Images courtesy Florida Department of Transportation

FDOT Upgrades for Interoperability

The Florida Department of Transportation (FDOT) is leveraging networking technology to expand operations and boost interoperability.

By Randy Pierce, Brian Kopp and Roger Madden

The Florida Department of Transportation (FDOT) has used low-band VHF analog radios operating between 45 and 47 MHz to provide communications with its road crews for more than 50 years. Throughout the 20th century, each FDOT district operated semi-autonomously and maintained its assigned area roadways by dispatching crews from a group of district maintenance yards that were usually county centric. FDOT operates statewide using seven geographic districts and the Florida Turnpike Enterprise (FTE).

In addition to FDOT's second-generation radio network, the agency is leveraging networking technology to provide desired new interoperability features that will help expand its operational envelope among its own internal districts and with partner public-safety agencies, such as the Florida Division of Emergency Management.

When FDOT first deployed two-way voice radios, the initial system used a set of simplex channels that permitted yard dispatchers to communicate with their own road crew vehicles. Simplex base station radios with antennas mounted at 30 to 60 feet in each yard permitted the yard dispatcher to communicate with vehicles out to a range of approximately 10 – 15 miles.

Because there were multiple yards in each district, this configuration performed relatively well. However, sharing information between yards in a district required the district radio operators to pass traffic between each other. This sometimes involved several dispatchers and mobile radio operators in between. The telephone was always an alternative, although rural locations sometimes suffered from telephone outages.

Mobile-to-mobile (M2M) and base-to-mobile (B2M) communications were all simplex. FDOT had four frequencies available statewide and devised a geographic frequency reuse plan that minimized the chance of interference between districts. All

200 – 500 vehicles within a district shared the same frequency. In the early 1990s, the 2,000 – 3,000 mobile radios statewide were replaced with multichannel radios that supported tone squelch, allowing some increased frequency use in each district.

Second-Generation Network

In the early 2000s, FDOT's second-generation mobile voice radio communications system was designed to give each district complete wide-area mobile voice radio coverage. In this design configuration, any FDOT vehicle, yard office or district headquarters office can communicate with each other anywhere in the district. The approach required an entire new statewide radio system. Not only were all the radios replaced, but a communications backhaul network was implemented to support the configuration.

Fortunately, FDOT used its statewide infrastructure of intelligent transportation system (ITS) microwave network towers to provide the backhaul network. The towers are all self-supporting and were designed for additional future ITS application capacity. They are located about 20 miles apart along Florida interstates and were originally installed for the motorist aid callbox system. The towers were used to deploy new low-band VHF radio antennas in each district at much higher heights than 60 feet and with greater density than the current number of yards in a district.

FDOT implemented an analog multicast voice radio repeater system in each district for its second-generation network. Multicast provides most of the same benefits of simulcast, but does not require the same precision in transmitter synchronization, so it is less expensive. Each district's radio system operates as a stand-alone radio network. In this configuration, multiple repeaters are installed throughout a district and linked to a district analog voter that is strategically located within the district. Microwave links connect the individual repeaters to the voter. All of the repeaters in a district share a common talk-in (receive) frequency. and unique talk-out (transmit) frequencies. A vehicle radio operator changes channels according to the nearest repeater site. When the vehicle radio transmits, all of the nearby repeaters receive the signal and send it over the microwave system to the district voter.

