by **Randy Frank** | Contributing Editor

MAKING VEHICLES AND HIGHWAYS INTELLIGENT

Intelligent transportation systems (ITS) encompass many applications and technologies. This report investigates a variety of communications issues that are being addressed, both in the vehicle and the infrastructure, to make vehicles and highways smarter.

The goal to conquer the shortcomings of roads and vehicles with existing and future technology is truly a global effort. Many facets of today's ITS efforts, sometimes called Smart Highways, were defined in the 1980s in Europe (PROMETHEUS, DRIVE I and II), Japan (RACS, AMTICS, and NeGHTS), and the U.S. (Mobility 2000). In the 1990s, the U.S. Intelligent Vehicle Highway System (IVHS) became Intelligent Transportation System (ITS). Among the advanced technologies required to make vehicles and the infrastructure smarter, no matter what the interaction is called, are a variety of communication technologies. Table 1 shows 16 ITS activities identified by the U.S. Department of Transportation[1].

The 16 activities include 13 that involve the infrastructure and vehicles and three that are more specific to just the vehicle. A number of communication technologies including radio, wireless, RFID, Internet, and dynamic signs provide possible solutions to exchanging information between vehicles and the infrastructure and between vehicles.

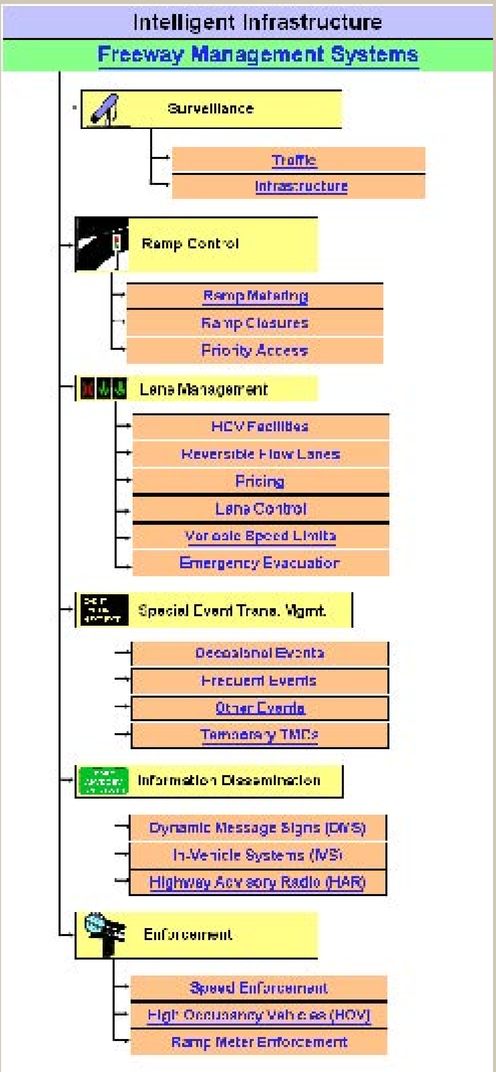


Figure 1. Communication in freeway management systems.

To understand the role of communication or the information dissemination technique as it is called in the Federal Intelligent Transportation Systems (ITS) program, a closer look at two of the 16 ITS activities is required. As shown in Figure 1, the next layer down in freeway management systems includes surveillance, ramp control, lane management, special event management, enforcement, and information dissemination. Some types of communication may be more appropriate for a particular situation than another. In other cases, it may be appropriate to use all three.

As shown in Figure 2, for electronic payments systems, the communication is, in most cases, simply identification. As a result, magnetic stripe cards, smart cards, in-vehicle transponders, or vehicle-mounted bar codes are sufficient. In a specific application, such as toll collection, radio-frequency identification (RFID) tags are the technology of choice.

RFID

One of the more advanced applications of RFID tags or transponders is in an automatic vehicle identification (AVI) system. An AVI system includes probe vehicles, electronic tags (transponders), roadside antennas, roadside readers, and a central computing facility. In probe vehicles, electronic tags can track the vehicle's speed, location, and travel time along roadways equipped with a tag reader infrastructure. The traffic management center monitors traffic and communicates traveler information.

