense traffic, interference situations occur so seldom that the system performance suffers only marginally. Also, the important aspect of DSRC standard conformance testing has been addressed. The status of the on-going standardisation work in ISO / TC 204 / WG15 has been reported. Finally, a non-exhaustive list of countries in which large-scale installations already exist / will exist in the near future have been mentioned.

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