Telecommunications and Information Technology Planning

The telecommunications and information technology planning function represents the highest-level system or network perspective of the Institute. This work includes planning and analyzing existing, new, and proposed telecommunications and information technology systems, especially networks, to improve efficiency and enhance performance and reliability. ITS performs this work for both wireline and wireless applications. This encompasses work frequently referred to in industry as "systems engineering."

All phases of strategic and tactical planning are conducted under this work area, as well as problem solving and actual implementation engineering. ITS engineers identify users' functional requirements and translate them into technical specifications. Telecommunication system designs, network services, and access technologies are analyzed, as well as information technologies (including Internet and Internet-related schemes).

Following is a summary of significant activities that occurred in the area of telecommunications and IT planning during FY 2008. Telecommunications interoperability relating to Public Safety communications remains the largest program area.

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Areas of Emphasis

Public Safety Communications Interoperability One of the largest programs at the Institute conducts broad-based technical efforts aimed at facilitating communications interoperability and information-sharing among wireless and IT systems within the public safety community. These activities are funded by the National Institute of Standards and Technology's Office of Law Enforcement Standards Program and the Department of Homeland Security, and are planned and performed with coordination among local, State, tribal, and Federal practitioners. Technical thrusts within the program, described in separate sections on the following pages, include:

Project 25 Standards Development

Project 25 Compliance Assessment Program

Public Safety Audio Quality

Public Safety Interoperability Test Tools

Emergency Telecommunications Service (ETS) Standards Development The Institute develops and verifies ETS Recommendations for ITU-T Study Group 9. The project is funded by the Department of Homeland Security's National Communications System.

Railroad Telecommunication Study The Institute assists the Association of American Railroads' frequency management office in developing their narrowband VHF channel plan and wideband-to-narrowband migration strategy for the U.S. railroads. The study is funded by the Federal Railroad Administration.

Multimedia Quality Research The Institute characterizes and analyzes the fundamental aspects of multimedia quality assessment. A primary goal of this research is to develop an algorithmic system to objectively assess multimedia quality by combining audio quality, video quality, and audiovisual synchronization information. The project is funded by NTIA.

Wireless Network Measurement Methods The Institute studies the performance characteristics of wireless networks and attempts to standardize measurement methods in order to better understand the applicability of different types of wireless networks to specific user requirements. The project is funded by NTIA.

Project 25 Standards Development

Outputs

- Technical requirements upon which Project 25 digital radio and system standards are developed.
- Technical standards contributions for conformance, performance, and interoperability testing of Project 25 radios and systems.
- Formal participation in the groups responsible for Project 25 standards development.

Project 25 (P25) is a partnership between the public safety communications community and industry manufacturers whose goal is the publication of standards for commercial interoperable land mobile radio (LMR) equipment (i.e., digital radios and infrastructure) that satisfies the complex and evolving needs of Federal, State, local, and tribal public safety communication users. Project 25 has been recognized through recent legislative and related actions as the preferred equipment and systems solution for LMR public safety users. The use of competitively offered P25 equipment continues to grow, with broad adoption by the more than 50,000 public safety organizations in the U.S. and by public safety organizations in over 54 countries. An example of a Federal user of P25 equipment and systems is the U.S. Department of the Interior, which owns and operates over 63,000 P25 radios.

ITS began advancing the development of P25 standards, which are approved and published by the ANSI-accredited Telecommunications Industry Association (TIA), shortly after the establishment of Project 25 approximately 20 years ago. Over the last five years ITS has supported the accelerated development of P25 standards to meet increasing user needs for functionally enhanced P25 equipment and systems, and to satisfy Congressional mandates concerning allocation of Federal funding for P25-compliant equipment and systems. In FY 2008, ITS continued its efforts to (1) assist the development of technical requirements for P25 standards; (2) propose technical approaches for the standardized testing of the conformance, performance, and interoperability of equipment implementing P25 interfaces; and (3) formally participate as user representatives in the P25 standards development process through focused technical, leadership, and organizational involvement.

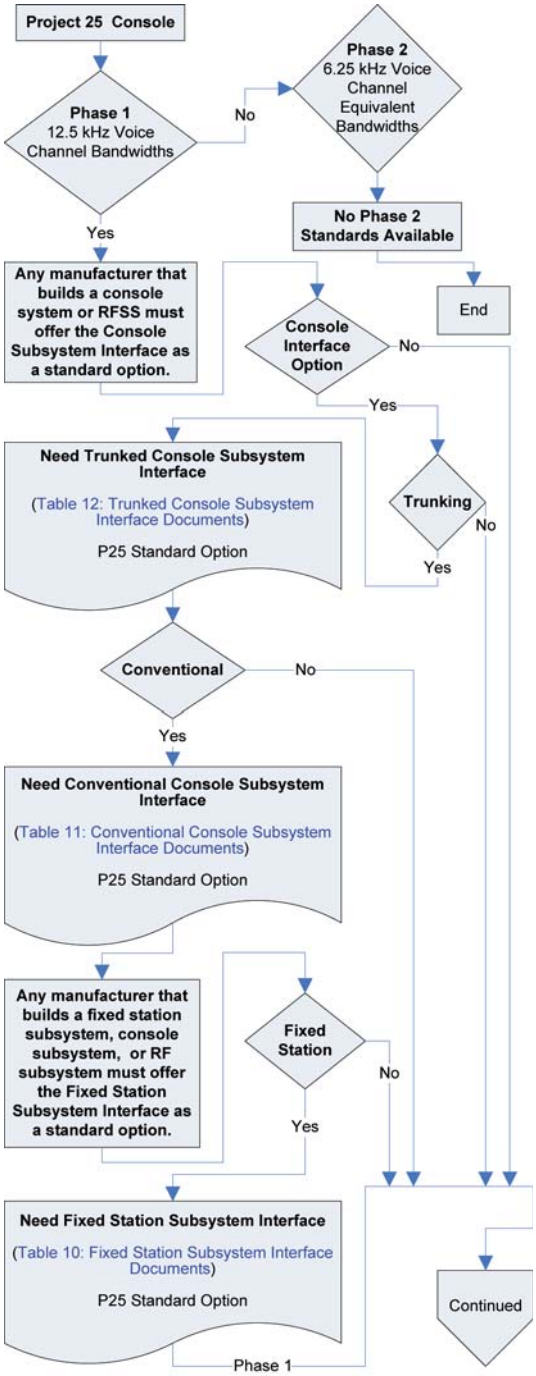
Of particular importance during FY 2008 was ITS involvement that directly assisted the approval of new P25 standards for the Inter-RF Subsystem Interface (ISSI) and other P25 interfaces recognized by Congress as critical to complete in the near-term. ITS efforts over several fiscal years contributed directly to the approval of a precedent-setting approach that defines P25 standardized tests used to assess the conformance of equipment that implements trunked voice services using the ISSI. ITS has implemented these tests as part of its ISSI Test Tool (ITT). ITS involvement also directly contributed to the approval of a new ISSI standard that specifies the test procedures and performance specification of equipment that implements trunked voice services using the Console Subsystem Interface (CSSI). The CSSI standards development support effort built upon the essential technical leadership role ITS played in the development of ISSI measurement methods and performance recommendations standards published in early 2007.

