



**RFID and Electronic Vehicle Identification in
Road Transport**

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Automotive & Road Transport Systems Network**

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1 Introduction

The HA EU Watch Project is providing intelligence for the Highways Agency on ITS developments in Europe and is carried out by TRL on behalf of the HA. The project is identifying opportunities for the HA to become more involved in Europe and summarises key information for decision makers and practitioners on activities related to Intelligent Transport Systems (ITS) in Europe.

The title of this IET (Institute of Engineering and Technology) seminar suggested it would be a straightforward review of the current state of the art in Radio Frequency IDentification (RFID) technology and systems applied in road transport. Several of the sessions provided that content. However, it also included presentations and useful discussion on the role of free form networks of transmitter/processor modules mounted on the vehicle and on infrastructure components. That technology appears to offer the prospect of major advances in the way road traffic is controlled and managed in the future. For example:

- Inductive loops could be eliminated in MOVA, SCOOT and incident detection applications.
- The need for significant quantities of street furniture could be removed, by making many signs and control signals available on a display inside vehicles.
- Guidance facilities and other aids for pedestrians, particularly the partially sighted, could be provided, via PDA based systems.
- A broad range of cooperative driving and anti-collision systems could be enabled.
- It could form the basis of charging and tolling systems, possibly overcoming some of the disadvantage of existing GNSS and DSRC technologies.

These possibilities are considered further in the Recommendations section of the report.

The programme for the Seminar is included as an Annex to this report. A selection of the presentations is available on the IET website, at:

<http://www.iee.org/Events/RFID2006.cfm>

Although the majority of this report is based on the seminar some extra material on relevant TRL activities has also been included. The views and recommendations in Section 6 are the author's views alone.

2 RFID

2.1 RFID in transport - basics

Riann Barnard of the RFID centre and I reviewed the basic elements of RFID systems in the first session of the day and they were also covered by Andrew Pickford in the final session. The IET has prepared a useful Factfile on RFID Technology (see Bibliography in Section 7) and only major points are included in this report.

The key components of an RFID system are:

- A tag, or transponder, which has a chip including some form of identity memory and transmit/receive circuitry, an antenna and, for active tags, a battery or link to a power supply.

- A reader or interrogator which, as the name implies downloads the identity stored on the tag.
- The system infrastructure e.g. an inventory control computer with a data port linked to a reader.

Tags can operate at a range of frequencies from the LF bands (30 to 150 KHz) to microwave frequencies e.g. the 5.8GHz tags conforming to the CEN TC278 Standards used in tolling and charging applications. There are 4 main options for powering and operating tags; many of the examples provided related to logistics and road tolling.

Passive tags do not have a battery or external power supply, but obtain power from a reader. The incident energy from a reader is picked up initially when the tag is read and part of it is rectified to produce power to energise the chip. The absence of a battery is an advantage but the only a limited number of functions can be provided and the range is limited to within about a metre. Typically these are used in stock control applications, including container identification, and for tolling in systems where vehicles are constrained to operate in lanes at toll gates.

“Pingers” include a battery and do not depend on the energy from a reader to energise them. They radiate the identity code at preset intervals e.g. every 10 seconds. Their advantage is that their construction can be relatively simple, because they do not need to include receiver circuitry, and they can transmit over long ranges. A typical example is an emergency beacon.

Transreflective tags are a half way house between passive and active tags. They can be employed for tolling systems operating at 5.8 GHz and covered by the CEN278 Standard. Typically the OBU includes a battery linked to a fairly powerful processor/memory, which provides a range of security functions and charging accounts as well as basic unit identification. However the transmission of data is passive. The input signal, usually from an overhead gantry, includes periods when it is modulated by data, which is received in the tag and processed. It also includes periods when a plain unmodulated carrier is transmitted. That carrier is reflected by a tuned antenna mounted on the tag. A portion of the antenna is switched by a special diode which is driven by the data signal from the processor. Hence the return from the tag is a phase modulated version of the transmitted signal. Inevitably the range is limited, although sufficient to allow communication between tags mounted on a vehicle and an overhead gantry. The directional nature of microwave communications means that it is possible to tightly define the read zone to allow one to one communication to be achieved with uniquely identifiable vehicles. That aids the enforcement process.

Active tags include both a receiver and powered transmitter driven by an internal battery or power supply. Such systems have been widely used in tolling applications in the US. They allow transmission of the identity signals over long ranges. For example in the US systems it was common to mount the roadside transponders on high poles or over-bridges. Zigbee modules and the equipment for the US VII system, discussed later, can be viewed as a special case of active tags, with each unit having the capability to act as a tag and a reader.

