Reflecting Tomorrow's Highways Today

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Using radio frequency identification to develop automated vehicle identification systems, Texas Instruments TIRIS has developed and installed several state-of-the-art AVI systems across the country. The systems that I'll discuss briefly were implemented according to the rules established by he California Department of Transportation's Title 21, which stipulates passive backscatter RFID technology for use in electronic toll collection. The installed systems use the 915 MHz ISM band with backscatter reflection and modulated passive reflectors.

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Highway or parking lot?

We all know that congested highways present us with tremendous problems worldwide. Traffic gridlock is a daily phenomenon in most urban areas around the world.

Not surprisingly, the whole notion of smart highways is subject to debate. Especially here in the U.S., the hodgepodge of vendors, materials, construction techniques, circuit designs, et cetera used to “solve” the problems are overwhelming to anyone trying to determine the best long-term solutions at the most affordable cost.

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One Solution—Tollroads

As you know, tollroads are making a comeback. Existing tollroads are being improved. Existing highways are being expanded to include toll lanes, like California's SR91.

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The California Way

California concluded that, given the right technology and strategy, tollroads could make money as well as to gain information about the traffic flow and even help adjust the traffic flow.

State Route 91, known as SR91, is a 10-mile-long stretch of key real estate east of Los Angeles. With 250,000 vehicles per day and a daily 4-hour-long peak, this stretch of concrete is one of America's most congested commuter corridors.

At the end of 1995, four new express lanes were opened for commuters who had subscribed to the FASTRAK Express Lanes system. Texas Instruments and MFS Network Technologies installed the privately financed ETC system.

With a 99% rate of accuracy, the system automatically recognizes the vehicle bearing the transponder tag, and the toll is automatically deducted from the motorist's account.

Another project in Orange County is found on a 5-mile stretch of road between Irvine and Laguna Hills. The ridership projections for the Transportation Corridor Agencies' (TCA) Foothill Corridor project almost immediately passed estimates.

Today, AVI customer "counts" almost meet the goals established for Year 2000. This is 4 years earlier than the projected counts!

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Using variable rates

Without reducing speed, motorists who have already subscribed and installed a transponder tag, can use the express lanes for about $1.75 a trip. However, depending on the hour, rates vary from $2.50 at peak hours to $.25 in low usage hours. These rates can be adjusted in response to traffic volumes as well. Electronic variable message signs, located one mile ahead of each entry point, provide motorists with the current tollrate. To stay in touch with the customer and the source of income, pricing policies are reviewed every few months.

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The SR91 system

Vehicle identification, traffic management, communications, identification of violators, and accounts management, are all part of the SR91 system at the hear of which is the TIRIS AVI system. The SR91 system also incorporates sophisticated technology with the following subsystems:

- Behind the scenes, SR91 uses a Digital Equipment Corp computer system based on a UNIX operating system and an Informix relational database.
- Fiber optic communications for high-speed transmission links between all the video, voice, and data systems
- In-road sensors to manage traffic flow
- Video that constantly monitors the entire highway
- Digitized video to capture vehicle and license plate images of violators
- Variable message signs to advise motorists of up-to-date road and traffic conditions as well as the toll rate
- Variable toll rates depending on road congestion and conditions

- Mobile communications with the California Highway Patrol.

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The Tags

This is the tag that's used for SR91. In this case, the user puts a deposit down at a convenient retail outlet for transponders and account management.

The transponder holds 256 bits of data . Data can include information about the transaction record type, the transponder ID number, the reader ID number, the transaction status code, and the error detection code. Tollroad operators can also specify unique customer data to be encoded and transmitted, such as date, entry and exit points, and distance traveled.

Title 21 requires the transponders to work over ranges of 20 feet or more, capture data from fast-moving cars, and operate at high frequencies.

The way it works, an RFID transponder responds to a query from the SR91 control system. The system asks for the transponder's identity, and the transponder replies by sending a code programmed in its memory. The system searches its database for that identity and grants privileges depending on the status of the ID. This entire process takes less than 4 milliseconds. TIRIS at SR91 identifies up to 12 different classifications or types of vehicles.

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What is RFID Backscatter?

In the backscatter approach, a radio frequency signal is transmitted in a pencil-thin beam to a transponder attached to the windshield or to the exterior of the vehicle. The signal triggers RF emissions that are then reflected—or “scattered” back—to the sending system. In other words, the transponder data wait for the right wave to pick them up so that the data can “surf” back to the reader.

A basic RFID backscatter system includes

A **reader**, the source of the signal. The signal is usually broadcast from a location that can read one reflector (tag) at a time. Here, the reader is part of the antenna system that sits on a gantry over the roadway, one per lane.

The **antenna** directs the beam to the expected reflector, much like you would direct a flashlight beam. It also receives the reflected emission.

The **reflector** is the transponder tag that is mounted on the vehicle. The transponder tag, which contains the identifying data, does nothing except wait for the signal to trigger the release of data. Therefore, it requires very little battery life or maintenance, is more reliable, and is less costly than a transponder that actively transmits its own signal.

The r**eceiver**, which usually sits at roadside, separates the reflector emission from the static emission from all other sources. The roadside unit also houses the **controller** that controls the data protocol of the reader.

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Enhanced features to meet real needs

Given the current battles for bandwidth, it is not surprising that retrofitting at the site is not during installation is not uncommon. For example, one problem that had not surfaced until the projects were well underway resulted from new FCC regulations that shrunk the available ISM band spectrum. This forced Texas Instruments TIRIS to redesign the receiver—a painful process under normal circumstances, but excruciating under accelerated schedules. Short of relying on a crystal ball to see into the future, AVI system providers around the world are faced with similar unpredictable occurrences.

To cope with real-life situations, Texas Instruments implemented extensions to Title 21 that actually improved on the specifications. New features include:

- Lane separation to prevent double-reads and cross-reads between two adjacent lanes.
- Extended message modes and multiple tag data blocks that can be accessed by the reader.
- Data encryption for data exchanged by reader and transponder tag.

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Enhanced features (cont.)

- Read/write capabilities that allow the reader to store and retrieve data from the tag, for example, a transaction timestamp and record of the point where the vehicle entered the tollroad.
- Unique agency code issued to the tag for administrative purposes.
- An acoustic signal telling the driver that a transaction took place.

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Backscatter Advantages

Compared to active technology, some of backscatter technology's advantages include:

- It consumes less power, so the battery life is much longer.
- It defines a more precise read zone. The system more accurately discriminates valid users from violators and it provides accurate readings despite close adjacent lanes.
- It communicates accurately with vehicles maintaining high speed on a limited-access open highway. From an 18-wheeler to a motorcycle, the size or type of vehicle does not prohibit the system from getting information from the tag.
- It reads more capably multiple tags in the interrogation field.
- It works effectively in environments with excessive dirt, dust, moisture, and poor visibility.
- It requires less expensive electronics.

- It allows the smallest possible bandwidth yielding the highest robustness against surrounding RF noise.

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As easy as possible

The greatest benefit of ETC is often going to be convenience. Making highways ‘smart’ ultimately means making it as easy as possible for the user to travel the highways with no impediments. Most users, we believe, would prefer to see toll-collecting as just a blur—an object to go past on the way to their destinations.

As installed AVI systems become more commonplace, the number of suppliers will first balloon and then contract as those with staying power emerge. Standardization from governmental efforts can only assist in the stabilization of the market. But by far the most important ingredients in the mix are experience and ability to adapt. They count in this market.