US Department
of Transportation

**Federal Railroad
Administration**

Research Results

**RR08-34
December 2008**

Wireless Passenger Communication System

SUMMARY

Equipping passenger trains with a back-up public address (PA) communication system for use by the train crew to communicate with passengers is feasible. In the event of an emergency (collision, derailment, etc.) in which the communication trainline circuit is broken, passenger rail vehicles equipped with PA/intercom systems lose the capability for communications throughout the entire train. The crew must be able to communicate to passengers to reduce confusion, curtail panic, and prevent circumstances which could result in injuries or further danger to passenger and crew.

The Federal Railroad Administration (FRA) funded a Small Business Innovative Research (SBIR) project that investigated the feasibility of developing and equipping passenger rail cars with a back-up communication system that is effective in the event of a break or interruption in the communication trainline. This back-up communication system would be powered independently of the car battery system and would allow for 1 hr of talk time from the initial break in the trainline circuit. The system would be accessible via a handset so that crew, as well as emergency responders, would be able to communicate instructions to the passengers from inside and outside of the train, within a given range.

DFuzion, Inc. was selected to research the development of its proposed Wireless Passenger Communications System (WPCS). WPCS utilizes 802.11x Wi-Fi mesh technology to create a fault tolerant, self-healing, secure, wireless mobile mesh network throughout the train consist. WPCS uses a wireless Voice over Internet Protocol (VoIP) hand held device for communication to the in-car wireless network access points, and ultimately the passengers. WPCS is powered by rechargeable DC sources that are trickle charged from the primary train power, so that the system continues to operate in the event of a loss of primary train power. The WPCS concept's feasibility has been verified through several computer simulations (Figure 1) that confirm that the wireless mesh network as a whole would continue to operate in the event of a severed communication trainline network and damaged mesh network nodes.

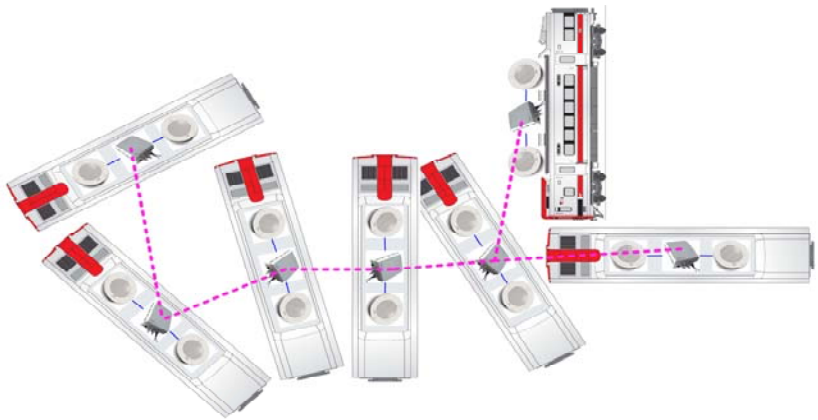

Figure 1: Wireless Passenger Communication System Car-to-Car Network

BACKGROUND

The Federal Railroad Administration (FRA) funds research for the enhancement of safety on passenger trains. Utilizing the Department of Transportation Small Business Innovative Research (SBIR) program, FRA funded a research project to investigate the feasibility of equipping passenger trains with a back-up communication system that would be used when the trainline communication network is compromised. DFuzion, Inc. conducted the research and developed the concept of the Wireless Passenger Communication System (WPCS) that would allow the train crew and emergency responders to keep the passengers informed in emergencies and provide guidance to all passengers in the event that the train needs to be evacuated.

OBJECTIVE

The objective of this SBIR research effort was to investigate the feasibility of designing and developing concepts for a backup public address (PA) communication system for passenger rail cars. This system would be effective in the event of a break or interruption in the communication trainline. The system would be independently powered and allow for 1 hr of talk time from the initial break in the communication trainline. The system would allow access to the communication network via a handset or train radio for the train crew.

APPROACH

A comprehensive technology survey of existing and emerging technologies that met FRA's requirements of a backup communications system was conducted. Technologies surveyed related to communication protocols, power systems, system controllers, transducers, audio amplifiers, radios, Wi-Fi and VoIP handsets, and more.