All of these have been used in some way in transport applications. For example inductive passive tags were developed for the original charging system developed for London in the late 1960s in the aftermath of the Smeed report on the economics of congestion charging. They operated at frequencies between 75 and 150 KHz. The technology was fully developed and tested, although the proposals did not make progress for other reasons. Pingers operating at bands in the region around 433 MHz have been proposed for inclusion in the number plates of vehicles, to allow a

vehicle licence plate or identity to be read simply as a vehicle passes. As outlined above Transreflective tags have been used for tolling and fully active tags have also been used for tolling in the US.

None of this represents particularly new technology: as outlined above passive tags have been around for almost 50 years and the physics which govern the operation have not changed. The key developments are increases in the complexity of functions that can be provided, and reductions in the size and cost of tags. For example the basic inductive passive tags used for stock control now cost a few pence in volume quantities.

A complex passive tag, the Transcore/3M demonstrator proposed for vehicle identification in Mexico City illustrates the range of potential applications. Within the tag there are 3 memories containing the following data:

- A unique identity, programmed into the chip at manufacture, and thereafter a read only memory (ROM);
- Vehicle details such as the chassis number, registration number, in a write once memory, normally written into by the vehicle manufacturer on the production line, and thereafter ROM;
- Other information, such as the results of the last vehicle test, including pollution information, in read/write memory, written by testing stations and read by service agents.

The tag is mounted on a frangible substrate with an adhesive backing which is attached to the windscreen of the vehicle. It provides evidence of tampering by showing coloured bars, visible from the roadside and is designed to destruct if an attempt is made to remove it from the windscreen.

2.2 The DfT EVI Review

Tags offer a number of policy and system options, particularly in Electronic Vehicle Identification (EVI) applications. The presentation from TRL reported on work commissioned some time ago by DfT to undertaken research into Electronic Vehicle Identification/Information applications, with a view to identifying applications and implementation barriers, and to support collaborative work within an EC programme (STREETWISE).

That study included a comparison of EVI with current methods of vehicle identification to identify the operational limitations. These current methods often use camera imaging techniques to identify a vehicle through the vehicle licence plate using an Automatic Number Plate Recognition (ANPR) system. The performance of these systems can be affected by environmental conditions, the physical condition of the vehicle licence plate and the location on the vehicle. In operation, recognition rates of typically 85-90% are achieved in good conditions but rates are often much lower in poor weather or lighting conditions or with very old or dirty plates. Enhancing the existing licence plate with an electronic wireless reading capability would greatly improve roadside identification and would open up options for a range of crime detection and stolen vehicle recovery applications as well as traffic management and control applications.

The analysis in the report and previous experience with the development and deployment of vehicle telematics suggests that the technology per se is not the main issue. The technical components already exist to develop an EVI system but the application of such systems will be feasible only if the legal, societal and institutional issues are addressed. A total of 19 potential applications were identified and

stakeholders consulted to identify the benefits and implementation barriers. At the end of the work a forward strategy was proposed.

2.3 ANPR Based Systems

As outlined above ANPR systems already offer a degree of Electronic Vehicle Identification (EVI) functionality, although the read performance would ideally be better and there are significant issues to do with the ease of changing plates as a fraud option. However ANPR does have a number of key advantages over radio frequency based EVI systems:

- All vehicles already have a vehicle licence plate. The introduction strategy is straightforward.
- It is possible for the image to be stored to complement the ANPR function. That allows manual reading, which can often identify plates which are unreadable by ANPR.
- The image can include a view of the vehicle, fixing its location and identity, which can be essential for enforcement.

Those advantages have led to the introduction of ANPR based systems, for example in the London Charging system and for traffic speed measurement.

At the seminar Rob Lamont of Parsons Brinkerhoff spoke about the application of ANPR in a project for the Highways Agency aimed at providing drivers with information on the delays at major roadworks on the A38 between Exeter and Plymouth. Real time information on the delays was provided via a number of outlets, including a website. No one item of the project was particularly novel, but it did involve solving a number of data management and fusion problems to produce the final system. It was an excellent example of how ANPR can be used as a component in an end to end system to aid traffic management.

2.4 Standards

The TRL presentation also reviewed standards developments in EVI. On behalf of the DfT, and following the study outlined in Section 2.2, TRL has undertaken the development of an EVI standard. This was through an approach to the European (CEN) AVI/AEI working group (Automatic Vehicle Identification, Automatic Equipment Identification) who had the technical expertise to undertake this work. TRL arranged a formal submission to the European standards organisation (CEN), for a New Work Item to the AVI/AEI working group. The group comprises CEN and ISO members and it was agreed through the Vienna agreement that CEN would lead the development of a CEN/ISO standard for Electronic Vehicle Identification.

