Considerations for Adopting VII-Based Tolling

By Michael Catalano, Ram Kandarpa and Tim McGuckin

As equipment vendors and automobile manufacturers begin testing 5.9GHz VII-based electronic payment applications, toll operators should consider the associated technological and business challenges in order to take advantage of the opportunities VII-based tolling offers. As far as the future of the tolling industry is concerned, vehicle infrastructure integration (VII) isn't an 'if' but a 'when' proposition. Many of the old assumptions about toll-collection and -payment systems will likely be turned on their heads as the industry moves from a regional application to a national, interoperable payment system. As a result, toll operators should consider and initiate the business case for supporting VII tolling.

The 5.9GHz VII systems being developed differ in several compelling ways from the technology and processes the toll industry currently employs for electronic toll collection (ETC). First, they are based on open standards and will be certified as standards-compliant and interoperable, which should be favorable to any enterprise that values having a choice of competing suppliers. Second, they have clear performance advantages in terms of latency, read distance, data rate, and security. Third, from a business and traffic-management perspective, VII systems permit many more applications that advance safety and mobility—key objectives of the toll industry.

Despite these advantages, VII tolling will pose new challenges to, and demand new best practices from, our industry. The manner in which these challenges are defined and met will influence how and when toll operators make the business case to justify procurement and deployment. These challenges relate specifically to the current business of toll collection and its technical requirements, which are unique among the 100+ applications that VII will support.

Comparison of System Architectures

Comparison of a typical ETC system with the expected VII-based toll-payment architecture reveals a new vehicle subsystem and network subsystem (see Figure 1). The VII vehicle subsystem comprises the vehicle's integrated onboard equipment (OBE), a toll-payment application, and the driver interface. The driver interface for tolling applications will vary depending on how each vehicle manufacturer incorporates its own unique audio and touch-screen display functions.

The VII network subsystem will include the roadside infrastructure or roadside equipment (RSE) and associated certificate authority (CA). The CA enables security for message exchanges between the toll-payment application in the vehicle and the toll-collection subsystem.

When a vehicle with a built-in 5.9GHz device comes within radio range of an RSE, a secure transaction will facilitate payment. The VII system permits additional flexibility with regard to tolling schemes, toll-payment options, and operating models. For example, the open architecture and flexibility can allow different transaction types for accessing express and priority lanes. In addition to tolling, VII will support other payment applications, such as parking and fueling.

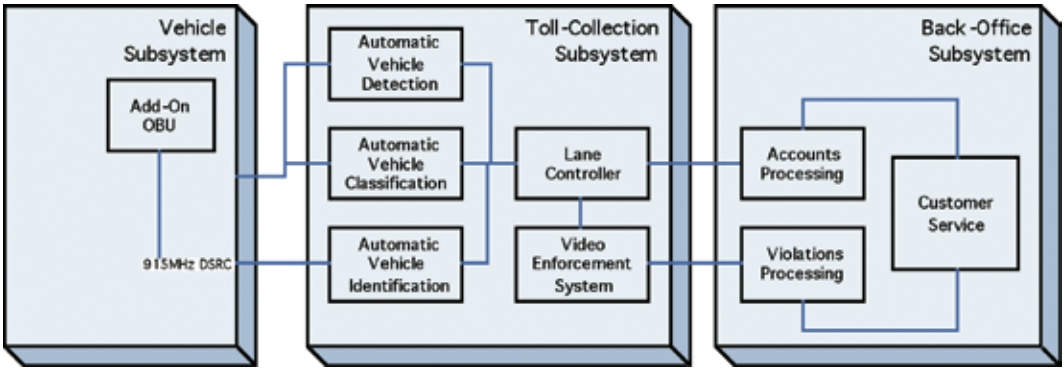
Toll-Payment Scenarios

For the initial national deployment, which is envisioned to occur sometime from 2011 to 2012, VII is expected to support the following types of tolling:

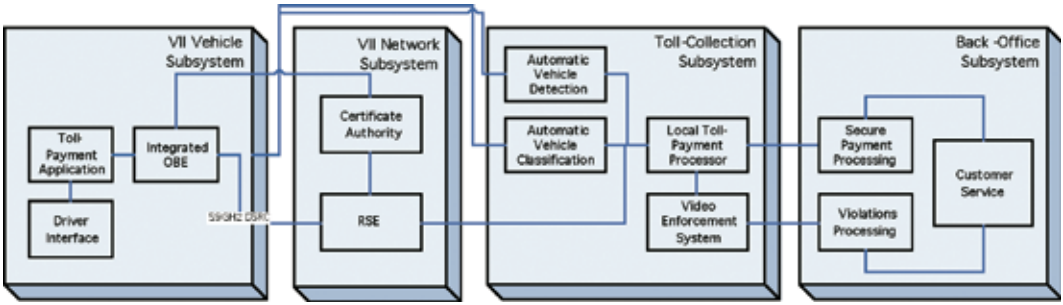
- Roads that charge a fixed toll at a given location (open system);
- Roads that charge a variable toll based on the distance traveled (closed system); and
- Roads that charge a toll for improved level of service (high-occupancy toll, or HOT, lanes) and that may charge variable amounts based on the level of congestion, the time of day, or the vehicle's entry/exit location.

For fixed-toll limited-access roads, VII-based toll payment will function very much like today's transponder-based toll-payment system. As an OBE-equipped vehicle approaches a toll-payment location, it will interact

Figure 1: Existing ETC System vs. VII-Based Tolling System



Typical Schematic of Current ETC Systems



Schematic of VII-Based Tolling Application

with an RSE. If the vehicle operator has enabled electronic payment on the OBE, it will electronically pay the toll and notify the driver of the valid payment.

For distance-based tolling applications, the OBE-equipped vehicle will interact with an RSE located at an entry point on the toll road and again with an RSE located at an exit. Upon exiting the toll road, if the vehicle operator has enabled electronic payment on the OBE, it will electronically pay the toll and notify the driver of valid payment.

Finally, for HOT-lane applications, an RSE located on the roadway prior to the HOT facility will interact with the vehicle and share the locations of HOT lanes and current toll rates. The tolls will be charged electronically on the HOT lanes via communication

between a qualifying OBE-equipped vehicle and an RSE at the toll-payment location.

In all three toll-road types described above, in the case of a failed payment or nonpayment, the vehicle will be treated as a violator and will be processed as such through the toll facility's existing video enforcement subsystem (VES) for image processing of the license plate. In other words, VII tolling doesn't intend to supplant an operator's VES system: image capture may still be the best enforcement means to back up the ETC system under VII.

Under VII, each of the three toll-road types is expected to support at least two methods of payment: account-based (similar to the transponder-based systems in use today) and credit card/debit based from within the vehicle at the toll-payment location (for point-of-sale transactions).

Technical and Operational Challenges

The toll industry's position as a VII stakeholder is exceptional because the industry is a current operator of dedicated short-range communications (DSRC) systems. Because the industry developed its existing technology and business practices around a different set of requirements and technical capabilities from what may be seen in VII systems, the migration to VII will naturally give rise to new challenges.

Vehicle classification. A key component of vehicle classification is interoperability, which is essential to VII's viability as a national system. Currently, no national standards exist for vehicle classification. Various toll agencies use equally variable metrics to measure and assess the classification of a vehicle. For example, one agency may use a simple car or truck classification; another may use axle count; another, length, width, and height information; and still others, a mix of vehicle height over the first axle and length. This often results in different vehicle classifications expressed as class 1, 2, 3, 4, 5, or more. These varied, traditional classifications must be addressed, because VII won't support any of them.

VII's stringent privacy policies dictate numerous restrictions on the types of identifying information that will be allowed to be transmitted.

Although no vehicle IDs, such as VINs, will be broadcast from the vehicle, there *is* support for generic vehicle classification information such as axle count, vehicle length and height, and distance between axles to be included in a VII toll-payment transaction. Obviously, such generic classifications will need to be mapped to a toll authority's own classification framework.