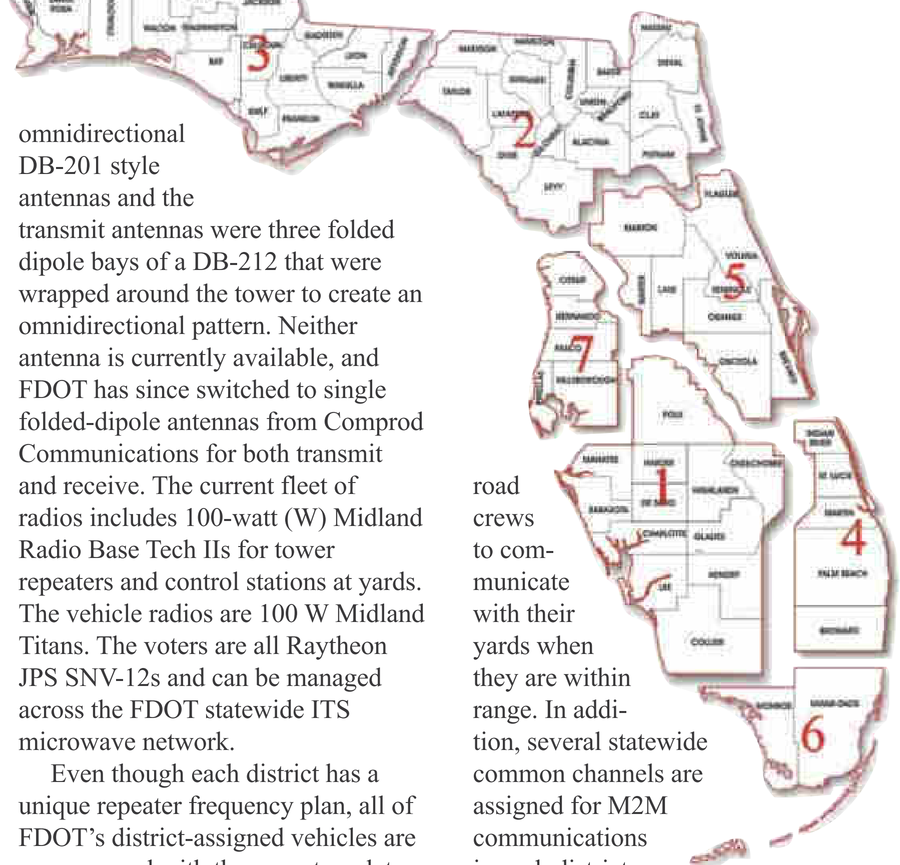
Once the voter determines which repeater site is receiving the best audio, it sends that copy of the received audio back out over the microwave network to each repeater transmitter. The repeaters have unique transmit frequencies, and all of them transmit simultaneously in the district. The vehicle radio channel selection determines which site the mobile radio will hear. All of the repeater channels in a district vehicle radio have the same transmit frequency. Within a district, changing repeater channels on the vehicle radio only changes which repeater site the vehicle radio is listening to.

To ensure the repeater system encounters minimal interference on low band, a band known for its long-range ducting properties, FDOT implemented Digital Coded Squelch (DCS) on all repeater inputs and outputs. Each district is assigned a unique transmit DCS code and a unique receive DCS code. The repeater receive codes are also inverted, again, to minimize the risk of interference. The repeaters are implemented as full-duplex radios using separate transmit and receive antennas vertically separated on the microwave towers. Each antenna system includes a two-cavity pass-reject filter. These cavities are 7-feet tall and require special planning for placement in a typical telecommunications shelter.

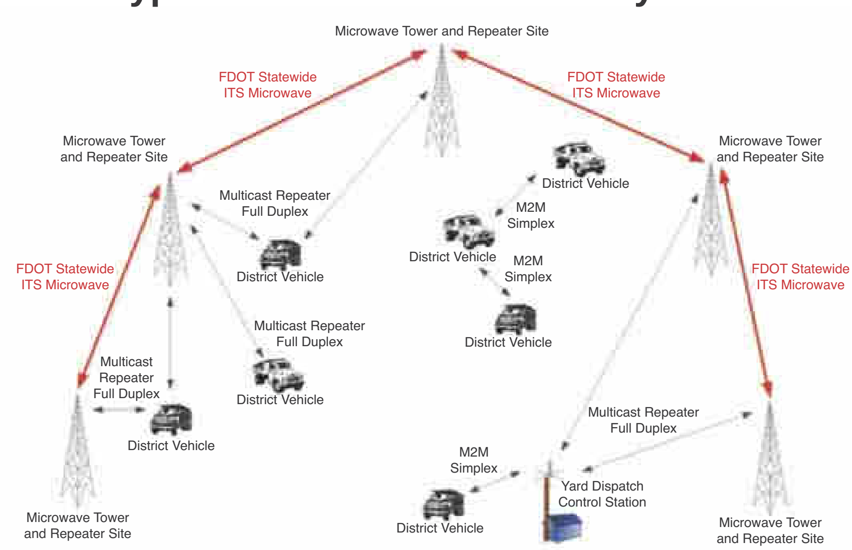
In some locations, FDOT has elected to switch to much smaller, rack-mounted high-Q filters, made by Fiplex Communications, to save space. In either case, with the filters and vertical separation, FDOT can achieve at least 80 decibels (dB) of isolation between transmit and receive frequencies. The receive antennas are typically mounted at the top of the microwave tower, and the transmit antennas are mounted below them. Originally, the receive antennas were omnidirectional DB-201 style antennas and the transmit antennas were three folded dipole bays of a DB-212 that were wrapped around the tower to create an omnidirectional pattern. Neither antenna is currently available, and FDOT has since switched to single folded-dipole antennas from Comprod Communications for both transmit and receive. The current fleet of radios includes 100-watt (W) Midland Radio Base Tech IIs for tower repeaters and control stations at yards. The vehicle radios are 100 W Midland Titans. The voters are all Raytheon JPS SNV-12s and can be managed across the FDOT statewide ITS microwave network.