Brian Stoneman of TRL represents DfT within ISO TC204 WG4/TC278 WG12 with the role of Editor to this Working Group. The group is currently developing an EVI standard to cater for a range of simple to complex user applications, with the user able to select the operational parameters to meet the requirements of each application. This can provide a low cost simple solution, or selection for a more complex application with a high level of security. The Vehicle Identification Number (VIN), a globally harmonised standard, serves as the unique vehicle identifier.

In parallel with this development there was commercial interest in a low cost tag: a label on a vehicle windscreen that would provide a unique vehicle ID. The requirement for this 'basic' tag was in central America, Mexico City, where it would be used within a small area to ID vehicle to monitor thefts and pollution (tag also could contain limited vehicle data). The tag has limitations in its operating range (4m) and

performance but meets the needs of this immediate application. The ISO Standard for this basic EVI tag is in the final stages of development.

3 Short Range Ticketing RFID Applications

Trevor Crotch-Harvey of Fenbrook Consulting spoke about the options opened up by the availability of low cost limited use (LU) smart RFID tickets for public transport applications. Smartcards are already in common use for public transport tickets e.g. the Oystercard, but they are significantly more expensive than paper or card tickets and only suitable for use by people who travel reasonably frequently. The reduction in the cost and increasing complexity of RFID devices, as outlined previously, has opened up the possibility of having very low cost smart tickets to replace the paper tickets and magnetic striped cards which tend to be used by occasional users at present. Costs are not yet at a level where these LU cards could replace paper tickets for individual journeys but are suitable for multi-journey travel.

That change offers a number of advantages. First, the LU cards can be made compatible with the ISO 14.443 compatible readers used for the mainstream smartcards; this results in savings for the transport operators. The second is that they can be highly flexible and offer tickets with a stored value which is decremented after each journey, limited time tickets, area/zone based tickets, carnets ('booklets' of tickets), event specific tickets and concession based travel, possibly in combination. These options increase the attractiveness of travel, allow the number of evasion options to be reduced and can result in savings for operators. Mr Crotch-Harvey said that studies on a typical conurbation with a 1.5 million population and the usual mix of public transport options have shown that the business case for LU smart tickets started to become attractive at a price of 20p each and generated a positive return when prices reach 10p. Typical prices are currently around the upper figure, depending on volume, and will fall as volumes sales develop.

As a result LU smart tickets are currently being launched in a number of major schemes around the globe including in Melbourne, Seoul, Moscow, Atlanta, Lisbon and the Netherlands. It is predicted that ticket volumes will be several billion units per annum by 2009.

The second presentation in this section by Mike Burden of Consult Hypericon dealt with the options created by the adoption of Near Field Communication (NFC) in transport. The NFC link technology was jointly developed by Philips and Sony and has the following characteristics:

- Very low power RF data links operating at 13.56 MHz
- Operating range up to 10cm
- Data exchange rates up to 424 Kbit/second, possibly more in future;
- Covered by Standard ISO 18029

NFC was designed originally for use in consumer equipment and toys; it permits a moderately fast data link to be established between two adjacent pieces of equipment without connecting them with plugs and sockets. The protocols used in the standard are designed to eliminate (or at least minimise) setting up issues.

The most recent development of NFC is to build it into mobile telephones, such as the Nokia 3320. That turns the mobile phone into a general purpose payment and display terminal. Typically the phone would be swiped across a reader after being put into payment mode, and probably after entry of a PIN for high value transactions. A number of trials and demonstrations are in progress around the globe including:

- Caen, France – NFC used as payment medium in some stores, in parking facilities and tourist sites
- Frankfurt – NFC ticketing trial for public transport. – includes relaying timetable information back into the phone for display to the user.
- Taiwan – ticketing trial.
- USA – making payments at toll booths.
- Work is in progress in the UK to make NFC phones compatible with the ITSO (Integrated Transport Smartcard Organisation) public transport ticketing standards, to enable use in areas which use ITSO.

This potential expansion of NFC enabled phones will create a whole new range of options for paying for and accessing travel services. It should make life easier for travellers. However it is in competition, in some ways, with the other payment methods, such as LU smartcards described above. It will be interesting to see if they both develop as predicted.

4 Vehicle to Vehicle and Vehicle to Infrastructure Communications

The most forward looking topic at the Seminar was opportunities opened up by using small integrated processor (with an external data port)/transmitter/receiver modules mounted on vehicles and on elements of the infrastructure. Modules are linked to a range of sensors and actuators on each vehicle which communicate with the modules on other vehicles (Vehicle to Vehicle communication) and on roadside elements (Vehicle to Infrastructure communication) to form and reform local data communication networks as the vehicle moves along the road. The exchange of information offers scope to engineer a broad range of systems to aid all road users.