Building on its FY 2007 efforts, in FY 2008 ITS submitted several significant technical contributions proposing practical approaches for assessing interoperability of equipment implementing the ISSI. The ISSI is the most important interface in supporting multi-agency use of P25 radios across different jurisdictions on a wide-area basis. ITS' technical approaches have been generally adopted, with the result that the ISSI interoperability test procedures standard is being rapidly advanced and is planned for completion in 2009. The publication of ISSI conformance, performance, and interoperability test standards will enable the subsequent completion of ISSI compliance test procedures in 2009. These compliance documents will enable ISSI equipment to be offered and procured in accordance with the P25 Compliance Assessment Program (P25 CAP).

During FY 2008, ITS leadership in the P25 User Needs Subcommittee (P25 UNS) continued to support the drafting of an updated P25 Statement of Requirements (P25 SoR), which is expected for approval in October 2008. Other examples of ITS' technical involvement in P25 during FY 2008 include several contributions supporting the development of the next generation P25 Common Air Interface (CAI), the Two-Slot Time Division Multiple Access (TDMA) standard, which is urgently needed to satisfy public safety and impending

regulatory requirements for more efficient use of limited radio spectrum. Integral to all ITS activities supporting the development of P25 standards is the conduct of formal P25 voting activities on behalf of ITS and its sponsors, which requires extensive committee involvement and associated coordination activities. During FY 2008, numerous letter ballot comments were submitted that enabled resolutions to be accomplished consistent with ITS and sponsor objectives. A significant number of P25 standards were completed, including 19 standards associated with the ISSI and other critical P25 interfaces.

ITS continues its outreach efforts to promote development and use of P25 standards, and to increase participation in the P25 standards process. For example, ITS was invited to organize a panel discussion on P25 standards at a major conference on radio communications held by the U.S. Department of the Interior and the U.S. Department of Agriculture. At this joint DOI/USDA radio workshop, held in February 2008, ITS conducted a session that summarized the status of the critical P25 interfaces, and presented a talk titled "Project 25 Standards Overview." Other outreach efforts included hosting a meeting at the request of representatives of public safety practitioners in the San Francisco Bay Area to assist their ongoing ISSI design and procurement efforts for the purpose of achieving multi-agency P25 system interoperability. Since 2006, ITS has maintained the *P25 Document Suite Reference* (P25 DSR) to track the current state of P25 standards documents (http://www.its.bldrdoc.gov/resources/p25/P25DocSelection.pdf). Understanding the status of specific P25 interface, equipment, and service standards helps public safety LMR system managers make planning and procurement decisions. The P25 DSR serves to describe the organization and relationships of the standards (see figure) necessary to build components of a P25 LMR system. The P25 DSR provides users, manufacturers, and government agencies a roadmap for charting progress and prioritizing standards development. The P25 DSR is also playing an increasingly important role in identifying the documents used for P25 compliance assessment purposes.



P25 DSR console decision chart example with references to tables listing applicable P25 standards.

The inter-related ITS public safety projects, which assist the development of high-priority P25 and other standards, are sponsored by several Federal organizations with a vital interest in advancing interoperable public safety communications. ITS activities focusing on P25 standards development continue to be sponsored by the National Institute of Standards and Technology Office of Law Enforcement Standards. In FY 2009, ITS will continue to support the accelerated development of Project 25 standards to further realize the commercial offering, procurement, and operation of interoperable LMR radios and systems that meet the mission-critical communication needs of the public safety community.

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Project 25 Compliance Assessment Program

Outputs

- Development of technical materials for DHS P25 CAP Governing Board.
- Grant guidance language for Federal Project 25 equipment grant programs.
- Laboratory assessment program management and subject matter expertise.
- Compliance assessment related Project 25 standards.

"... Testing was something that for a long time public safety assumed occurred, but then they realized that their toasters were tested to a higher degree than their radio systems." – Dereck Orr, NIST/OLES Communications Program Manager

For several decades, public safety agencies have been purchasing and using equipment made by disparate manufacturers and operating on disparate spectrum. As a result, this equipment often cannot interoperate, preventing many public safety agencies from communicating when responding to critical incidents that threaten lives and property. Public safety and industry have partnered through Project 25 (P25) on developing standards that allow radios and other components to interoperate regardless of manufacturer – enabling emergency responders to exchange critical communications. The goal of Project 25 is to specify formal standards for interfaces between the various components of a land mobile radio (LMR) system – commonly used by emergency responders.

After many years of effort, industry is incorporating standards into the radio and communications equipment used by public safety, but there is currently no independent method for purchasers to verify that the equipment is actually compliant with those standards. In fact, preliminary test data indicates that some radios currently sold under the Project 25 label do not meet all of the standards' requirements. To address this issue, ITS, in conjunction with the National Institute of Standards and Technology's Office of Law Enforcement Standards (NIST/OLES) and the Department of Homeland Security's Office of Interoperability and Compatibility (DHS OIC), built a coalition of public safety users and communications equipment manufacturers to create an independent compliance assessment program that will test the equipment for standards compliance.

The Project 25 Compliance Assessment Program (P25 CAP) is a voluntary program that allows P25 equipment suppliers to formally demonstrate their products' compliance with a select group of requirements within the P25 suite of standards. The purpose of the program is to provide emergency response agencies with evidence that the communications equipment they are purchasing meets P25 standards for performance, conformance, and interoperability.

