Electronic toll collection (ETC) has been a natural application for Dedicated Short Range Communication (DSRC) technology since its first commercial use in 1987. Now DSRC can claim to be a proven mass-market technology for road charging applications with multiple, competing suppliers. But where does DSRC go from here? Enhanced applications and Value Added Services may be the answer.

Dedicated Short Range Competition

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SURVIVAL OF THE FITTEST

It could be argued that a technology has succeeded when it does not form a significant part of the decision process to select a service that depends on that technology. In effect, the technology becomes 'transparent' and users no longer need to focus on the advantages and disadvantages of alternative underlying technologies. Instead, a user selects a service package that assumes one or more underlying technologies.

Decisions made by the early adopters have already ensured that all available technology alternatives have been tested and validated against the claims made by the industry pioneers. User expectations are fragile and initially managed by an uncoordinated cluster of suppliers competing for leadership, each seeking to establish market share growth and aiming to be regarded as the benchmark in the minds of the purchaser and end user. Those technologies that don't make it, or are rejected in favour of an alternative technology, are ultimately discarded on the technology scrap heap. The Betamax versus VHS battle is well known. X400 gave way to the all-embracing Internet as a message bearer and GSM displaced ETACS in Europe for personal mobile communications. The story of Dedicated Short Range Communication (DSRC) is no different.

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The need to reliably and securely identify and record the passage of a moving vehicle is at the core of electronic toll collection (ETC) and road user charging (RUC) schemes. The means by which a vehicle is temporarily linked with a roadside-mounted application server for the purposes of account identification is a natural application for DSRC. The technology is cheap (although this has not always been the case), reliable and interoperable solutions are now available from multiple independent sources.

To get this far DSRC has run the gauntlet of the technology selection process to emerge as the most dominant global technology for plaza-based and inter-urban open highway toll collection by private road operators and public agencies governments. Alternative, competing technologies including optical barcode, low frequency transponders and Infrared (IR) have all been demonstrated or piloted but, of these, the only consistent technology competitor to DSRC has been IR and this remains largely unproven. So will DSRC maintain its leadership in the light of new technology competition in new application areas? Will DSRC truly become the defacto solution, not only for toll operators but vehicle manufacturers and consumers world-wide, for new road charging applications? We consider the options below.

The DSRC story so far…

1987 World's first commercial deployment (Ålesund, Norway).
1991 First large references established in US (Dallas Tollway, US) and Europe (Dartford River Crossing, UK).
First generation multi-lane DSRC system (Dallas Tollway) using multiple single lane systems.
1991 CEN initiates standards development process.
1992 Proprietary designs flourish in Europe and North America resulting in growth of isolated, incompatible ETC reference systems.
1993 Malgara Multi Lane Free Flow system introduced as Europe' first.
1994 First sub US$30 tag design announced in US – two years ahead of delivery.
1996 Pre-standard designs announced by multiple vendors in Europe.
First large-scale co-ordinated procurement initiative (*EZ*-Pass, New York, US).
1997 World's first commercial pilot of multi-lane DSRC with multi-lane enforcement (Tauern Autobahn, Austria)
Regional interoperability projects started (TIS, France).
1998 First smart-card secured transaction demonstrated.
of CEN standards concluded for 5.8GHz operation.
Standardised DSRC links announced by several vendors.
Validated simulation models representing all elements of multi-lane free flow systems prepared by several vendors (Rekening Rijden, The Netherlands)
Multiple DSRC technology vendors co-operated to demonstrate interoperability in the EU-sponsored A1 project.
1999 Emerging evidence of separation of infrastructure procurement from tag procurement (e.g. National Toll Roads, Eire).
DSRC interworking reference projects established.
5.9 GHz DSRC carrier frequency adopted in the US as basis of standards development and interoperability required by federally-subsidised procurements.
2000 Routine interoperability capability deliverable by DSRC vendors and integrators.
Accumulated tag sales reach 15 million - up from 10 million in 1998.

Fig 1 DSRC archaeology

GROWTH

In October 1987, when the small community of Ålesund on the west coast of Norway elected to fund the building of a bridge and tunnel network with tolls, the principle of a remotely reading an electronic tag to link a vehicle passage with a toll account was novel. A radio-linked tag (at that time operating at 2.45GHz) was the device that, in the minds of the consumer, became the benchmark for paying tolls efficiently. In fact the long-term commercial viability of the Ålesund bridge and tunnel network could not have been secured without the low operational costs, security and reliability provided by ETC.