Even though each district has a unique repeater frequency plan, all of FDOT's district-assigned vehicles are programmed with the same template. This means that District 2 road crew vehicles, for instance, could support an emergency response in neighboring District 5 or in any other district, without reprogramming and without a vehicle equipment change out. The template also includes a unique local district simplex frequency to permit road crews to communicate with their yards when they are within range. In addition, several statewide common channels are assigned for M2M communications in each district and for other needs. Various tone coded squelch assignments are associated with these simplex channels.

FDOT Districts

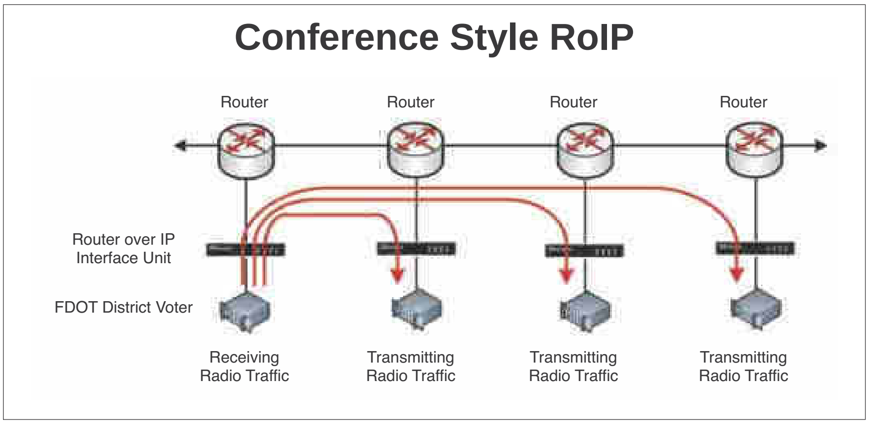


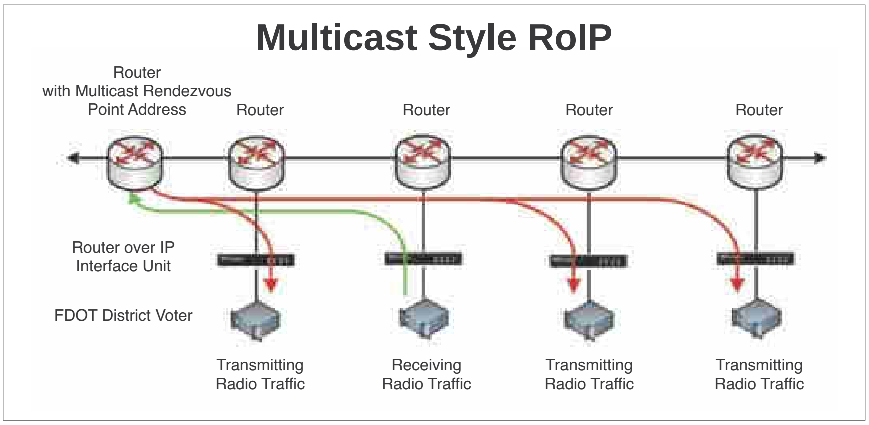
Typical FDOT District Radio System



Interoperability Features

The second-generation radio system also addressed issues related to the reliability of public utilities, especially in rural locations or during severe weather events. The system was built using FDOT's own microwave network to tie together district repeater sites with a district voter. Leased commercial telecommunications circuits were not necessary. This not only saves on operational expenses, but also ensures that FDOT is fully aware of any issues regarding network connectivity. In rural locations, where most FDOT yard facilities and microwave towers are, and during severe weather events, commercial power can be unreliable. The mobile voice radio network is deployed at FDOT's microwave network sites where both backup batteries and propane generators with





high-capacity underground tanks are installed. These special features help ensure the system is always operational, especially when it is needed most — before, during and after severe weather events.