RFID tags are typically either passive or active. Passive tags do not have a power source. The passive tag rectifies the RF power transmitted by the reader to power its dc circuitry. Without an internal battery it does not have a shelf life or (electrical) expiration date. The active tag has its own battery and a transmitter, which provides a greater signal and operating range. The operating life depends upon usage but can last up to 10 years. Both the passive and active tags have ITS applications.

Intelligent Infrastructure	Communication*
Arterial Management	DMS, IVS, HAR
Freeway Management	DMS, IVS, HAR
Transit Management	IVS, IT/W, IWP
Incident Management	DMS, HAR
Emergency Management	none identified
Electronic Payment	RFID**
Traveler Information	W, 511, P, R, IVS
Information Management	none identified
Crash Prevention and Safety	none identified
Roadway Operations and Maintenance	PDMS, HAR, IWP
Road Weather Management	DMS, IWP, HAR
Commercial Vehicle Operations	RFID, GPS, W**
Intermodal Freight	RFID, GPS, W**
Intelligent Vehicles	
Collision Avoidance Systems	none identified
Collision Notification Systems	GPS, W**
Driver Assistance Systems	W**
*Information Dissemination Technique	
**Identified at lower level in ITS analysis	
Abbreviation code:	
RFID	
Wireless (W)	
Internet (I)	
Phone (P)	
Radio (R)	
Dynamic Messaging Signs (DMS)	
In-Vehicle Systems (IVS)	
Highway Advisory Radio (HAR)	
In-Terminal Wayside (IT/W)	
Internet/Wireless/Phone (IWP	

Table 1. ITS activities and communication requirements.

The toll collection system using an RFID tag is similar to Figure 3 except that the roadside tag reader and its antenna are part of the tollbooth. When a user's vehicle enters the toll lane, the antenna reads the transponder mounted on the vehicle's windshield or license plate. As the vehicle passes through, the user's account is charged the proper amount. Feedback is provided to the driver by an electronic display or lights. For a vehicle without a transponder, the system identifies a violation and cameras take photos of the vehicle and the license plate for processing.

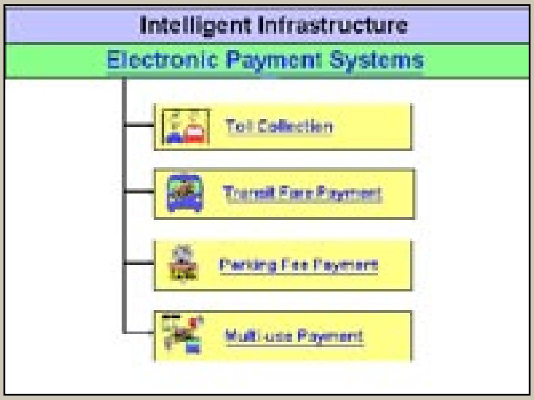
Systems such as Virginia's Smart-Tag or E-Z Pass communicate with the driver through lights at the toll station. A green light means proceed and indicates that the account balance is above the low balance level. The driver can still proceed with a yellow light, but the account balance is at the low balance level and needs to be replenished. A red, blue, or white light indicates that the account is out of funds or a problem with the transponder (including a low battery) so the system cannot be used. The communication is simple but effective since the driver does not slow down to pass through the tollbooth.

A passive RFID tag such as Intermec Technologies' Intellitag mounts on the vehicle's windshield and is primarily used for highway toll collection and for parking lot or gated community access. The 1.81 x 3.11 x 0.51-inch tag is manufactured on a flexible substrate that includes an adhesive for ease of attachment. Operating at a frequency range of 915 MHz, the unit has a read range of 13 feet and both read and write capability.

An active RFID tag, such as e-Plate's e-Tag shown in Figure 5 provides a greater range. This assembly is an integral part of the license plate. Transmitting the vehicle's unique identifier, the self-powered unit has a battery life of up to 10 years. A single reader can identify dozens of e-Plates on vehicles moving at any speed at a distance of up to 100 meters. The secure system has a128-bit encryption option, incremental output shift to stop replay attacks, and built-in anti collision software. The U.K. Department for Transport is testing the RFID plates in a trial that is expected to begin in 2005.

