

Case Study:
Applications of IEEE 802.11b Wireless Standards
in the Realization of a New Service Paradigm
for New Jersey's Garden State Parkway

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Executive Overview:

Established in 1952 by the New Jersey State Legislature, the New Jersey Highway Authority currently owns and operates the Garden State Parkway (GSP), which stretches 173 miles from the New York State line to Cape May, NJ. The Highway Authority generates 80% of its revenue from tolls collected along its route.

The Highway Authority's plans to open 3 new interchanges, as an extension of their current 45 locations, to ease toll-plaza congestion and accommodate demand for expected increased volumes of traffic. Interchange 77 is presently built, but tolls are not being collected, interchange 89 is currently under construction while interchange 69 is currently in the design stage.

The addition of these new interchanges have prompted the NJ Highway Authority to pursue a feasibility study to determine how their technicians could utilize wireless technologies to improve day-to-day operational efficiencies, and improve overall operational integrity of the toll collection system. As envisioned, an estimated 17 technicians could utilize the new wireless technology throughout 45-toll plaza locations – realizing an operational efficiency of nearly 50%. Currently, two technicians are needed to repair improperly aligned cameras and radar systems at each toll plaza facility. (Currently, one technician, located within the administrative building is required to work in synchrony with a second technician, located outside in the toll-lane area.) . Deployment of a wireless access technology could enable one technician to work independently at each toll site to complete requisite maintenance tasks in less time than a two-person team - resulting in a very significant improvement in overall productivity with a commensurate reduction in system down-time.

This theme was pursued by a team of DeVry students to fulfill the requirements of the NCM Capstone Senior Project at DeVry University in North Brunswick, NJ. Information from IEEE Standards documents were used to provide comparisons of data rates, operational frequency bands, range, and power levels associated with the IEEE 802.x suite of standards. DeVry students planned and implemented RF propagation studies to determine workability of one or more IEEE wireless standard options at two toll plaza locations.

Present System

The New Jersey Highway Authority currently has a total of 45-toll plaza locations, and is continually challenged with the difficult task of maintaining and upgrading the 173 mile parkway. Field technicians are responsible for maintaining radar, image acquisition systems, and toll collection machines at each toll plaza location.

Each toll plaza is equipped with a computer based toll collection system, consisting of devices such as lane controllers, servers, workstations, Ethernet LAN equipment and various types of roadway sensors. Of the 45 toll-plaza locations, 15 are supervised and 30 are unsupervised. Locations designated as supervised locations employ a redundant server and a maintenance workstation. The maintenance workstation is either located in a toll recording room, or located in a dedicated stand-alone building. A toll recording room is an equipment room, located within the main administration building. A stand-alone building, (designated as an unoccupied enclosure building), is a separate building located a short distance from the administration building collocated at the toll plaza. Of the 15 supervised locations, there are 12 locations that involve stand alone buildings and 3 locations that contain toll recording rooms. At these 15 supervised locations, no more than two workstations (the plaza supervisor's workstation and the maintenance workstation) are in use at any one time.

The 30 unsupervised locations fall into two categories: primary slaves and secondary slaves. Primary slaves connect into the existing SONET backbone via a router and a SONET multiplexer (MUX). Secondary slaves connect to the primary slaves via fiber, without the use of a router or SONET multiplexer (MUX). Both the primary and secondary slave systems communicate through the main toll plaza. The primary and secondary slaves have a SONET ramp connection, consisting of a SONET LYNX MUX, a Cabletron router, and a Cabletron 24-port switch – which handles all the lane controllers and a terminal server connecting directly into the router.

Toll lane transactions use a personal computer (PC) based system. This PC based system shows the transactions gathered from a lane controller located in the toll lanes. The lane controller records two transactions - cash and EZPass. The information gathered during a transaction is processed and communicated over a fiber backbone to a main controller located in the plaza administration building. The transactions are then distributed in different directions depending on whether they are cash or EZPass. A data base of cash transactions is retained at each toll plaza for local auditing purposes. All EZPass transactions are sent to the customer service center, located in Secaucus, NJ.

On the outskirts of the toll lanes, the NJHA provides microwave antennas that are used for voice and data communications between toll plazas and maintenance facilities. In addition, this microwave link is also used for relaying Ultra High Frequency (UHF) mobile radio communication services for trucks on the road. Table 1.1 lists the radio-based devices that are located within a toll plaza.

Table 1.1 Existing devices that operate on radio frequencies

Devices	Frequencies
EZPass	915 MHz
Doppler Radar	24 GHz
Microwave Antennas	6 GHz
Truck Radios	800 MHz

Equipment Room

The equipment room contains a variety of different components. This equipment ensures that toll lanes function correctly and also provides a systematic way of recording all the functions and transactions throughout the day. The following is a list of the networking devices identified throughout the NJHA toll plazas:

- Router
- 24-port switch
- Power Supply
- OC3 Add/Drop Multiplexer
- Raid Server
- Communication Gear
- Lane Control

Proposal for a New Information Networking Environment

Potential target solutions identified by the student project team included: IEEE 802.11a, IEEE 802.11b, and IEEE 802.11g. IEEE Standards documents were used to provide comparisons of data rates, operational frequency bands, range, and transmit/receive power levels.