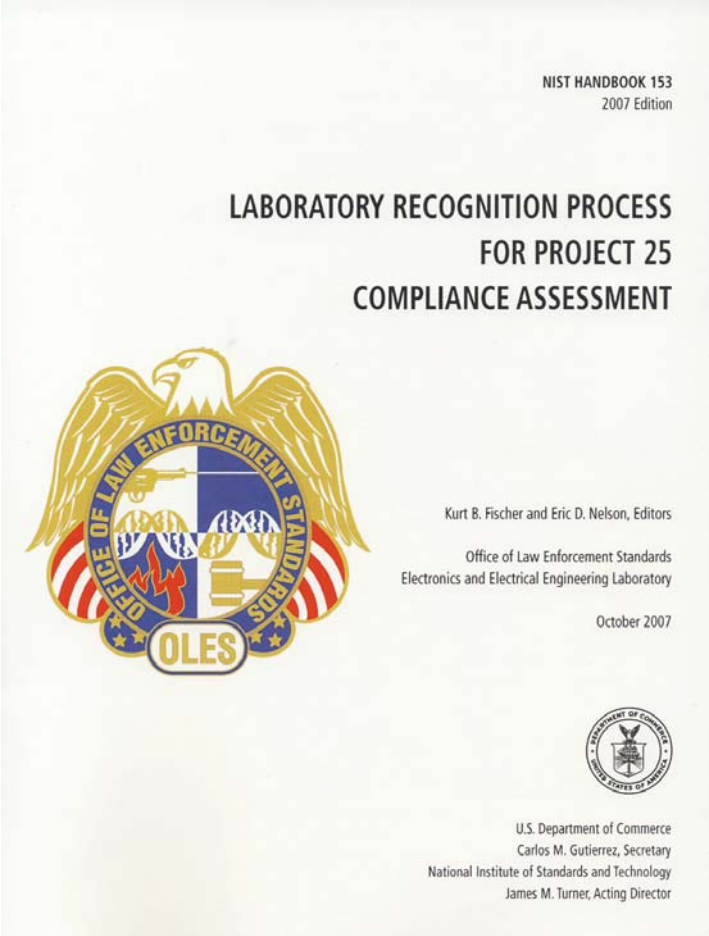
The program requires test laboratories to demonstrate their competence through a rigorous and objective assessment process. Such a process promotes the user community's confidence in, and acceptance of, test results from recognized laboratories. All equipment suppliers that participate in the P25 CAP must use recognized laboratories to conduct performance, conformance, and interoperability tests on their products. P25 equipment suppliers will release summary test reports from recognized labs along with declarations of compliance. This documentation will serve to increase the public's confidence in the performance, conformance, and interoperability of P25 equipment.

Performance, conformance, and interoperability issues are likely to occur in all communications technologies and especially in those like P25 with protocols that constantly adapt to changing user requirements. Such problems should be resolved within the P25 CAP, and notably, before product launch and deployment. Further, the declaration of compliance-related documents developed by program participants will provide useful technical information about the equipment.

P25 CAP will provide more than 50,000 emergency response agencies nationwide with a consistent and tractable perspective of P25 product compliance. It will also provide a means of verifying that billions of Federal grant dollars are being invested in standardized solutions and equipment that promotes interoperability.

A number of important milestones were reached in FY 2008:

- The P25 CAP Governing Board was created, and several critical requirements documents have been released, including the Testing Requirements, Supplier's Declaration of Compliance Requirements, and Summary Test Report Requirements. ITS drafted all of the Compliance Assessment Bulletins currently approved.
- The laboratory assessment process was begun in 2008, where ITS provides subject matter experts for the process, as well as leadership in the form of the P25 CAP Deputy Laboratory Program Manager.
- ITS continues to work within the standards development process of TIA to ensure timely release of standards that directly impact the P25 CAP, namely test standards for the Common Air Interface and the Inter-RF Sub-System Interface.
- ITS assisted in developing Federal grant guidance language for DHS that affects how Federal grant money is used by state and local public safety in the purchase of communications equipment.


NIST HANDBOOK 153
2007 Edition

LABORATORY RECOGNITION PROCESS FOR PROJECT 25 COMPLIANCE ASSESSMENT

Kurt B. Fischer and Eric D. Nelson, Editors

Office of Law Enforcement Standards
Electronics and Electrical Engineering Laboratory

October 2007

U.S. Department of Commerce
Carlos M. Gutierrez, Secretary
National Institute of Standards and Technology
James M. Turner, Acting Director

Cover of the NIST Handbook drafted by NIST/OLES and ITS.

In short, the P25 Compliance Assessment Program:

- Was mandated by Congress in legislation.[1]
- Is a cost effective solution. ITS is supporting OLES/DHS in their effort to recognize existing independent laboratories to conduct the testing rather than building a large centralized facility.
- Is a voluntary program that allows P25 equipment suppliers to formally demonstrate their products' compliance with a select group of requirements.
- Is a partnership of ITS, DHS OIC, NIST/OLES, industry, and the emergency response community.
- Was launched in 2008, with the assessments of labs to begin in late 2008.
- Is an example of government making a minimal investment that catalyzes industry and the community it serves to develop a solution that will affect billions of dollars in purchases.

1 House Report 109-241 – "Making Appropriations for the Department of Homeland Security for the Fiscal Year Ending September 30, 2006, and for Other Purposes."

Senate Report 109-088 – "Department of Commerce and Justice, Science, and Related Agencies Appropriations Bill, 2006"

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Public Safety Audio Quality

Outputs

- Technical reports describing experimental conduct and results.
- Contributions to standards bodies regarding measurement methods for public safety audio quality.

When a public safety practitioner's life is in danger, the ability to call for help, to warn others, to communicate, is essential. However, some background noises encountered in the public safety environment, such as sirens, chainsaws, and personal alert safety systems (PASS), can interfere with digital communication. Sometimes this interference is so severe that it can prevent a practitioner and the person talking with him or her from understanding each other at the most critical moments. To understand how background noise affects voice communications and to determine what technology improvements are needed to overcome any background noise issues, ITS and its program sponsors (the National Institute of Standards and Technology/Office of Law Enforcement Standards, the Department of Homeland Security/Office of Interoperability and Compatibility and the Office of Emergency Communications) have worked with practitioners to develop and implement tests that measure how digital radios operate in the presence of loud background noise.

The Public Safety Audio Quality project takes an innovative approach to addressing the needs of the public safety community. Working directly with practitioner agencies, the project conducts both field and laboratory studies in order to increase the awareness of public safety requirements, conduct experiments that reflect the real environment in which public safety must operate, and quantify potential communications technology issues and identify solutions for those issues.

The field studies conducted by the project are essential to understanding the environments in which public safety practitioners must operate. To date, field measurements and recordings have been made in a variety of public safety vehicles, and at several fire scenes to provide information specific to noises encountered by the fire service. These field studies provide information on radio usage, operational environment, and common practices of public safety personnel. Typically these field studies will involve two types of recordings. The first is recordings of overall operation that help increase understanding and comprehension of public safety operational requirements. The second type of recording is a high-quality digital recording of a specific environmental noise that can be shared with the community and also used in laboratory experiments.

The high-quality digital recordings are used to reproduce real-life sound levels inside a sound-attenuated chamber which contains an ITU-Standard Head and Torso Simulator (HATS) (Figure 1). The HATS has a calibrated speaker representing the mouth and calibrated microphones representing each ear. Using these capabilities, the HATS can be used to simulate a conversation in any noise environment for which a recording exists. Utilizing a pair of these chambers containing HATS enables both halves of a conversation to be simulated and recorded for later analysis or playback to a subjective listener panel.

Figure 1. A Head and Torso Simulator (HATS) "talks" to a digital radio. The signal is transmitted to a companion HATS that "listens," enabling recording for later analysis or playback to a subjective listening panel.