GPS COMMUNICATION

A vehicle's global positioning system (GPS) receiver communicates with several of the 24 satellites for position measurements and navigation in ITS. Recent advancements such as SiRF's SiRFstarIIA target increased



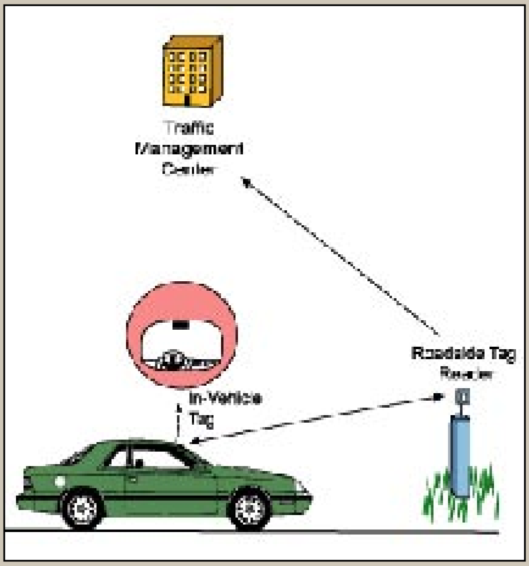


Figure 2. Communication in electronic payments systems.
Figure 3. Vehicle-based traffic surveillance using tags (Courtesy of California Center for Innovative Transportation[2]).

integration for easier interfacing in the vehicle and reducing system cost that should help expand the usage of these systems into more vehicles. The SiRFstarIIA is a system on chip approach that provides more than 65 MIPS of processing power and peripheral control and interfaces. The unit's GPS2A has an ARM720 core, a 12-channel GPS/SBAS (satellite-based augmentation system) tracker engine, a D/A converter and serial audio interfaces for the vehicle's audio system as well as a CAN V2, USB 1.1, two UARTS, 34 general-purpose I/O pins for control/display and system interfaces, and more. This allows the unit to directly control and interface many of the vehicle's GPS-related functions. The chip interfaces to an RFIC, the GRF2i or GRF2i/LP, which has an on-chip VCO and reference oscillator and an integrated LNA.

VEHICLE INFRASTRUCTURE INTEGRATION (VII)

The 1998 Transportation Efficiency Act for the 21st Century (TEA-21) authorized the Intelligent Vehicle Initiative (IVI) as part of the U.S. Department of Transportation's (U.S. DOT) ITS program. IVI's mission is to reduce the number and severity of crashes through driver assistance systems. One of the conclusions from this effort is that achieving major improvements in safety at intersections and in road departure crashes will require some level of communication between vehicles and the transportation infrastructure. To facilitate this communication, the Federal Communications Commission set aside bandwidth for dedicated short-range communications (DSRC) at 5.9 GHz. However, the International Standards Organization (ISO), the European CEN organization, Japan, Korea, and other nations are actively pursuing standards for similar purposes.

By communicating the data from the numerous sensors already installed on vehicles to the infrastructure through DSRC, the Vehicle Infrastructure Integration (VII) coalition expects to make significant progress to reduce the more than 40,000 deaths that occur

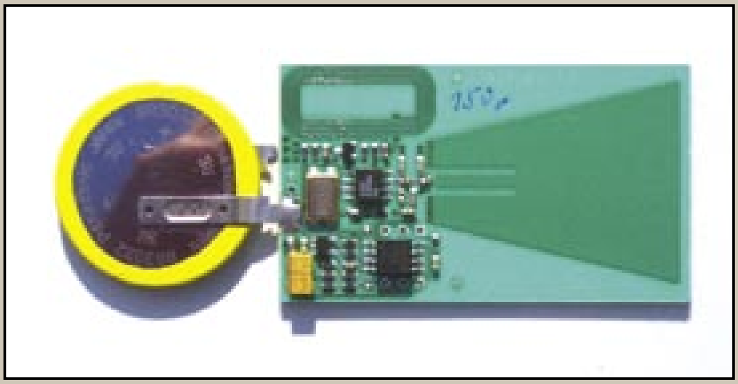
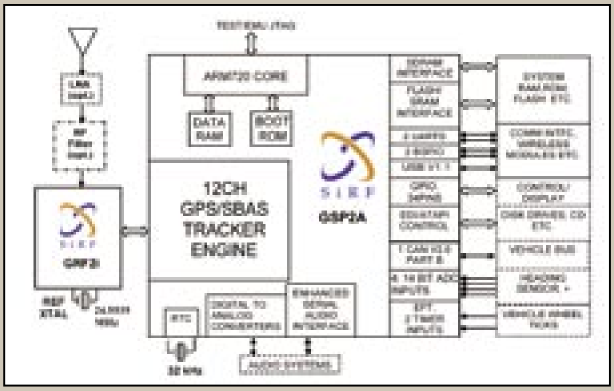