Working with industry and FRA subject matter experts, a set of preliminary design requirements and specifications for the WPCS prototype design was developed. The WPCS design integrates the following functional components:

- Secure mobile wireless mesh network,
- Audio transducers,
- Wireless handheld audio devices,
- Configuration and management software,
- Power and vehicle interfaces.

The WPCS secure mobile wireless mesh network incorporates 802.11x Wi-Fi communications and features fault tolerance, self-healing and self-configuration. This enables the WPCS to operate even when parts of the system are damaged. Wi-Fi technology has been proven in the rail environment, even in tunnels. WPCS mesh network components include wireless access points, mesh nodes, and radio frequency antennas. WPCS employs internet protocol (IP) audio distribution to transmit audio over the in-car wireless mesh network.

The crew can deliver audio messages via the WPCS wireless handheld audio devices. Transducers will convert these messages to an analog signal before amplifying the message and broadcasting it into the appropriate rail car. The WPCS wireless handheld devices provide access to the WPCS configuration and management software, and discover and assign IP addresses to the loudspeakers/intercom on the local train network. Figure 2 shows the configuration and operation of the WPCS system.

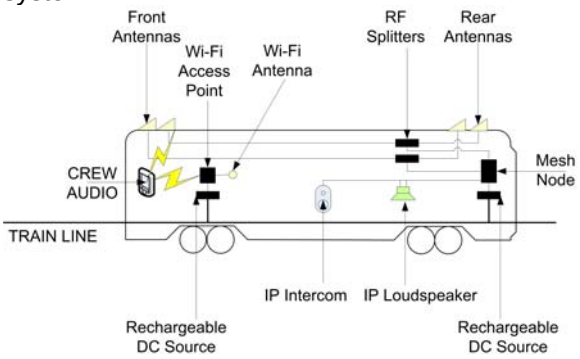

Figure 2: Overview of Wireless Passenger Communication System

The WPCS configuration and management software allows for built-in testing, auto diagnostics, and system management. Diagnostic checking would determine the number and status of transducers connected to the network as well as the status of the rechargeable DC

power source for each node. Once the system diagnostic check has been completed, the train may be cleared for departure.

The WPCS is powered by a rechargeable DC power source such as battery packs or supercapacitors. The DC sources are trickle charged from the train's main power source during normal operations. When primary train sources fail, the WPCS components operate exclusively from their DC sources. When the vehicles are not operating, the WPCS components enter a sleep mode to conserve power.

The WPCS will exist and operate in both wired and wireless modes to facilitate the highest degree of network reliability in the rail environment, which is where cars are switched frequently from train to train and where trains may operate side by side. At the beginning of the day's run, the system on each train can be configured in wired discovery mode. The system can then be switched to wireless operations at any point thereafter. Each train operates on its own secure wireless local network to prevent interference from adjacent trains equipped with similar WPCS.

All WPCS installations on passenger rail cars will be identified as members of the WPCS "forest." Each lead vehicle owned by an operating authority will have a mesh server node installed. The server node will be assigned a specific service set identifier (known as SSID), identifying it as the "local train network." Multiple, redundant server nodes may be configured on the consist to ensure system survivability during a catastrophic event. Any car connected to any vehicle with a server node during daily operations will become a member of the local train network during initial system configuration. Each in-car IP loudspeaker and intercom is connected to a mesh node and can be recognized as a unique IP address on the local train network. Consequently, as new cars are joined to the train and new mesh nodes join the local train network, the system can identify (during wired discovery mode) the new loudspeakers/intercoms and assign them an IP address applicable for operating on the local WPCS train network. Prior to train departure, the train crew will use the WPCS handheld device to test the WPCS components of its local network.

The WPCS will always be in standby mode when used as a secondary wireless communication system. The system may be brought out of the standby mode by the loss of trainline connectivity or manually by crew members with the WPCS handheld mobile device. Once the WPCS has engaged, the crew may use the mobile handheld device to communicate to all train passengers from inside or outside the train. The mobile device uses a lightweight VoIP client to communicate to the wireless mesh network via Wi-Fi access point. During an event, this communication is broadcasted to all surviving loudspeakers/ intercoms (IP addresses) for passengers to hear.