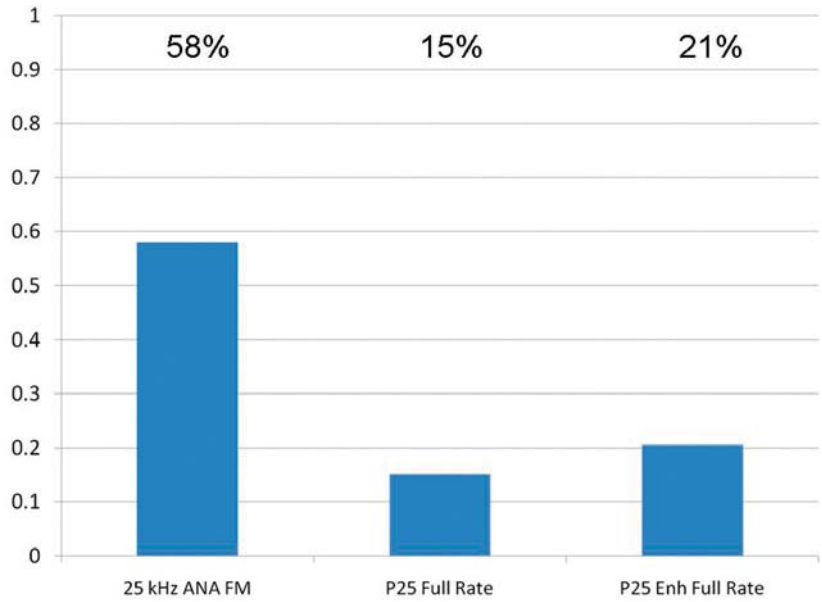

Figure 2. The biggest observed difference in intelligibility scores for radio systems (25 kHz analog (ANA) FM, Project 25 Full Rate, and Project 25 Enhanced Full Rate) was in the presence of PASS noise.

In the most recent subjective experiment, a variety of fire-specific noises were mixed with speech to perform an intelligibility test. The noises included such sounds as a chainsaw, a fire-hose fog nozzle, a low air alarm from breathing apparatus, and a PASS alarm. The experiment compared the intelligibility of digital and analog radio communication systems in the presence of such noises. Results were published in an NTIA Report[1] and companion recommendations published by the International Association of Fire Chiefs.[2]

The results showed that there were some conditions where analog radios performed significantly better than digital radios. Some of the IAFC recommended best practices included:

- Train all personnel to properly use the assigned radio equipment in conjunction with all components of the protective ensemble.
- Fire departments should be actively involved in the design and development of requirements for any communication-system implementation from the beginning.
- Incident commanders should evaluate background noise in the environment as a safety consideration in task assignments. Additional personnel may need to be assigned to a task to ensure communication capability when there are high levels of background noise in the environment.
- System managers and users should work with their vendors to ensure that their radios and accessories are compatible and configured with the optimal system settings to maximize audio intelligibility in high-noise environments.

In FY 2009 the project will focus on identification of strategies and technologies that can improve the intelligibility of digital radio systems in the presence of loud background noises (Figure 2). The work will continue to involve the IAFC and the Project 25 communities.

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1 Atkinson, D. and A. Catellier, "Intelligibility of selected radio systems in the presence of fireground noise: Test plan and results," NTIA Technical Report TR-08-453, Jun. 2008. http://www.its.bldrdoc.gov/pub/ntia-rpt/08-453/

2 IAFC Digital Problem Working Group, Interim Report and Recommendations: Fireground Noise and Digital Radio Transmissions, International Association of Fire Chiefs, Jun. 2008. http://www.iafc.org/digitalproject/

Public Safety Interoperability Test Tools

Outputs

- An ISSI reference implementation.
- Software capable of conformance testing the ISSI protocol.

The importance of the Project 25 (P25) suite of standards has been conveyed by Congress through several pieces of recent legislation. With Congress providing grants to local, State, and Federal government for the acquisition of public safety telecommunications equipment, the suite of P25 standards is necessary to ensure interoperability among different levels of government. The Inter-RF Sub-System Interface (ISSI), one of seven P25 interfaces, has top priority for completion. ISSI can be thought of as a network protocol that can utilize a standard network interface card. The intent is for this interface to be present in future deployments of P25 Radio Frequency Sub-Systems (RFSS). When the ISSIs of various RFSSs are interconnected, IP packets that contain encoded voice can be transmitted and received. The ISSI is important to public safety agencies because it will foster competition among RFSS manufacturers. Over time, this increased competition should drive down costs. An ISSI interface also promotes interoperability between RFSS manufacturers, allowing a consumer to implement a P25 network of RFSSs from multiple vendors.

Testing the ISSI Interface

A balloted scope one version of the P25 ISSI Messages and Procedures for Voice Services (TIA-102.BACA) specification was released in August 2006. A formal published version of the ISSI conformance test document is expected in late 2008. These tests will verify that the vendor implementation under test conforms at a message level to what has been specified in TIA-102.BACA.

To verify objectively that a vendor conforms to TIA-102.BACA, a reference implementation of the ISSI protocol stack has been developed, the ISSI Test Tools (ITT). ITS developed this software in conjunction with the National Institute of Standards and Technology (NIST). Since ITT is implemented in Java, the software can be loaded on a desktop PC with a Linux or Windows operating system. A single instance of ITT can emulate one of four different roles in a P25 ISSI-based network: (1) calling serving RFSS, (2) calling home RFSS, (3) called home RFSS, and (4) called serving RFSS. ITT will be placed in a test configuration, as defined in the conformance test document, which will fulfill one of the four roles depending on the test case under consideration. The number of vendor RFSSs and roles may vary depending on the test case requirements.

When attempting to determine a particular vendor's conformance, the preferred configuration is to test in isolation the ISSI of the vendor's RFSS. This scenario implies that there is only one vendor RFSS with a real ISSI and the rest of the ISSI interfaces are emulated by ITT. An example of this test architecture is shown in Figure 1. The number of emulated ISSIs and the role of the emulated interfaces will vary depending on the test case under consideration.

Since ITT cannot emulate the P25 common air interface, the behaviors of (or events generated by) subscriber units are emulated in the ITT software. From the ITT graphical user interface (GUI), the user selects a conformance test case to execute. Figure 2 shows the layout of the ITT GUI. After the test case has been executed, the user can view the session initiation protocol (SIP) and real-time transport protocol (RTP) Push-to-Talk (PTT) messages exchanged between ISSIs in a graphical message sequence chart (MSC). Upon completion of test case execution,

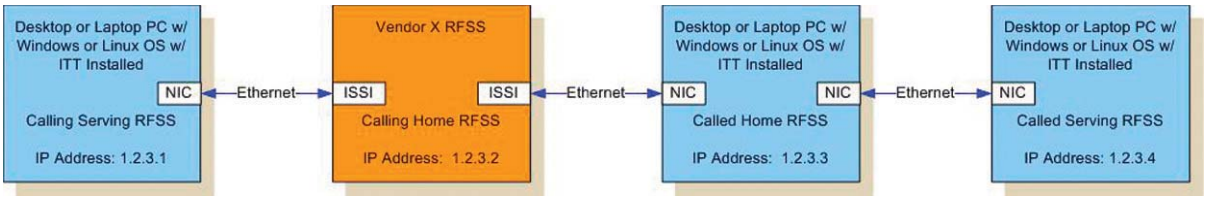

Figure 1: Test architecture with three instances of ITT. Note that IP addresses are for example purposes only.