In my presentation I attempted to introduce a bottom up approach. EVI has been around for a few decades but progress is relatively slow in transport applications apart from specialist areas such as ticketing and bus identification. In principle EVI should be an enabler to solve a range of problems, such as eliminating inductive loops for traffic measurement and control, automatic enforcement, charging, low cost data gathering and after theft recovery. It is clear that the current generation of EVI does not provide the mix of functionality and ease of use required to provide these. What characteristics would EVI need to provide these functions? Enhanced EVI, with improved communication options and greater intelligence seems to be the way forward. Modules which include processing and communications capability mounted both on the vehicle and at the roadside appear to be a powerful enabling technology for new systems. I mentioned some recent work on bus scheduling in China, based on Zigbee technology, discussed below.

Prof. Phil Blythe of Newcastle University spoke enthusiastically about the opportunities opened up by these modules and smaller successors, known colloquially as “smart dust”. We then visited a selection of demonstrators set up at the university based on **Zigbee** modules, one of the commercially available units. These modules are a card with processing and communication circuits, typically measuring about 1.5cm by 2.5 cm. In applications which require battery power often the lithium cell used is larger than the module. They are commercially available at a price of about £30 in small quantities, and operate in bands between 800 MHz and 2.4 GHz, depending on the licensing arrangements in the country. Usually in the UK they are used in the open band at just over 2.4 GHz. Normally they operate with data rates up to 250Kbps. Communication ranges are typically up to about 30 metres.



Figure1. A typical commercial Zigbee module

We saw a demonstrator with a module linked to a hand held 'Blackberry' PDA which communicated with units mounted on infrastructure elements, such as pedestrian crossings, and included a GPS receiver. A system like this could provide route guidance for pedestrians; with special displays they could provide facilities for people with specialist needs, for example blind people could be provided with an audio "display" via a headphone. We also saw a localised dynamic route guidance demonstrator, where the in car display interacted with Zigbee modules mounted on lamp posts.

Another demonstration, indoors, showed how an element of position fixing could be built into a Zigbee network if a receiver measured the signal strength from all transmitters within range and applied an algorithm to measure the spacing from each. Inevitably this is an uncertain process; at the operating frequencies used, the signals bounce from all sorts of surfaces and interference patterns are established. Nevertheless the work is interesting in that it will enable the potential accuracy of the position fix to be established.

Zigbee technology normally allows communication at up to 250Kbps, which is ideal for domestic control functions (e.g. security systems and toys, the original target market) and for low speed or pedestrian systems. That data rate is unlikely to make it suitable for complex driving situations, with multiple vehicles driving at speed within range of a vehicle or infrastructure module.

Sergio Grosso of Newcastle University spoke about the EMMA and TRACKSS EU projects. It is now becoming relatively straightforward to develop short range data communication links, and there are readily available technologies and Standards, such as Zigbee, Bluetooth, 802.11b (Wi-Fi), GPRS and spread spectrum communications as well as proprietary systems. The challenge is to integrate the processor/communications networks into workable systems.

TRACKSS (Technologies for Road Advanced Cooperative Knowledge Sharing Sensors) is aimed at linking together all of the separate processors and sensors on a vehicle with roadside sensors. Examples of the current and possible future on-vehicle sensors include all of the engine management sensors, brake pedal sensor, steering actuator output, speed measurement, on board anti collision radar, ABS signals and a GPS receiver. Off board sensors and interfaces include the state and potential

change time of traffic signals ahead. All of these are linked by the communications network. TRL is a partner in TRACKSS, developing an on board passive mm (millimetre) wave pedestrian sensor. There are three main test sites in TRACKSS, one in Paris, concentrating on optimum junction management strategies, and others in Berlin and Valencia, aimed at developing a range of safety and traffic management systems.

EMMA (Embedded Middleware in Mobility Applications) complements TRACKSS and is aimed at developing the software which links the various individual sensors and processors, which will generally use a range of technologies and various communication protocols.

Both EMMA and TRACKSS are ambitious programmes, and have each been running for less than a year. In principle, if successful, they will provide a framework to develop a range of integrated systems to make driving more efficient. For example a vehicle in a road network with traffic signals could travel at an optimum speed to minimise stops and emissions. Route guidance systems could provide routes optimised for all sorts of parameters e.g. to minimise CO₂ outputs. If a pedestrian with mobility problems were equipped with a simple handheld terminal then he/she could have enhanced access at pelican crossings.

Professor Margaret Bell spoke about the possibility of building low cost environmental monitoring sensors into the types of network outlined above. Such equipment is normally in fairly bulky static installations at present. Inevitably coverage is patchy. If sensors could be included in vehicles, linked to the type of network outlined above, it would be possible to monitor the full road network. The initial challenge is to develop reliable low cost sensors.

