The AT/Comm distributed approach to Electronic Toll Collection (ETC) provides for the greatest flexibility in designing/implementing ETC. This distributed approach shares the processing requirements of ETC between the roadside processing capability and that of the multitude number of processors residing in the respective transponders. As a result of this large and diversified computing power, the toll pricing options readily supported are many. And tangential support, for such things as taking a transponder out of service via radio, is also provided. There are principally six options for toll pricing:

1. Standard, Fixed Price, Open Tolling
2. Standard, Fixed Price, Closed Tolling
3. Mixed, Fixed Price, Open/Closed Tolling
4. Commuter Pass Pricing, Open/ Closed Tolling
5. Commuter/Fixed Pricing Hybrid
6. Congestion Pricing

Each of these is detailed separately to follow, with a description of the payment options for each pricing method.

1
Standard, Fixed Price, Open Tolling

This pricing method mirrors that of conventional open toll pricing. Each class of vehicle has a fixed price toll for each passage through a payment lane. This method of pricing is typically associated with bridge, tunnel, or across-the-road highway barriers. With the AT/Comm ETC system, the toll schedule for all classes is broadcast to all transponders from a broadcast radio beacon just prior to the payment plaza/ramp/lane. The transponder then determines the toll to be paid based on its class, and pays the respective toll as the vehicle passes through the lane. At a minimum, the I.D. of the transponder and the toll paid is conveyed to the in-lane system for audit.

Payment options for Standard, Fixed Price, Open Tolling include:

- cash
- credit card
- bank transfer
- post-pay
- clearinghouse

2
Standard, Fixed Price, Closed Tolling

This pricing method mirrors that of conventional closed toll pricing. Each class of vehicle has a fixed price toll, based on the entry and exit point for that respective trip. This method of pricing is typically associated with toll roads that have multiple entry/exit interchanges. With the AT/Comm ETC system, the toll schedule for all classes and entry/exit combinations is broadcast to all transponders from a broadcast radio beacon just prior to the exit payment plaza/ramp/lane. The transponder then determines the toll to be paid based on its class and entry point conveyed to its memory upon entry, and pays its respective toll as the vehicle passes through the lane. At a minimum, the I.D. of the transponder and the toll paid is conveyed to the in-lane system for audit. For very large toll schedules (greater than 150 entry/exit interchanges) the toll schedule is placed in a nonvolatile (EEProm) memory in the transponder at the time of transponder initialization. A 1,000 interchange toll system requires a 16K bit EEProm. The toll due is calculated by the transponder based on the entry and exit data conveyed to it by the respective entry and exit broadcast radio beacons. Changes to the toll schedule can be made from any broadcast radio beacon.

almost absurd task of sharing data. Most clearinghouse models suggested to date rely on centralized account maintenance and validation methods. These have all failed to reach implementation due to the obstacles presented by shared data requirements.

The AT/Comm ETC system distributes the account maintenance and validation process by placing the primary accounting and account validation in the transponder, thus eliminating the need for a real-time centralized process for account debiting and validation of sufficient funds in the lane. Effectively, each agency in the region collects prepayment of regional tolls, thus providing that a fund of toll prepayment exists at each toll authority. At month's end, the settlement software system reconciliation takes place which directs funds exchange between agencies through a simple banking relationship. This process is now patent-pending and will be described in detail later in 1995.

Disabling a Transponder

Transponders that have been identified as being stolen, lost, or out-of-service for bad credit or non-payment of tolls can be disabled readily. In order for a transponder to conduct a transaction in a payment lane, it must have first passed through a radio field just prior to the payment plaza/ramp/lane. If for any reason this does not occur (patron puts unit under seat, for example), the transponder will be silent in the payment lane, thus be considered a violation if alternate conventional payment is not made.