ITT declares either pass or fail. Figure 3 illustrates the SIP MSC generated as a result of executing test case 9.1.1 — Unconfirmed Group Call Successful. Raw IP packet data can be rendered by clicking on the message of interest in the MSC. ITT has a packet processing capability that will render an MSC based on the Ethereal packet capture (PCAP) file that is fed in for processing. Wireshark (formerly Ethereal) is used to capture packets off the wire and can save the captured packets in the PCAP file.

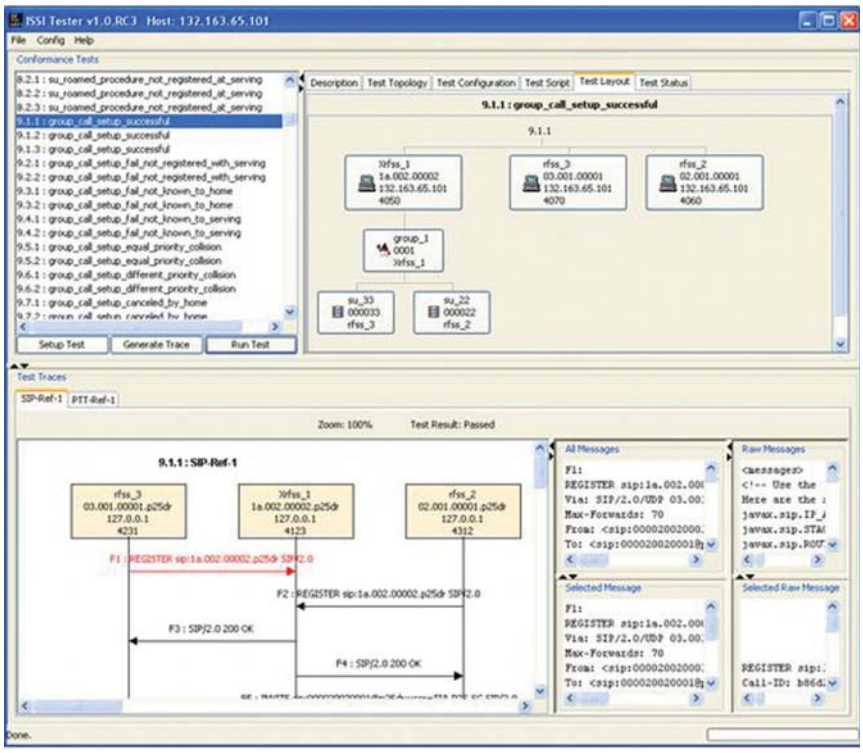

Figure 2. ITT conformance test tool GUI.

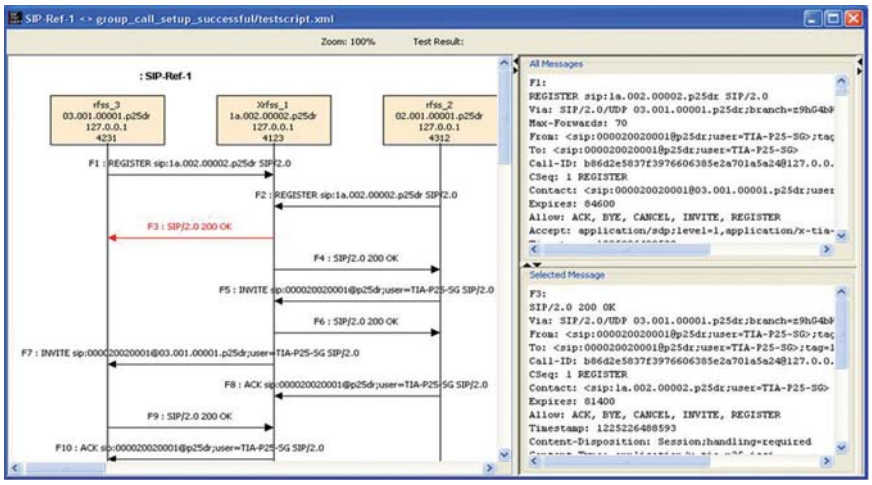

Figure 3. SIP MSC for Unconfirmed Group Call Successful.

Other Project 25 Wireline Test Tools

ITT is being expanded to test two other wireline interfaces: the Fixed Station Interface (FSI) and the P25 Trunked Console Sub-System Interface (CSSI). The FSI standard, TIA-102. BAHA, was published in 2006. The CSSI was published in April 2007 and is an addendum to TIA-102. BACA.

The purpose of the FSI is to enable connectivity of a fixed station (i.e., base station) to an RFSS. It can be thought of as a protocol stack. The intent of the FSI is to allow interoperability between conventional fixed stations and RFSSs. The purpose of the CSSI is to enable the connectivity of a dispatcher's console to an RFSS. The CSSI is very similar to the ISSI. The conformance test document TIA-102.CADA for the FSI has been published. The conformance test case development for the CSSI may begin at the end of 2008.

In addition to expanding ITT's capability to test additional P25 interfaces, ITT is also being expanded to test the performance of the ISSI according to the Project 25 ISSI Measurement Methods for Voice Services standard. This is scheduled for completion by early 2009.

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Emergency Telecommunications Service (ETS) Standards Development

Outputs

- Technical contributions to ATIS Technical Committee PRQC.
- Technical contributions to ITU-T Study Group 9.