Inherent to mesh network technology and by design, the WPCS can continue to function even if most of the mesh nodes and loudspeakers or intercoms are not functioning. WPCS is designed to have no single failure point and allows network access from multiple handheld mobile devices in the event the primary train crew is incapacitated. The use of multiple redundant Wi-Fi access points throughout the consist offers the ability to establish wireless communications at any point inside or outside the train consist.

The WPCS is designed with multiple layers of security. The access nodes may be encrypted against malicious use. The WPCS may also employ the physical-layer security provided by a 4.9 GHz band, utilized by emergency responders.

RESULTS

DFuzion performed a proof-of-concept computer simulation to test the WPCS using the Network Simulator 2 (known as NS-2) with iNSpect, a visualization and analysis tool that can be used for wireless visualizations. The proof of concept simulation was performed for a 6-car train, a 12-car train, and a 20-car train. The simulations were run with one wireless mesh node placed in the middle of each rail car. In the simulations, it was assumed that the cars were derailed and a variable number of the wireless nodes were damaged or were unable to join the wireless mesh network. A message was sent from the

"crew node" to the local car WPCS network. In the simulation, the mesh network was able to reconfigure itself and transmit the message being sent, bypassing the damaged nodes. Figure 3 depicts a scenario where, of the 20 available wireless mesh nodes, 9 nodes are broken and 11 nodes are functioning. As shown, even with almost half of the wireless mesh nodes removed from the network, the nodes are intelligent enough to route messages from Node 0 to the last node. This simulation demonstrates the survivability of the wireless mesh network in a catastrophic event.

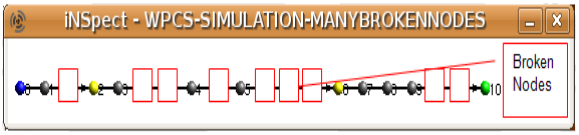

Figure 3: WPCS Proof-of-Concept Simulation

The proof-of-concept simulations validate that WPCS provides minimal delay in audio transmissions, ensuring that the passengers are receiving the latest news from the crew. The simulations also validate that the WPCS is self-configuring and self-healing after a catastrophic incident.

CONCLUSION

Equipping passenger rail cars with a secondary PA communication system for utilization during incidents in which the trainline communication network is severed is feasible. DFuzion, Inc. developed the Wireless Passenger Communication System concept and established its feasibility. The WPCS is a secure, fault tolerant, self-healing wireless mesh network that is based on IEEE 802.11x Wi-Fi technology. The WPCS is independently powered for 1 hr of talk time, from the initial break in communication trainline. The system is accessible to the crew from mobile handheld devices. The proof-of-concept simulations conducted demonstrated that WPCS can maintain a working communication network in the event of a break in the communication network trainline on rail cars.

FUTURE WORK

A prototype of the WPCS may be developed and demonstrated in the commuter rail environment. The communication network trainline of a WPCS-equipped commuter will be severed to test the effectiveness of WPCS. Once the WPCS is proven in the rail environment, the system could be expanded to offer emergency communication capability to the hearing disabled passengers via wireless signage. Future revisions of WPCS will add bi-directional (passenger-to-crew) communications. The WPCS will also have the ability for zoning to allow the train crew the ability to send specific instructions to specific rail cars.

ACKNOWLEDGEMENT

DFuzion, Inc. conducted the research on behalf of FRA. The principal investigator for DFuzion, Inc. was Robert J. Borgovini.

CONTACT INFORMATION

Melissa Shurland
Program Manager
Federal Railroad Administration
Office of Research and Development
1200 New Jersey Ave, SE - Mail Stop 20
Washington, DC 20590
(202) 493-1316
melissa.shurland@dot.gov

Eloy Martinez
Program Manager
Federal Railroad Administration
Office of Research and Development
1200 New Jersey Ave, SE - Mail Stop 20
Washington, DC 20590
202-493-6348
eloy.martinez@dot.gov

Keywords

Public address (PA), communication, secondary, trainline network, wireless, passenger safety, mesh network, emergency