RF propagation data gathered from the wireless pilot conducted at the Raritan South toll plaza demonstrates that the IEEE 802.11b wireless LAN technology can be effective and efficient in a toll plaza environment. Currently, two equipment technicians are needed to repair improperly aligned cameras and unplugged radar systems at each toll plaza facility. Incorporating IEEE 802.11b wireless technology into the Ethernet LAN will eliminate the need for a second technician and enable one technician to work independently at each site and complete requisite maintenance tasks in less time resulting in a very significant improvement in overall productivity with a commensurate reduction in system down-time.

Wireless mobile access to network resources will increase efficient communication from a toll booth to a centralized server.

IEEE 802.11b wireless technology fulfills the maximum toll plaza roadway distance requirements and operational needs of equipment technicians. IEEE 802.11b technology is also easy to manage and scalable enough to support multiple users. The security options built into the

IEEE 802.11b standard such as WEP and MAC address filtering will adequately protect against potential attacks to the network.

The NCM Project Team suggests implementing IEEE 802.11b wireless technology at one or two toll plaza sites to pilot the system design, before rolling it out to all 45-toll plazas.

To address the issue of wireless signal quality and connectivity, the student-team suggests the following:

- At each toll plaza facility conduct a site survey that includes spectrum analyzer tests to determine proper placement of access points and detect potential co-channel interference.
- In multi-branch lane toll plazas, install an external omni directional antenna mounted to a mast on the rooftop of toll plazas to provide seamless roaming coverage within branch lanes. In multi branch toll plazas that have a taller administration building in front of the UE building, install an external omni directional antenna mounted to a mast on the rooftop to provide seamless signal coverage.
- In single branch lane toll plazas with distances less than 300 feet, one access point mounted on the wall or ceiling inside the equipment room should provide seamless roaming coverage within toll lanes. For single branch toll plazas with distances greater than 300 feet, install an external directional antenna mounted to a mast on the plaza rooftop to provide seamless roaming frequency coverage within toll lanes.

The data gathered from the wireless pilot demonstrates that IEEE 802.11b wireless technology can be easily integrated into the toll plaza environment. Wireless technology clearly increases efficient communication from a toll booth to a centralized server. Equipment technicians will be able to repair toll lane problems on the fly throughout 45-toll plaza locations. Mobile access to network resources eliminates the need of a second technician and enables technicians to complete daily tasks faster; increasing productivity, and creating a more efficient workplace environment. Garden State Parkway customers will also benefit because the faster technicians can make adjustments out in the toll lanes, the quicker they will be able to re-open troubled toll lanes, alleviating traffic on the Garden State Parkway. In addition, the installation of a wireless LAN technology eliminates the need for a costly cable installation.

Comments on Deployment of Future IEEE 802.11b Wireless Systems

The performance of an indoor/outdoor wireless LAN in a toll plaza environment can be plagued by propagation issues associated with co-channel interference, Rayleigh and/or Rician fading and signal shadowing. Therefore, a site survey that includes spectrum analyzer tests should be performed at each toll plaza location to identify amplitudes of unwanted radio signals that could potentially interfere with the wireless LAN signals. Antenna diversity techniques will likely minimize the impact of signal delay spread and reduce impairments associated with multi-path propagation at toll plazas that experience heavy vehicular traffic.

Summary of Results and Next Step

Incorporating IEEE 802.11b WLAN technology as an extension to the local Ethernet LAN will enable efficient communication from a toll booth to a centralized server. Mobile access to the toll data system will eliminate the need for a second technician when repairing improperly aligned cameras and unplugged radar sensors; therefore, increasing the efficiency and effectiveness of the technical team.

Furthermore, The NJHA must allow for network expansion. As a result, stacking the existing 24-port Cabletron switch with a 5-port switch will accommodate additional wireless access points and future network expansion. The results of this feasibility study indicate that IEEE 802.11b wireless LAN technology will be effective in a toll plaza environment. The results from the wireless pilot conducted at Raritan South toll plaza verify the network performance that equipment technicians will experience. The pilot demonstrated adequate signal quality with 100KB file transfer time intervals of one second or less, and seamless frequency coverage within a toll plaza environment. IEEE 802.11b satisfies the Highway Authority's 600 feet toll plaza roadway requirements and provides seamless frequency coverage within toll lanes.

The wireless pilot test in this feasibility study was performed between 9:00a.m and 1:00p.m, during off-peak traffic hours. Future wireless pilots should be conducted during peak traffic hours to ensure the recommended IEEE 802.11b wireless LAN will satisfy operational requirements under heavy traffic conditions where there is a higher risk of significant multi-path propagation that could result in severe signal fading in the 2.4GHz band.