Since 1987 DSRC technology has successfully migrated from the market of proprietary isolated applications to being the focus of co-ordinated procurements by informed concession holders or operators from multiple vendors competing to provide an ETC or RUC application. DSRC is no longer regarded as being limited as a retrofit option on existing lanes at toll plazas but is now applied to open highway, multi-lane free flow applications (Fig 1).

THE OPEN ROAD AHEAD

Charging on the open highway poses many challenges. No longer are vehicles constrained between concrete dividers; they are allowed to roam freely between lanes at full highway speeds, unless of course they are stuck in congestion. Electronic charging that works reliably regardless of vehicle speed is now a critical requirement. For many highways world-wide this is already a reality.

Since the pioneering Ålesund installation (still in operation) over 11,000 toll lanes in 30 countries have been equipped to serve over 15 million tag-equipped motorists daily. New York, Oslo, Singapore, Santiago de Chile, Sydney, Melbourne, Toronto and Manila amongst other cities have all elected to use DSRC as the basis of ETC schemes on existing and new highways.

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As the dominant technology for vehicle-to-roadside communications, DSRC has made two leaps; from the toll plaza to the open highway and from proprietary, isolated solutions to multi-vendor procurements backed up by public domain standards. However, charging is more than about communicating with a tag fitted to moving vehicle. ETC and RUC require several components working together 24 hours a day, 365 days of the year to collect revenue from all road users at lowest operational cost to the highway operator. So, what about the benefits to the user?

MEETING USER NEEDS

Users should only have to pay for the services consumed - a process called 'charging'. Suspected violators need to be accurately detected, identified and ultimately targeted for payment - a process known as 'enforcement'. Both the charging and enforcement processes must be accurate: charges must be applied correctly to each vehicle regardless of its position on the highway and an audit trail must be created for follow-up administration. Often charges depend on declared vehicle classification so the enforcement system must be able to identify false declarations.

As the adoption of ETC increases several studies have shown that motorists are more willing to use ETC when it is applied to other familiar services such as parking and access control. The ETC system should therefore be scaleable to permit expansion to support new applications and over a wider geographic area. Finally, the user should be able to use the same tag at other charging points on other local highways and each operator should be able to procure tags from multiple sources on a long-term basis. Both of these benefits require *interoperability,* a late arrival on the DSRC scene, but possibly the most important contributor to current market growth and a benefit to highway operators and users.

INTERwhat?

After the adoption and necessary debug of the CEN DSRC standards a progression of initiatives, including TIS and the EU-sponsored A1 project resulted in an innovation that now enables highway operators to separate the procurement of roadside system from tags. Interoperability (Fig. 2) of DSRC in Europe was a product of a debugged CEN DSRC standard supported by multiple vendors participating in EU and regional government-sponsored projects. Highway operators were shown for the first time that one vendor's tag could work with another vendor's roadside DSRC system although true tag roaming can only be delivered when highway operators ensure contractual interoperability similar to the way that GSM handsets can seamlessly move between GSM networks bound by bi-lateral roaming agreements.

Commercial Benefits of Interoperability

The benefits of interoperability are often treated as purely technical. The commercial benefits are far more important and include:

- Promotes creation of multiple supply chains from multiple vendors - reduced procurement risk. Potential for suppression of monopoly pricing.
- Facilitates technology comparison by highway operators – removes communication link capability from selection process. Simplifies procurement.
- Separation of infrastructure procurement from tag procurement – separates high cost / low volume (lane equipment) procurement from low cost / high volume (tags) procurement. Simplifies procurement.
- Continuous competition for infrastructure expansion and new tag business – economically most efficient for highway operator. Lowest cost or greater benefits delivered.
- Allows geographic expansion from multiple road operators to proceed without co-ordination in technology selection – reduced complexity procurement for large projects. Simpler expansion.
- Encourages new tag supply chains – direct sales to highway users by third party outlets. Increased user choice.

Fig 2. Interoperability

Scaling a proprietary ETC system geographically seems more like *intra*operability than *inter*operability. The economic efficiency (to the operator and user) of cost competition is usually lost when a single source (or non-standardised) technology is adopted. European manufacturer-led initiatives such as the 'A1' project have taken the interoperability debate further by specifying CEN standards-compliant transaction models that includes provision for end-to-end security. This approach provides a 'shrink wrapped' approach to specifying a useable subset of transactions to ensure minimum service level interoperability between different vendors' products. This 'profiling' is a necessary step beyond standards to get ETC and RUC into a concentrated multi-authority road network typical of many developed countries. Similarly, developing countries using private finance to upgrade highways and infrastructure have more confidence knowing that specifying standards-compliant products simplifies the initial procurement whilst multi-vendor interoperability reduces long-term procurement and operating risks.