Any pre-plaza broadcast beacon can be programmed to broadcast a list of invalid transponders. This list can be up to 10,000 I.D.'s per broadcast station. The broadcast list is completed within the following parameters:

Baud Rate*	Max List Size	Time to Complete
9600 bps	150	.5 sec
19,200 bps	300	.5 sec
64 kbps	1,000	.5 sec
300 kbps	5,000	.5 sec
600 kbps	10,000	.5 sec

*assumes Manchester coding

Alternatively, a transponder can be invalidated in a payment lane with a periodically conveyed list, resident in the lane processor card associated with the AT/Comm ETC system. This will support up to 64,000 invalid I.D.'s and will perform a pass/fail analysis at highway speeds. However, this method sacrifices the potential to warn a driver of an invalid transponder before he/she is in the lane. Many consider this a safety hazard, as the patron might stop at a sustained red light in a lane where following ETC vehicles are accustomed to passing through at 25-40 mph. With an audio/visual prewarning, this would not happen. Also, in-lane invalid listing is significantly more expensive than preprocessing invalidation.

Conclusion

The AT/Comm ETC system is both the most powerful and most cost effective system in operation today. The use of distributed processing to reduce the requirement for real-time centralized account processing and in-lane validation has been demonstrated in real bids to be between 30% and 70% less expensive than more centralized validation ETC systems. And, the inclusion of the motorist in the information loop (display, audio speaker, keypad) provides a platform for a variety of other IVHS applications. Best of all, the AT/Comm system is available and operating today.

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Payment Options

There are principally five options offered for the payment of tolls for ETC using the AT/Comm system.

1. Cash Prepayment
2. Credit Card Prepayment
3. Automatic Bank Transfer Prepayment
4. Post-Payment
5. Inter-Agency Settlement System (Instead of Clearinghouse)

CASH PREPAYMENT of tolls is the most straightforward means of accommodating prepaid ETC. Patrons without credit or credit cards can even participate in ETC using this option. The prepayment of tolls using cash is easily done in a designated lane, akin to the sale of tokens, without the requirement of physically handing over a roll of tokens. This typically takes 6-8 seconds in the lane. Alternatively, prepayment stations can be set up and located conveniently for customers to bring in their transponder to be "recharged" with a cash balance.

CREDIT CARD PREPAYMENT of tolls is the most convenient means of accommodating prepaid ETC. Patrons wishing this option simply provide a credit card authorization at the time of transponder purchase or at any subsequent time. The transponder is programmed to increase its balance when the balance reaches $10.00. The next time the vehicle passes through a payment lane, this increase in balance is noted, and the patron's credit card is debited by the prepayment amount, say $50.00.

AUTOMATIC BANK TRANSFER PREPAYMENT of tolls is similar to a credit card prepayment option but instead of debiting a credit card, a patron authorization to transfer money from their respective account to the toll agency is used. Cash, credit card, and bank transfer options all take advantage of the distributed processing nature of the AT/Comm system by providing account maintenance and balance display in the transponder, with toll and prepayment audit conducted by a central database/computer.

POST-PAYMENT of tolls is very convenient but is usually only available to a certain group of patrons, typically commercial fleets. In this mode, the transponder effectively acts as an AVI system, simply conveying its I.D. as it passes through the payment lane. A bill is sent to the patron weekly, monthly, or annually.

Finally, the INTER-AGENCY SETTLEMENT SYSTEM instead of the Clearinghouse option, using the distributed processing power of the AT/Comm system, offers patrons in a region with several toll facilities a payment plan that allows them to prepay a single amount, usable at any participating facility. This option requires cooperation between agencies, but unlike other clearinghouse plans, does not require third party handling of agency funds. The balance remaining in the transponder can be displayed to the patron and either cash, credit card, bank transfer, or post-payment options can be used. From the patron's perspective, in a region where multiple toll agencies/facilities exist, a single prepayment of tolls for usage on multiple facilities is most convenient. From the perspective of the respective toll authorities, however, the clearinghouse plan presents significant political, policy, legal, and practical obstacles that must be cleared before implementation. At the heart of these obstacles is the issue of third party handling of funds and the practicality of regionally-shared data. Many authority bond covenants preclude third party revenue handling and even those authorities that are free to use third parties for revenue collection are hesitant to take that risk. Exacerbating the difficulties of third party fund handling is the