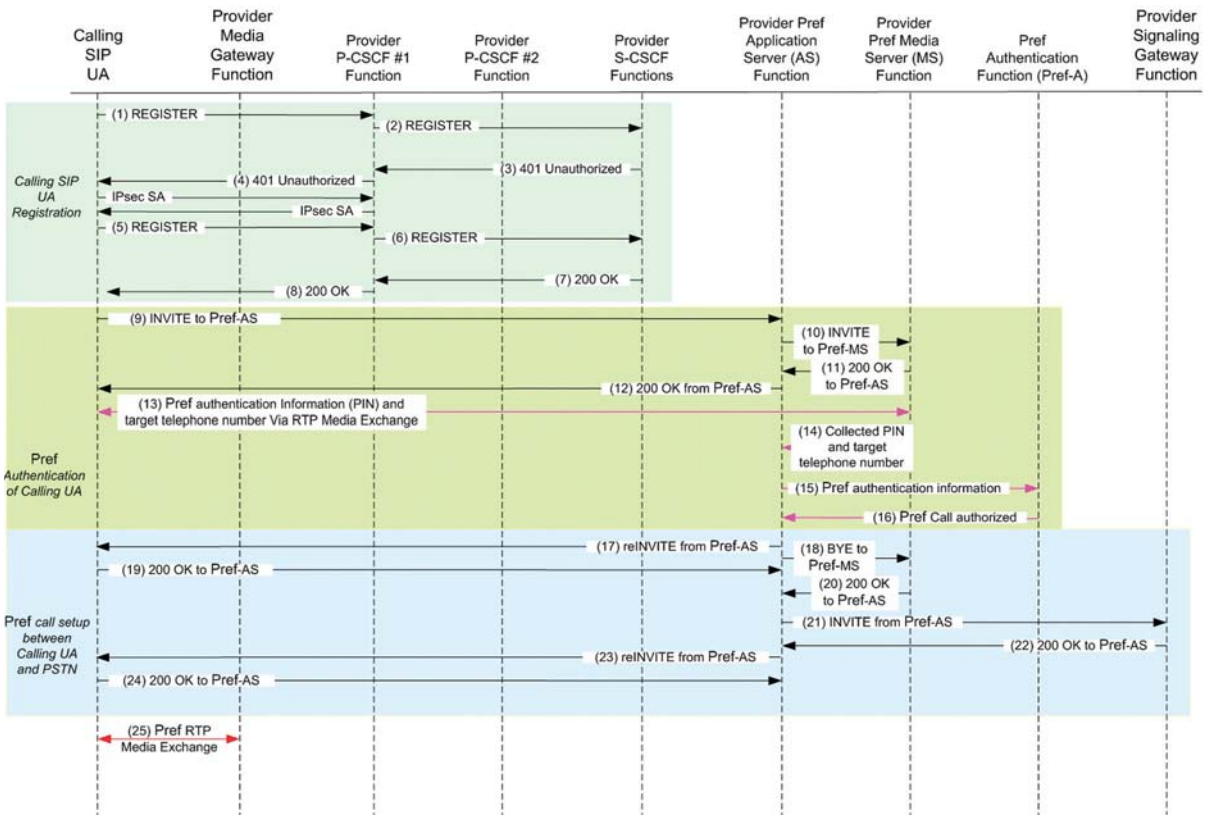
In the aftermath of the 2001 terrorist attacks, the Federal Government has become very interested in priority treatment for emergency communications. While the Government Emergency Telecommunications Service (GETS) has served emergency workers well for many years, it has been limited to the Public Switched Telephone Network (PSTN) in the United States. The Emergency Telecommunications Service (ETS) is envisioned as a GETS-like service that will be available internationally and encompass virtually all wireless and wireline communications networks. Types of traffic to be carried include voice, video, database access, text messaging, e-mail, FTP, and web-based services.

The ETS Standards Development project conducts laboratory studies, requirements and specification development, and security analyses to further the approval of standards supporting National Security/ Emergency Preparedness (NS/EP) and Critical Infrastructure Protection (CIP) initiatives. This project is funded by the National Communications System (NCS) — a part of the Department of Homeland Security (DHS). The work supports NCS in its mission to protect the national security telecommunications infrastructure, and to ensure the responsiveness and availability of essential telecommunications during a crisis.

The ETS Standards Development project provides contributions to three standards development organizations. These are the International Telecommunication Union's Telecommunication Standardization Sector (ITU-T) Study Group (SG) 9 and two American National Standards Institute (ANSI)-accredited groups: the Alliance for Telecommunications Industry Solutions (ATIS)'s Performance, Reliability, and Quality of Service Committee (PRQC), and the Society of Cable Telecommunications Engineers (SCTE). ITU-T SG 9 is the Lead Study Group, internationally, on integrated broadband cable and television networks and the SCTE produces North American Standards for the cable industry. PRQC works in the areas of Quality of Service (QoS), Reliability, and User-Plane Security, and produces North American Standards. In SG 9, ITS develops and verifies Recommendations to support preferential telecommunications services and user authentication. One major goal of this project is to ensure that future ETS mechanisms and the current GETS service will interoperate over broadband cable television networks in their delivery of voice, data, and multimedia communications.

In PRQC, ITS provides ETS expertise relating to priority support and network security. During FY 2008, an ITS engineer served as co-editor of several ANSI and ATIS Standards and Technical Reports. These provide guidelines, specifications, and requirements for aspects of ETS communications and network and computer security. An ITS engineer served as the Chair of PRQC's Security Task Force where he leads security standardization for the Network User Plane.

The standardization work in ITU-T SG 9 is focused on the IPCablecom and IPCablecom2 families of Recommendations. These Recommendations define the protocols and signaling to be used on broadband cable television networks to support telephony, multimedia, and Internet access. The IPCablecom Recommendations have been standardized in ITU-T SG 9, and equipment implementing them is currently in production worldwide. IPCablecom2 has recently been approved and equipment will be deployed in the coming years. One goal of this project is to identify where additions or changes might be needed to support GETS-like capabilities. This effort also involves work with the Internet Engineering Task Force (IETF), since many of the underlying protocols used in IPCablecom2 (as well as some of the ETS mechanisms) are under development in the IETF. An ITS engineer served as editor and principal author of ITU-T Recommendation J.260, "Requirements for preferential telecommunications over IPCablecom networks," in SG 9. An ITS engineer also serves as the editor of three Draft new ITU-T Recommendations:



VoIP preferential treatment using PIN authentication message flow.

- J.preffr, "Framework for implementing preferential telecommunications in IPCablecom networks,"
- J.prefa2, "Specifications for authentication in preferential telecommunications over IPCablecom2 networks," and
- J.prefp2, "Specifications for priority in preferential telecommunications over IPCablecom2 networks."

J.preffr will provide a framework for standardizing preferential services and priority user-authentication in cable networks. J.prefa2 and J.prefp2 will provide specifications for IPCablecom2 networks that satisfy the requirements set forth in J.260.

The figure, from J.prefa2, shows a call flow diagram indicating how a VoIP Preferential Call (e.g., an ETS call) would be established on an IPCablecom2 network connecting to a PSTN gateway using a PIN for authentication.

In FY 2009, ITS will continue to work on the development and standardization of ETS in ATIS PRQC, SCTE, and ITU-T SG 9. The project will address technologies in the NGN and interactions with the IPCablecom and IPCablecom2 networks. This work on ETS must of necessity be conducted with the help of representatives from network providers and cable television equipment manufacturers, as well as NCS. The work in FY 2009 will focus on priority and security in the NGN ETS as well as GETS and ETS specifications in the IPCablecom and IPCablecom2 networks.

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Railroad Telecommunication Study

Outputs

- Assistance to the Association of American Railroads' frequency management office in developing a narrowband VHF channel plan and wideband-to-narrowband migration strategy for U.S. railroads.

The Federal Communications Commission's (FCC) Third Report and Order[1] mandated that all private land mobile radio (PLMR) users shall use narrowband radio transmissions by January 1, 2013. The U.S. railroad industry had already begun implementing fleet-wide migration strategies to transition all of their 25-kHz bandwidth radio equipment to 12.5-kHz bandwidth-capable equipment.