Figure 4. A window-mounted 915 MHz passive RFID tag. Photograph courtesy of Intermec Technologies.
Figure 5. An active RFID tag. The e-Tag mounts on the vehicle's license plate. Courtesy of e-Plate.



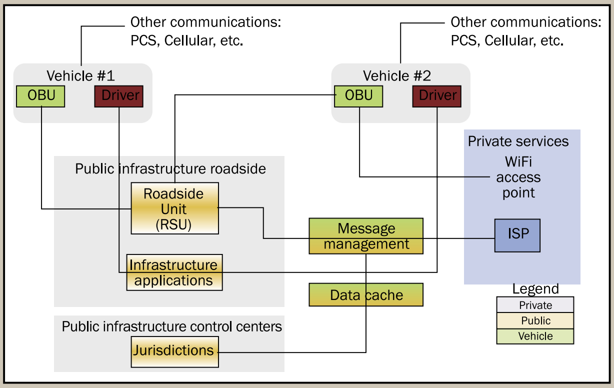


Figure 6. SiRFstarIIA block diagram. The GPS2A and GRF2i interface directly to other vehicle systems and require minimal additional components. Courtesy of SiRF.

Figure 7. VII tier 1 architecture. Courtesy of TransCore[6].

on U.S. roads each year. The collation consists of members from the U.S. DOT, the automotive industry, American Association of State Highway and Transportation Officials (AASHTO) and state DOTs.

The present program plan calls for completing proof of concept activity and system design in the first quarter of 2006 for the DSRC. The fabrication of a DSRC prototype and initial standards should be completed in 2005. These activities clear the way for field operational test plan and deployment plan phases, and, ultimately, a field operational test. Field testing is scheduled to be completed by the end of 2007. In the field test, vehicles will be equipped with the global positioning system (GPS) and a DSRC transceiver, or on-board unit (OBU). Measurements such as input air temperature, status of ABS or traction control, and others will be communicated along with the GPS data--exact position, speed, acceleration and direction of the vehicle. This data is dubbed probe data. The key to communication is the DSRC.

The 5.9 GHz DSRC is a short- to medium-range communications service for public safety and private operations in roadside to vehicle and vehicle to vehicle communications. DSRC provides very high data transfer rates to minimize latency in the communication link in relatively small communication zones. The communication is intended to complement cellular communications. The interaction between vehicles, the public infrastructure, and private services is shown in Figure 7. The 5.9 GHz DSRC system will employ tags and readers. Unlike existing RFID tags that operate in a master-slave arrangement, the DSRC system will be more like a peer-to-peer system, where either end of a link can initiate a transaction. Other differences include a modulation approach to break data into smaller parts rather than sending it in series over a narrow channel.

With 5.9 GHz, the transmission range of the DSRC is up to 1000 meters and the transmission rate is from 6 Mbps to 27 Mbps compared to less than 30 meters range and 0.5 Mbps data rate for 915 MHz RFID tags. Under the overall project management of Highway Electronics' Roger O'Connor, Raytheon, Mark IV, TransCore and Sirit are developing the prototype DSRC unit, while the standards (IEEE 1609 and IEEE 1556 and IEEE 802.11p) are concurrently being developed.

CONCLUSION

Today's RFID and GPS communications have significantly improved traffic flow and added reaction capability to telematics systems in the event of an accident. However, with a Federal Highway Traffic Safety Administration goal to cut road fatalities in the United States by 50% within 10 years, the increased communications capability of DSRC will be required. At the same time, other developments within ITS will advance as well. The combination should provide a vehicle that is much safer, even if it does talk to other cars or to the roadway.

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ABOUT THE AUTHOR

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