In the final session on this topic Jack Opiola of Booz Allan Hamilton spoke about the Vehicle Infrastructure Integration (VII) programme in the US. Again this is based on the concept of a network linking processors/actuators/sensors in infrastructure elements and in vehicles. The primary objective is to improve road safety, but he cited a range of potential applications including:

- Electronic payment – parking, fuel and toll collection
- In vehicle signs and warnings (e.g. work zones, potholes, speed limits and queues ahead)
- Enhanced ramp metering control
- Traffic signal change warnings and optimised vehicle control
- Collision warnings and avoidance at intersections.

VII is being progressed in the US by a consortium which includes the major vehicle manufacturers and a range of public and private sector bodies. The aim is to make a presentation to Congress in 2008 to seek Federal funding and support.

The underlying technology concept behind VII is much the same as that of TRACKSS or the Zigbee based systems i.e. the hardware consists of processor/transmitter/receiver modules on the vehicle linked to a range of sensors and actuators which communicate with the modules on other vehicles and on roadside elements to form and reform local data communication networks as the vehicle moves along the road. Perhaps the main difference is the significant level of engineering resource already being invested in VII. That includes work on the RF (radio frequency) design and frequency requirements – VII will operate with 7 channels each 5MHz wide in a band at 5.9 GHz. There is already a substantial volume of development in progress on modelling the operation of the communication

network, on architecture development, on software and on system security and integrity issues.

5 Discussion and Conclusions

5.1 Implementation Barriers

This was an interesting and thought provoking seminar. Clearly there is a great deal of work in progress on EVI and the options opened up by integrated processor/communication modules. The systems made possible appear to offer substantial improvements in traffic management, road user convenience and road safety. Yet none of the concepts are particularly new. RFID tags for vehicle applications have been around for decades and the concept of constantly forming and reforming short range computer networks linking vehicles and infrastructure was the basis of PRO-COM, one of the technology elements in the PROMETHEUS Eureka programme launched by the European Motor industry in 1986.

It is pertinent to ask why so little progress has been made on implementing systems based on these technologies and concepts. The technology is moving on – the hardware elements of systems are smaller, cheaper, use less battery power and have greater processing power than ever before - but will these changes overcome the barriers which have limited the introduction of such systems?

The first major barrier to any Intelligent Transport System (ITS) which involves investment in technology on both vehicles and infrastructure is to generate a business case which works for both areas. Organisations are cautious about installing infrastructure if there will be no mobile units on day one and take up is voluntary, and possibly slow. That poses a significant risk; it is seen as the role of the entrepreneur rather than the public sector. On the other hand the public sector generally, and central Government in particular, are wary about making installation mandatory in vehicles; that uses up political capital, or public goodwill, and is only likely to happen when Government or a regulator sees a very clear community benefit from requiring road users to install systems. Often mandatory systems will also need to be agreed internationally, which imposes further delay and complexity.

The second barrier to systems which involve equipment in the vehicle is the difficulty of moving quickly from a situation with no in-vehicle units to one where all vehicles which should participate in or use the system are equipped. Ideally the unit can be quickly fitted by the operator/owner without any wiring; a typical example is a passive EVI tag for tolling which is stuck by the driver onto the inside of the windscreen. Anything which needs professional installation or permanent wiring into the vehicle's electrical system imposes major costs and barriers to take up. The alternative is to have equipment installed on the production lines but that would necessitate international agreement and a gradual installation in the vehicle fleet; typically taking 10 years to reach a 90 per cent fit level.

These barriers to the implementation of ITS with equipment in the infrastructure and also in the vehicle limit the types of system which come to market. If a commercial system promoter believes that a system can generate sufficient income then the company will fund the infrastructure to aid the sale of the in-vehicle equipment. Trafficmaster is a major UK example.

Alternatively if a public body, such as a road operator, is sufficiently convinced of the case for having a system it can provide the infrastructure and make in-vehicle equipment mandatory. The tolling system for the M7 Sydney Bypass opened in 2006 is a recent example. Vehicles wishing to use the road must have a tag in the vehicle; any without a tag are detected by the enforcement system, which uses

cameras and ANPR, and subjected to enforcement action. Alternatively the public authority can attempt to find ways of bypassing the need to have both sides of the system in place. The best example is the London Charging zone, which uses ANPR in the infrastructure and the only on-vehicle element is the license plate. It is far from ideal as a charging system, but did sidestep the implementation barriers.

Hence, systems relying on EVI or communication/processing modules are only likely to come into use if it is possible to identify so-called “killer applications” which will justify the necessary up front investment, including the political capital involved in making vehicle operators/owners fit a unit in their vehicle if it was not something they would fit voluntarily. If such applications can be identified and implemented then it is often possible to piggy back other services onto the technology.

One obvious potential “killer application” at present is tolling/road pricing. However to be recognised as such a system based on communication/processing modules would have to offer distinct advantages over alternative approaches.