"*Scaling a proprietary ETC system geographically seems more like 'intraoperability' than interoperability…*"

NEXT STEPS

Highway operators provide the road user with a well-defined service; a safe and reliable travel experience at a cost to users (directly or indirectly). More sophisticated services may require interfaces with third parties including neighbouring highway operators and other providers of travel services including parking houses and traffic management agencies. Furthermore, the road charging system is a source of information on travel behaviour (to help target investment between modal alternatives), travel patterns (to assist travellers make long-term modal choices) and congestion (to enable informed decision on mode and/or route). In short, the information generated can form a part of regional ITS strategy development and ITS operations.

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Commercial viability for all publicly and privately financed highway build programmes requires low operating costs and minimum environmental impact. DSRC meets these requirements but, more importantly, could ensure commercial viability where conventional methods of collecting charges could not. The desire to charge motorists as a policy instrument to manage congestion has hit the headlines in congested capital cities world-wide and, although commercialisation of existing highways is now a possibility, the barrier to implementation in many developed countries is not economic but institutional. Paying for road use has never been an attractive proposition for users so the development of bundles of services around the vehicle-to-roadside communication link represents a primary growth area for DSRC vendors and suppliers of complementary technologies.

In this broader context, the supply chain that currently designs, develops, integrates and operates DSRC technology and road charging systems that use DSRC cannot afford to be complacent. DSRC has been used in applications requiring a dedicated, high speed, localised, secure bi-directional communication bearer, for example vehicle-to-roadside communication for ETC and RUC. Interoperability features provided by DSRC permit new supply chains for tags (more correctly called on board equipment) independently of highway operators, analogous to the relatively simple process of buying a pre-paid mobile phone (Fig 3.). This shift from operator-centric interoperability to consumer-centric interoperability follows the migration from multiple single project procurements to co-ordinated procurements that impact a regional travel network.

New Routes to Charging for Road Use

- The mass market example: buying a pre-paid mobile phone:

  The user chooses the outlet, the network operator, the mobile 'phone / tariff combination. The phone is owned by the user and the contractual relationship / application profiles are defined by the installed SIM card. No bills. Enforcement through denial of network service. Roaming taken for granted.

- 'Operator-centric' interoperability for RUC:

  The highway user contacts the highway, bridge or tunnel operator directly. The tag is distributed by (and owned by) the operator. Fees are collected by the operator or by an authorised agency. Enforcement immediate (i.e. barrier) or deferred penalty (owner traced through license plate identification). Roaming technically possible but depends on bilateral agreements between highway operators.

- 'Consumer-centric' interoperability for RUC:

  The user chooses the outlet, on-board unit, preferred travel Value Added Services Provider (VASP) and bundled services / tariff / billing mix. The on-board unit is owned by the user and contractual relationship / application profiles defined by an installed SAM (Security Application Module) owned by the travel services provider. Enforcement through immediate denial of services and deferred penalty (owner traced through license plate identification). Roaming between charged highway segments for all (or most) services taken for granted.

Fig 3. Interoperability perspectives

Extensions to tag functionality with a smart card permit applications to be partitioned. However, the Holy Grail for DSRC is to extend the communication from a roadside system *through* an on-board unit to in-vehicle functions. This concept is already moving from the drawing board of automotive manufacturers to commercial reality. Speed control systems, intelligent cruise control and stolen vehicle location schemes are all being demonstrated with DSRC-like technology. In addition, new charging applications, such as urban road pricing, distance-based tolling and green area tolling provide new challenges for existing manufacturers and their technologies.

The recent fees paid by mobile operators for third generation mobile licenses will need to be recovered through high value added applications. However, DSRC can also provide a motorist with a temporary high bandwidth connection to roadside infrastructure fed by content providers of traffic information and other travel-related Value Added Service Providers at a fraction of the cost of the investment in 3rd generation wireless networks.

Furthermore, DSRC already incorporates many of the mechanisms required for secure end-to-end transactions between the roadside infrastructure and applications that could reside within the vehicle itself. These security features, backed up by encryption techniques at both ends of the client-server link, are already available and could support additional payment events for high-value niche segments and mass-market applications.

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Since technology vendors already provide the DSRC technology toolkit, it now requires innovation by application developers, highway operators and other value added travel service providers to provide service-related benefits to road users. This may help further justify the commercialisation of existing highways whilst delivering the much needed incentive to motorists to accept road charging.

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