A subsequently issued FCC communiqué[2] urged the PLMR community to consider directly migrating from 25-kHz bandwidth wideband (WB) architectures to 6.25-kHz bandwidth "very narrowband" ("VNB") architectures, and bypass migration to 12.5 kHz bandwidth narrowband (NB) architectures altogether. Migration to VNB equipment offers opportunities to deploy technically superior solutions and creates additional spectral capacity. However, 6.25-kHz bandwidths mandate a digital radio implementation, as analog FM is just not feasible at such very narrow bandwidths. This presented unique challenges in devising a plan that would accommodate a direct migration to VNB in tandem with a two-step migration policy, from WB to NB to VNB, as had already been embarked upon by some railroads.

Since the Federal Railroad Administration (FRA) oversees railroad safety in the United States, and since PLMR communications is an integral element of ensuring railroad safety, the FRA asked ITS to monitor the activities of the Association of American Railroads (AAR) and to provide technical guidance where and when appropriate, as the AAR implemented the FCC's mandates.

The AAR, familiar with ITS' earlier work related to the analysis of a 1999 railroad channel plan realignment proposal,[3] asked ITS to collaborate with their railroad frequency management office to develop a new VHF channel plan. This jointly developed plan exhibits the following characteristics:

- Complies with current FCC direction to migrate to 12.5-kHz bandwidth equipment.
- Facilitates eventual migration to 6.25-kHz bandwidth equipment.
- Includes 24-kbps data channels.[4]
- Encourages the use of trunking technology.
- Facilitates mixed use of conventional repeaters or simplex usage as secondary users on trunked channel allocations.
- Facilitates mixed use of simplex (peer-to-peer) voice channels as secondary users on data channel allocations.
- Retains frequency sharing agreements with Canadian Railroads along the northern US border.

The figure shows a diagram of the band plan. Channel numbers use different numbering format schema to differentiate between the types of modulation and bandwidths (example: channel 008 is a narrowband analog channel at 160.23 MHz, while channel 08 is a wideband analog channel at 160.23 MHz).

For non-trunked repeater or trunking system use, "like" channels are grouped for use within a geographic region or trunking system. For example, the set of yellow color-coded paired frequencies in the figure could belong to a single trunking system or to a regional collection of non-trunked standalone repeaters (for example, 160.215 MHz paired with 161.055 MHz plus 160.305 MHz paired with 161.145 MHz, and so on). These color-coded frequencies (yellow, orange, green, etc.), although

1 Federal Communications Commission Third Report and Order in Docket No. WT 99-87, FCC 07-39, released March 26, 2007.

2 Federal Communications Commission Fourth Memorandum Opinion and Order in Docket No. WT-99-87, FCC 08-127, released May 13, 2008.

3 J.M. Vanderau and E.J. Haakinson, "An evaluation of the proposed railroad VHF band channel plan," NTIA Report 99-370, Sep. 1999.

4 The AAR has awarded a research and development contract to private industry to develop an integrated voice plus data radio to support their anticipated data needs for train control and mobile office applications and interoperate with VNB digital voice.

Channel Plan with 25 kHz, 12.5 kHz and 6.25 kHz Numbering Schemes

Base Transmit / Mobile Receive

Channel Number 25 kHz	12.5 kHz	6.25 kHz	Freq.
	104	302	160.1775
05	005	303	160.1850
	105	304	160.1925
06	006	305	160.2000
	106	306	160.2075
07	007	307	160.2150
	107	308	160.2225
08	008	309	160.2300
	108	310	160.2375
09	009	311	160.2450
	109	312	160.2525
10	010	313	160.2600
	110	314	160.2675
11	011	315	160.2750
	111	316	160.2825
12	012	317	160.2900
	112	318	160.2975
13	013	319	160.3050
	113	320	160.3125
14	014	321	160.3200
	114	322	160.3275
15	015	323	160.3350
	115	324	160.3425
16	016	325	160.3500
	116	326	160.3575
17	017	327	160.3650
	117	328	160.3725
18	018	329	160.3800
	118	330	160.3875
19	019	331	160.3950
	119	332	160.4025
20	020	333	160.4100
	120	334	160.4175
21	021	335	160.4250
	121	336	160.4325
22	022	337	160.4400
	122	338	160.4475
23	023	339	160.4550
	123	340	160.4625
24	024	341	160.4700
	124	342	160.4775
25	025	343	160.4850
	125	344	160.4925
26	026	345	160.5000
	126	346	160.5075
27	027	347	160.5150
	127	348	160.5225
28	028	349	160.5300
	128	350	160.5375
29	029	351	160.5450
	129	352	160.5525
30	030	353	160.5600
	130	354	160.5675
31	031	355	160.5750
	131	356	160.5825
32	032	357	160.5900
	132	358	160.5975
33	033	359	160.6050
	133	360	160.6125
34	034	361	160.6200
	134	362	160.6275
35	035	363	160.6350
	135	364	160.6425
36	036	365	160.6500
	136	366	160.6575
37	037	367	160.6650
	137	368	160.6725
38	038	369	160.6800
	138	370	160.6875
39	039	371	160.6950
	139	372	160.7025
40	040	373	160.7100
	140	374	160.7175
41	041	375	160.7250
	141	376	160.7325

Integrated Voice plus Data Radio

Channel Number 25 kHz	12.5 kHz	6.25 kHz	Freq.
42	042	377	160.7400
	142	378	160.7475
43	043	379	160.7550
	143	380	160.7625
44	044	381	160.7700
	144	382	160.7775
45	045	383	160.7850
	145	384	160.7925
46	046	385	160.8000
	146	386	160.8075
47	047	387	160.8150
	147	388	160.8225
48	048	389	160.8300
	148	390	160.8375
49	049	391	160.8450
	149	392	160.8525
50	050	393	160.8600
	150	394	160.8675
51	051	395	160.8750
	151	396	160.8825
52	052	397	160.8900
	152	398	160.8975
53	053	399	160.9050
	153	400	160.9125
54	054	401	160.9200
	154	402	160.9275
55	055	403	160.9350
	155	404	160.9425
56	056	405	160.9500
	156	406	160.9575
57	057	407	160.9650
	157	408	160.9725
58	058	409	160.9800
	158	410	160.9875
59	059	411	160.9950
	159	412	161.0025
60	060	413	161.0100
	160	414	161.0175
61	061	415	161.0250
	161	416	161.0325
62	062	417	161.0400
	162	418	161.0475