5.2 Tolling and Charging Applications

The Department for Transport is currently examining the possibility of installing a road pricing system on all UK roads. It has identified that the need is for Time, Distance and Place (TDP) based charging i.e. a charge should be applied for each part of a journey. The charge should be flexible and be based on the time of travel, specific to the road link(s) used and proportional to the distance travelled on them. The key functions required to provide such charging are:

- The system should record the presence of the vehicle on the link with the TDP parameters, calculate the charge and add it to an account.
- If for any reason the transaction is incomplete or fails, the system should provide a time stamped secondary record of the presence of that vehicle on the link. That secondary record should be sufficiently robust to allow it to be used for legal enforcement action, if necessary.

The two main contender technologies at present are DSRC (Dedicated Short Range Communications) based charging and GPS/GNSS (Global Positioning System/ Global Navigation Satellite System) based charging.

DSRC based charging is currently being evaluated by TfL for use in London and forms the basis of a number of charging systems around the globe. Essentially a transponder mounted on a cantilever or gantry above the road communicates with a charging on board unit (OBU), usually fixed to the inside of the windscreen. The charging unit can be an EVI tag, in which case the account is maintained in the system infrastructure, or may include a built in accounting system, often based on a plug in smart card. Communication is at 5.8GHz, as specified in the CEN TC278 Standard. The directional nature of microwaves, and the use of a directional antenna above the road, allows a tightly defined charging zone to be established, usually slightly smaller than a vehicle. That means that one to one charging takes place. Multiple zones, and multiple overhead antenna units, are required for multi lane roads. If the transaction fails for any reason a photograph of the license plate is recorded for follow up action. There needs to be at least one charging point on most network links to provide universal charging.

The main drawback of DSRC based charging for a national charging system and all roads is that it would be costly. There are about 27,000 major links on the UK road network and twice as many if all minor routes are included. Each link would need a charging site with a gantry or cantilever from which to suspend charging units, cameras and ancillary units, such as lighting for night time use and laser based

classifiers. The geometry and cleanliness of some items is critical; it would demand a significant set up and ongoing maintenance effort.

GPS/GNSS based charging demands a more complex OBU than DSRC based charging. Essentially the vehicle OBU constantly calculates its position using the signals from the navigation system satellites and records that on an internal “map” stored in the processor. That “map” can contain details of speed limits or be used for routing, as in the currently available navigation systems. If each road link has an associated charge it is possible to add that to an internal account. That account can be maintained in a smart card or transmitted to the infrastructure from time to time, for example in a GPRS (General Packet Radio Service) data link.

GPS/GNSS based charging also has a number of drawbacks. One is the potential for error – the position fix is noisy, particularly in moving vehicles and in complex environments such as urban routes with high buildings or under trees. That can lead to errors in determining which of two relatively close routes the vehicle is on, possibly with different charges. Some of these errors could partly be overcome with careful system design. However, the major issue is the secondary enforcement action. If the charging transaction fails for any reason, either due to system imperfections or deliberate action by a driver wishing to evade payment, then there is no inherent record of the presence of the vehicle at a particular point on the network. A separate secondary recording system is required, probably based on cameras either fixed at particular points on the network or mobile units on enforcement vehicles. That would necessitate a separate complex and costly subsystem.

It seems likely that integrated processing/communication modules could play a part in reducing the cost and complexity of either charging approach. The key difficulty and cost contributor with both types of system is vehicle localisation – if there are several vehicles in an area is it possible to ensure that the correct one is identified for charging and/or enforcement action?

Modules could make a contribution but to do so would ideally include a ranging feature, allowing the separation between modules to be established, ideally within a fraction of a metre. The position of vehicles could then be established very precisely on the road by triangulation using two roadside modules with a known separation communicating with the vehicle module. An element of position fixing can already be established by modules by including a GPS receiver as an input to both on-vehicle and roadside units. However, as outlined above, the position fixes are noisy and suffer from latency; effectively a random time delay between fixing the position and producing it as an output. The resulting accuracies are unlikely to be sufficient to separately identify vehicles which may only be a couple of metres apart and moving at speeds up to 120kph or more. A ranging function built into the communication link between modules would be needed to achieve a sufficiently accurate current fix.

If a ranging function were included which allowed modules, and the vehicles to which they were attached, to establish their relative positions, then the charging function could then be built into the data transfers between modules and infrastructure, using the same protocols as in DSRC based charging. No overhead gantries or cantilevers would be needed, only pairs of small boxes mounted on roadside posts, a few metres apart. That charging system could replace or augment either DSRC based or GPS/GNSS based charging. If the integrity of the signal on the on-board unit could be guaranteed then that could also be the basis of enforcement – essentially the on-board unit would pass a “digital certificate” to the infrastructure indicating the vehicle identity. There would however, still be a need for a secondary enforcement system to record, probably by photographing number plates, the identity of vehicles without a working on board module. However, it should be possible to use a sparser distribution of detection points than for GPS/GNSS based charging on their own.