How the correct classification is determined in exceptional cases (such as a passenger vehicle towing a trailer) will be based on the practical experience of the toll industry. How the toll industry supports the integration of demand- and incentive-based toll charging with vehicle classification when, say, the incentives expire after a period of time (for example, as with alternative-fuel vehicles) is another question. At the least, toll authorities should request detailed information from their automatic vehicle classification (AVC) equipment suppliers on how their systems will support these types of applications in the future.

Existing lane-configuration design. The extent to which the toll industry will be able to augment existing lane configurations during the planned migration to VII tolling is poorly understood. Near-term plans to add HOT lanes can be seen as an opportunity to investigate new designs that will easily support VII tolling in the future. Obviously, existing designs will need to coexist with VII as the percentage of vehicles with an embedded device grows.

Because VII's performance envelope is greater than that of current ETC systems, a number of questions need to be kept in mind as the industry moves ahead:

First, how will a toll operator preserve its investment in current lane-configuration hardware and software while also maintaining technology that supports next-generation DSRC systems? Second, with existing systems and automatic vehicle identification (AVI) algorithms currently tuned for read distances of 30 to 60 feet and next-generation DSRC toll applications being designed to support distances significantly greater, will we be able to associate 915MHz tags with the correct vehicles and also determine

their classification? And third, how much will it cost to analyze and design the new lane configurations and systems required to support any mixed-use period; that is, can the same gantry infrastructure be used for 5.9GHz VII tolling equipment?

Account provisioning, authentication, and portability. Since future vehicles will be manufactured with the 5.9GHz VII onboard unit (OBU) already installed, the process of provisioning a vehicle for use with VII toll infrastructure will differ from linking a toll tag's ID number with a customer account. Provisioning systems should thus support multiple methods so that existing toll tags and VII-enabled vehicles can be provisioned for the same network.

Authentication methods will also change. Existing 915MHz tags based on regional network standards will use a different type of authentication from next-generation DSRC devices, which may drive up transaction processing costs during the mixed-use period.

Additional challenges will stem from account portability, which will soon become a reality. How the industry supports account portability will be driven by the toll-industry stakeholders involved in drafting the national interoperability specifications. Are there existing business models for the toll industry that will assist operators during this transition? Certainly there may need to be authorized third parties that can assist toll authorities with account creation, provisioning, and settlement, but these externally supported functions will also enable interoperability with all other VII-based networks.

Multiple account links. In the new world of VII, vehicle operators will likely use touch-screen displays and/or voice controls to access a range of in-vehicle applications. This will entail a significant mental shift from today's environment, in which the toll tag is the application.

As they can with other purchases, consumers and drivers will expect to be able to use different electronic sources of funds to pay for things, and in the context of VII, this capability could well originate in a "banking" menu in the car. Customers will appreciate the flexibility of being able to use either credit or debit accounts to manage travel expenses, but the motorist's ability to change the link from a credit card to a debit card as he or she drives

toward a tolling gateway will create additional back-office challenges. The added convenience and utility of switching accounts on the fly may be demanded by commercial vehicle operators as well as others, to support expense reporting for the business use of personal vehicles, for example.

Regional transportation partners such as toll authorities and transit authorities may also "contribute" to individual account balances through their sponsorship of variable and demand-based toll initiatives designed to promote more efficient use of surface transportation and improve mobility (in other words, incentive programs). For example, a regional transportation council might bring together toll authorities, transit agencies, and participating employers to determine how discounts and credits could work to encourage drivers to use express toll lanes for accessing a transit parking facility and transferring to a bus, rapid transit, or commuter rail. Participating employers could give credits back to employees who use public transit.

How will tolling authorities guarantee that they receive payment for services if they no longer "own" the account and the customer? Existing credit-risk management processes may need to be analyzed and improved upon. Should poor-performing postpaid accounts be switched to prepaid status on the fly, as it's done in the cellular industry? How will the effectiveness of discounts and incentives be measured and accounted for?

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The settlement processes used by wireless carriers and the banking industry could provide workable models. Still, there will be some pain involved as tolling authorities prepare for an interoperable and integrated national network with potentially hemispheric roaming capability. Here again, the best practices in other industries can be leveraged to support these more complex revenue-management processes.