During the past 10 years, FDOT has completed most of the statewide deployment of this second-generation radio communications system. It is essentially fully operational with only a few isolated coverage gaps that are off the interstate rights of way remaining. These gap locations are being addressed on a site-by-site basis with tools including licensed microwave spurs at 960 MHz and tower-sharing agreements with partner agencies. The districts have begun to use the new radio system and have reduced cellphone use by switching some internal communications to the new system. As the districts have reduced the number of yards they operate, centralizing maintenance, the system configuration has proved to be a good fit.

A new twist in the FDOT district-centric radio system configuration is the recent internal mandate to support interoperable communications among the districts, state public-safety partners and FTE, which operates a separate, stand-alone UHF radio network. For the past three years, FDOT has been investigating various telecommunications network technologies that can support interoperable communications while leveraging the investment in FDOT's second-generation mobile voice radio communications system. The most promising technology — VoIP — brings FDOT's analog voice communications into the world of computer networks. When voice radios, not voice telephones, are the source of the analog voice communications, the technology is usually called radio over IP (RoIP).

Whether it is VoIP or RoIP, the general idea is to convert the analog voice and any necessary control signals to digital form where they can be sent over a computer network and re-created at the far end as analog voice again. The use of the computer network in between permits interoperability to be achieved without significant difficulty. The statewide ITS network makes this possible for FDOT. What is different for interoperability is that the statewide ITS network can easily interconnect the digitized voice radio traffic of one district with that of another.

To deploy this concept in an efficient way, FDOT has adopted the use of a networking protocol called multicast — not to be confused with radio multicasting as discussed earlier. This protocol ensures that even though many users may be engaged in a voice conversation together, the bandwidth of the statewide ITS network is still used efficiently. In traditional conference-style VoIP and RoIP, a digitized copy of the voice conversation is sent over the network to each user. If the number of users doubles, the network bandwidth needed must double. With multicast, only one copy of the conversation is sent from a common rendezvous point to the users, and they all share it, no matter how many end users there are.

To further explain how multicast RoIP works for FDOT, consider an example network segment where several voters are interfaced with RoIP interface units connected to the FDOT statewide ITS network — the complete ITS network comprises both fiber and microwave. Through these interfaces, the radio traffic from any district can be cross connected with that of another district by enabling or disabling IP ports or the interface units themselves. The difference between conference-style RoIP and multicast RoIP is illustrated in the figures to the left. In the multicast example, the shared outbound copy of the digitized audio arrives at all of the voter locations that are to transmit the audio.

The use of multicast to support interoperable mobile voice radio communications is now a reality for FDOT. The agency has successfully tested separate multicast RoIP networks using the Raytheon JPS NXU-2A and the Omnitronics IPR-110+. In fall 2015, an interoperability connection was established between FDOT Districts 2 and 3 and the state of Florida emergency operations center (EOC). With this connectivity, an FDOT road crew working in Jacksonville to assess a damaged bridge after a hurricane can be monitored in real time by the Districts 2 and 3 headquarters, the FDOT central office and the state EOC. This level of simultaneous situational awareness will ensure, for instance, that resources are positioned as soon as possible and that the impact on traffic flow in adjacent districts can be assessed quickly. Within the first few months of 2016, it is anticipated that both District 5 and the FTE UHF radio network will join this first mobile voice radio communications system interoperability network. To simplify the name, FDOT coined the term Statewide Radio Bridging Network (SRBnet).

This new version of FDOT's mobile voice radio communications system adds an important interoperability feature to the communications tools available to the districts. The technological achievements of the second-generation mobile voice radio communications system will continue to support FDOT's operations, but with this new, generation 2.5, interoperable version of the system, FDOT can more easily support the expanding impacts of modern, intelligent transportation. ■

Fast Fact

The Florida State Road Department, the agency that preceded FDOT, was formed in 1915 by the state legislature.

Randy Pierce, Florida Department of Transportation (FDOT) telecommunications administrator, started with FDOT in 2006 after working as a communications engineer for the Florida Department of Management Services overseeing EMS and emergency support service (ESF-2) for 16 years. Pierce served in the U.S. Navy and the U.S. Navy Reserves, retiring in 2003 after 28 years of service. He holds an extra class amateur license (AG4UU).

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