It is beyond the scope of this report to identify the optimum ranging approach. Digital Signal Processing techniques, probably based on deriving the correlation function between a transmitted signal and a received one might also be useable and should be compatible with the largely digital environment of the network. Identification of the best approach might necessitate research.

That is all speculative. Nevertheless it does seem possible that there might be opportunities for significantly reducing the cost and complexity of road pricing systems if processing/communication modules with ranging capabilities were included on every vehicle. If that happened then it would open the door to a range of other attractive options. For example the unreliability and maintenance cost of inductive loop detectors buried in the road surface is a constant problem for traffic managers. These loops could be eliminated by using two modules at the side of the road, a few metres apart, which communicated with the modules in passing vehicles and measured the length of the communication paths. The traffic passing a virtual loop on the road would be recorded and used in the same ways as the signal from loops at present.

5.3 Conclusions

As outlined previously both EVI and networks of fixed and mobile processor/communication modules are not new concepts. However, they do appear to have potential to revolutionise many aspects of transport and traffic systems in future decades. Yet there must be a risk that this potential remains unrealised unless a “killer application” can be identified, which leads to their widespread use in the vehicle population. Charging and pricing could be one such application, but would probably necessitate the introduction of a ranging/separation measuring function in modules.

If modules with a ranging function were available on all vehicles, this would open the door to a broad number of systems, including:

- Inductive loops could be eliminated in MOVA, SCOOT and incident detection applications. At its simplest vehicles would indicate when they pass over a virtual loop on the road surface; that would save the current installation and maintenance costs. However new strategies might emerge, for example based on the speed profile of vehicles approaching a junction or incident.
- New, improved control algorithms could be developed for motorway ramp metering and speed control systems if more detail was available about the operating parameters of the approaching vehicles.
- Vehicle classification and traffic data collection systems would be improved and simplified if the vehicle declared parameters such as its speed and class as it passed points on the network.
- The need for significant quantities of street furniture and signs on all types of road could be removed, by making many signs and control signals available on a display inside vehicles.
- Guidance facilities for pedestrians could be provided, particularly the partially sighted, via PDA based systems.
- A broad range of cooperative driving and anti-collision systems could be enabled if accurate vehicle-vehicle ranges could be established readily and reliably. It would be an enabling technology for the CVHS (Cooperative Vehicle Highway System) projects which are in progress in the US, Europe and Japan.

- Finally, as outlined above, it could form the basis of charging and tolling systems, possibly overcoming some of the disadvantage of existing GNSS and DSRC technologies.

6 Recommendations for the Highways Agency

As outlined in the conclusions it is likely that the technology of networks of processor/communications modules on vehicles and roadside elements could be used to aid the Highways Agency achieve its targets of safe roads, reliable journeys, and informed travellers. For example the improvements in incident detection and anti collision systems could contribute to safety, more reliable detection at traffic signals and improved strategies for motorway control would enhance journey time reliability and the additional information available in the vehicle or in hand held units would inform travellers. The challenge is to turn that potential into reality.

Although there is a great deal of technology available there are a number of challenges to be overcome. These include:

- a. Is it possible to dynamically form and reform local networks of the type envisaged in this report as vehicles drive along the road? In principle it should be possible; in reality it might be difficult. The work on protocols in EMMA and in projects such as CALM are a starting point but work on system modelling might be needed to explore the communication parameters, including data rates, that would be needed.
- b. How viable would it be to introduce a ranging function into modules to allow the relative positions of vehicles and roadside elements to be developed? In concept this is simple. A module would “know” a statement of the following type: “I am module *xyx* and I am *yy* metres from module *yyx* and *zz* metres from *xyy*” which could then be built into a “map” showing the position of vehicles within, say, a 50 metre range.
- c. If the characteristics of modules were known it would be possible to start examining the potential impact of systems. Some would only be viable if all vehicles had modules, some would still be effective if only a proportion of the traffic had them.
- d. What should the introduction strategy be? As outlined previously, such systems are only likely to come into being if a “killer application” can be developed which is either sufficiently attractive to either the public or private sector to justify the expenditure needed to get the system up and running. If that application would only work at fit levels near 100%, how would that level be achieved?

These are all substantial questions. However, the Highways Agency is not alone in having an interest. The DTI, via the innovITS UK Centre of Excellence, DfT through its work on CVHS, and the EU, through TRACKSS, are already examining the technology and standards issues involved in items a) and b) above, although there seems to be little work on ranging, which would greatly improve the scope of the technology. **It is recommended that the Highways Agency maintains active engagement with these projects to ensure that its needs are taken into account.**

In addition the Highways Agency should also begin to form a view on the benefits of such systems, by undertaking a “What if?” study. If such modules existed and were present in every vehicle what would the gains be in terms of the HA objectives? That work would involve a mix of brainstorming to develop the full possible range of applications and analytical/modelling studies to estimate the scale of the potential benefits. These need not be particularly complex – the aim would be to form a focus for debate. Some of the analyses probably exist for other projects.