Payment enforcement systems. Automated plate-recognition systems will continue to be relied upon as VII tolling use ramps up. Some amount of read errors associated with mixed-mode use will likely change the amount of manual reviews required during this period. New violation enforcement techniques such as those employed in national road-user charging projects around the world might be adopted by the U.S. toll industry. For example, U.S. toll operators could consider mobile enforcement combined with other temporary roadside enforcement techniques to sample and check VII operations. Such enforcement schemes may be considered more cost-effective than current image-based license-plate captures. In essence, the U.S. toll industry currently doesn't fully understand when a payment violation should be triggered in the 5.9GHz environment compared with existing 915MHz systems, and it must in order to evolve.

Additional questions relating to payment violation processing will of course be raised during any mixed-use period. Will there be different procedures for violation processing based on the toll-collection technology used in the vehicle? How will we measure and achieve efficiencies with multiple automated and manual work flows for payment enforcement, AVI, and violation processing?

Back-office models. How will tolling back-office operations evolve to address the increasing challenges posed by multiple user-driven requirements? Will the industry continue to move forward with its existing transaction-processing business models? Can we create a hybrid model by incorporating settlement processes, differentiated pricing, and other lessons learned from wireless carriers? Who will govern the industry's future settlement and clearing rules? What new systems and interfaces need to be supported? How will support of these new systems and additional interfaces affect operating costs?

Some of these business-model questions should be explored in the near term, especially during plans for technology upgrades. IBTTA member participation in HOT-lane conversions and variable-pricing pilots may require more advanced back-office functionality. System upgrades associated with these initiatives should be seen as opportunities for improving the

efficiencies we have already gained with ETC.

Interoperability. While largely viewed as a successful application, most current 915MHz ETC systems rely on proprietary vehicle-to-roadside communications (that is, one vendor's AVI equipment can't communicate with another vendor's transponder). However, suppliers already familiar with deploying these ETC systems have gained valuable experience that will help in integrating VII systems with existing ETC solutions. Also helpful will be consideration of the transaction-processing methods used in other industries, such as wireless telecom and mobile banking/commerce, as the tolling industry adapts its best practices to incorporate interoperability operating requirements.

In the end, interoperability will require a three-pronged approach—technical, financial, and contractual—to determining the "right" business model. Toll operators will want to know that technical interoperability with VII provides a means to read every vehicle passing their tolling points. Given this assumption, the key issues in choosing the right business model appear to be how the operator gets paid and by whom (financial interoperability) and in what time period funds will be provided through a settlement process (contractual interoperability).

Further Exploration

IBTTA, and through its offshoot the OmniAir Consortium, is in an excellent position to promote the integration of next-generation DSRC and to champion interoperability between different ETC vendors. Cost reductions, best practices, and efficiencies gained with the increasing standardization of communications, networking, and back-office technologies in other industries can be referenced in moving forward.

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To better understand the true value of these variables, the industry could benefit from more information about its own transactional costs in order to create a starting point for the analysis. Without this point from which to measure incremental improvements, it will be more difficult to measure, in turn, the true value of any changes to

the toll industry's current operating and business practices encouraged by VII.

Regional authorities that are planning to participate in HOT-lane and variable-price tolling initiatives should also more earnestly explore alternative electronic payment methods and supporting technologies, to help them prepare for the day when in-vehicle commerce application portals are the norm and not the distant future. These initiatives could be catalysts to improve the perceived value of tolls among customers through increased flexibility and convenience.

The Promise Ahead

Although the full promise of ubiquitous and interoperable vehicle tolling and commerce isn't easy to fathom, these applications will certainly arrive—with or without substantial government investment in VII in the near term. The industry is fully aware, from a regional perspective, that the expansion of tolling interoperability has enhanced the average motorist's perception of the benefit of the pay-per-use model. Furthermore, the industry also knows that there is mounting public

frustration over traffic congestion, which will affect future infrastructure investment decisions. As the foremost representative of the worldwide toll industry, IBTTA plays an important role in shaping strategy for incorporating innovative technologies such as VII. In doing so, it will address these issues as part of an integrated and managed approach for the entire transportation community.

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