None of this work is particularly urgent - implementation issues and the need to achieve international Agreements and Standards all mean that a system based on computing/ communication modules in every vehicle is some time off, probably at least a decade, perhaps more. However it would be valuable to start now and contribute to the debate and work which will shape the evolution of such systems and ensure they help the Highways Agency achieve its future objectives.

7 Bibliography

Radio Frequency Identification Device Technology, A Factfile prepared by the IET, available on <http://www.theiet.org/factfiles>.

8 Glossary

AEI	Automatic Equipment Identification
ANPR	Automatic Number Plate Recognition
AVI	Automatic Vehicle Identification
CALM	Continuous Air-interface Long and Medium range – standards designed to provide a flexible and adaptable networking layer between the provision of a service and the receipt of a service, enabling services to be largely media independent
CEN TC278	European Technical Committee responsible for ITS standards
CVHS	Cooperative Vehicle Highway Systems
DSRC	Dedicated Short Range Communications
EMMA	Embedded Middleware in Mobility Applications - EU funded project
EVI	Electronic Vehicle Identification
GNSS	Global Navigation Satellite System - the combined total of all satellite navigation and positioning systems offering signal reception world wide
GPRS	General Packet Radio Service – standard for data transmission by packet, with a speed of 64 Kbit/s
GPS	Global Positioning System – US satellite positioning system used to pinpoint geographic locations world wide
IET	Institute of Engineering and Technology
innovITS	UK Centre of Excellence for transport telematics and sustainable mobility
ISO	International Standards Organisation
ITS	Intelligent Transport Systems
ITSO	Integrated Transport Smartcard Organisation
LU	Limited Use
MOVA	Microprocessor Optimised Vehicle Actuation – system for controlling traffic signals at junctions
NFC	Near Field Communication
OBU	On Board Unit
PDA	Personal Data Assistant

PROMETHEUS	European motor manufacturers' collaborative research and development programme during the 1980s
RF	Radio Frequency
RFID	Radio Frequency Identification
ROM	Read Only Memory
SCOOT	Traffic adaptive signal control system
STREETWISE	Euro-Regional Project: Seamless Travel Environment for Efficient Transport in the Western Isles of Europe)
TDP	Time, Distance, Place
TRACKSS	Technologies for Road Advanced Cooperative Knowledge Sharing Sensors
VII	Vehicle Infrastructure Integration
VIN	Vehicle Identification Number

9 Annex A The Seminar Programme

- 10.15 Chairman's Welcome
Professor Phil Blythe, Director Transport Operations research Group,
Newcastle University
- 10:20 **Session 1: RFID State of the Art and Standardisation**
- 10.20 Innovative RFID Applications in the UK
Riaan Barnard, Research Manager, RFID Centre Ltd
- 10.40 Standards, Applications and Architectures
Dr William Gillan, Business Manager, TRL
- 11.00 Refreshments
- 11.30 Introduction to the Newcastle Wireless Intelligent Corridor (followed by demonstration)
Professor Phil Blythe.
- 13:30 **Session 2: Innovations in RFID**
- 13.30 Pervasive Environmental Monitoring of Traffic Pollution using Wireless Sensors
Professor Phil Blythe, Professor Bayan Sharif and Professor Paul Watson,
Newcastle University
Professor Margaret Bell, Leeds University
- 13.50 Near Field Communications (NFC) in Public Transport
Mike Burden, Consult Hyperion
- 14.10 Low Cost Smartcard Ticketing using RFID
Trevor Crotch-Harvey
- 14.30 Collaboration Among In Vehicle and Infrastructure-Based Sensing Technology for Automotive Applications: The EMMA and TRACKSS EU Projects
Sergio Grosso, Dr Alan Tully and Dr Budi Arief, University of Newcastle Upon Tyne, UK
Antonio Marques and Manuel Serrano Matoses, ETRA, Spain
- 15:20 **Session 3: EVI: Electronic Vehicle Identification**
- 15.20 Requirements for a National EVI System
Andrew Pickford, Transport Technology Consultants
- 15.40 Vehicle Infrastructure Integration (VII) in the US -Enhancing Safety, Enabling Mobility
Jack Opiola, Principal Consultant, Booz-Allen Hamilton
- 16.00 Customers First- Improving Driver Information
Rob Lamont, Principal Engineer, Parsons Brinckerhoff
- 16.20 Discussion**
- 17.00 Close