Mobile Transmit / Base Receive

Channel Number 25 kHz	12.5 kHz	6.25 kHz	Freq.
63	063	419	161.0550
	163	420	161.0625
64	064	421	161.0700
	164	422	161.0775
65	065	423	161.0850
	165	424	161.0925
66	066	425	161.1000
	166	426	161.1075
67	067	427	161.1150
	167	428	161.1225
68	068	429	161.1300
	168	430	161.1375
69	069	431	161.1450
	169	432	161.1525
70	070	433	161.1600
	170	434	161.1675
71	071	435	161.1750
	171	436	161.1825
72	072	437	161.1900
	172	438	161.1975
73	073	439	161.2050
	173	440	161.2125
74	074	441	161.2200
	174	442	161.2275
75	075	443	161.2350
	175	444	161.2425
76	076	445	161.2500
	176	446	161.2575
77	077	447	161.2650
	177	448	161.2725
78	078	449	161.2800
	178	450	161.2875
79	079	451	161.2950
	179	452	161.3025
80	080	453	161.3100
	180	454	161.3175
81	081	455	161.3250
	181	456	161.3325
82	082	457	161.3400
	182	458	161.3475
83	083	459	161.3550
	183	460	161.3625
84	084	461	161.3700
	184	462	161.3775
85	085	463	161.3850
	185	464	161.3925
86	086	465	161.4000
	186	466	161.4075
87	087	467	161.4150
	187	468	161.4225
88	088	469	161.4300
	188	470	161.4375
89	089	471	161.4450
	189	472	161.4525
90	090	473	161.4600
	190	474	161.4675
91	091	475	161.4750
	191	476	161.4825
92	092	477	161.4900
	192	478	161.4975
93	093	479	161.5050
	193	480	161.5125
94	094	481	161.5200
	194	482	161.5275
95	095	483	161.5350
	195	484	161.5425
96	096	485	161.5500
	196	486	161.5575
97	097	487	161.5650
	197	488	161.5725

Railroad VHF channel plan, 2008.

allocated as primary usage for trunking systems, could be used for conventional repeaters as secondary users, or as simplex channels as tertiary users. White color-coded frequency pairs, such as 160.47 MHz paired with 161.31 MHz, would be reserved for non-trunked repeater use as primary, and simplex channels as secondary.

The frequency range from 160.74 MHz to 161.475 MHz would be reserved for eight 25-kHz wide data channels and two narrowband simplex voice channels.

In the American/Canadian border areas, the turquoise color-coded assignments depicted in the "Freq" columns of the figure (and their corresponding channel numbers) are reserved for use on the United States side of the border, while the pink color-coded assignments are reserved for use on the Canadian side of the border, per an earlier 1960 agreement between the governments of the United States and Canada. The red color-coded assignments (encompassing 160.1775-160.2075 and 161.5725 MHz) are only authorized for railroad use in Canada, not the United States.

This plan is quite flexible in that it promotes an orderly migration to a structured channel plan. Should a geographic region require trunking to alleviate radio traffic congestion, it could implement one or more of the eight 6-channel trunking groups (i.e., the yellow or orange or green, etc., channel groups in the figure). A trunking system, if instituted, would not have to use all six channels allocated to it. Conventional repeaters could be assigned these channels, but as secondary users. If a region implemented trunking or expanded its use of allocated but unused trunking channels, incumbents on those channels would need to either relocate to new channels, or join the trunking system.

A similar methodology would apply to simplex voice users on trunked, repeated, or data channels. As replacement technology would be deployed in a region, incumbents would have to relocate to different channels, or adopt the same technology as used by the primary users on those channels.

This plan supports a direct migration from WB equipment to VNB digital equipment in tandem with a two-step migration path with an intermediate migration to NB equipment.

The AAR adopted this channel plan in August 2008. Its adoption preceded its September 2008 policy statement urging railroads to replace outdated legacy equipment with "tri-mode" (WB, NB, and VNB) capable radio equipment. These tri-mode radios are now available in the commercial marketplace.

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Multimedia Quality Research

Outputs

- Technical contributions to VQEG.
- Technical contributions to ITU-T Study Group 9.

The transmission of audio/video (multimedia) signals over wireline and wireless channels has increased exponentially in the past decade. In particular, the distribution of multimedia signals over wireless links to devices such as laptops, personal digital assistants (PDAs), and cellphones is widespread and the need for quality measurements is great. The widespread use of digital technology for the transmission of audio and video signals has led to the need for new objective quality assessment methods based on human perception. ITS has a long history of successful research in the areas of voice and video quality assessment. Until recently, however, the development of an objective measure of overall multimedia quality has not been adequately addressed.

Multimedia is defined here as the combination of audio and video in the communication of information. The objective of the ITS Multimedia Quality Research project is to characterize and analyze the fundamental aspects of multimedia quality assessment. A primary goal of this research is to develop an algorithmic system to objectively assess multimedia quality by combining audio quality, video quality, and audiovisual synchronization information.

In FY 2008, ITS conducted two subjective experiments to advance this work. The first experiment utilized video at CIF resolution (Common Intermediate Format: 352 by 288, square pixels) compressed at several bit rates and accompanying audio also compressed at several bit rates. These audiovisual signals were combined in a full matrix design to facilitate data analysis. Figure 1 shows the average quality of the multimedia sequence for a given condition. In this test the data indicate that the video quality was more important to the viewer than the audio quality. Further tests with different levels of quality will need to be undertaken before we can know how to fully interpret these results.

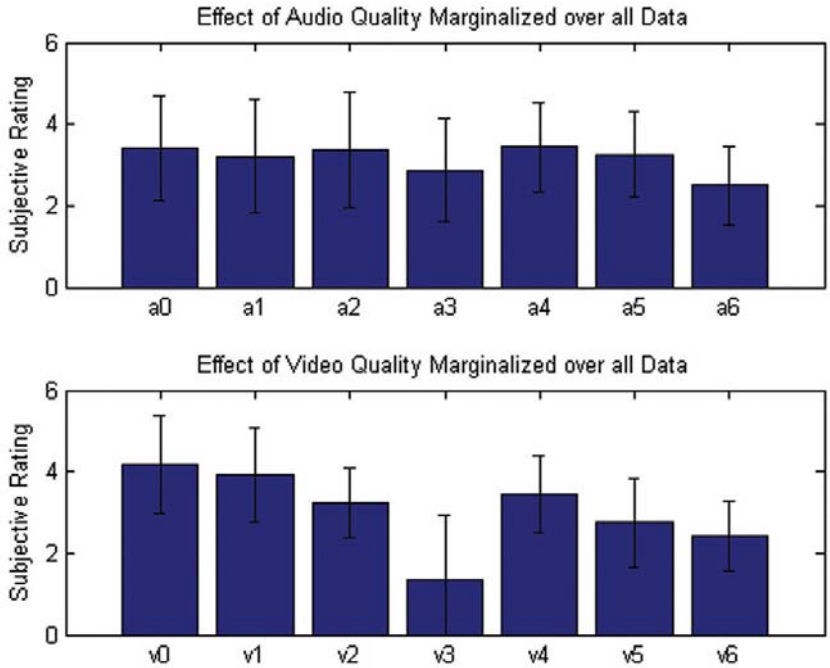

Figure 1. Effect of audio and video quality on overall multimedia quality.

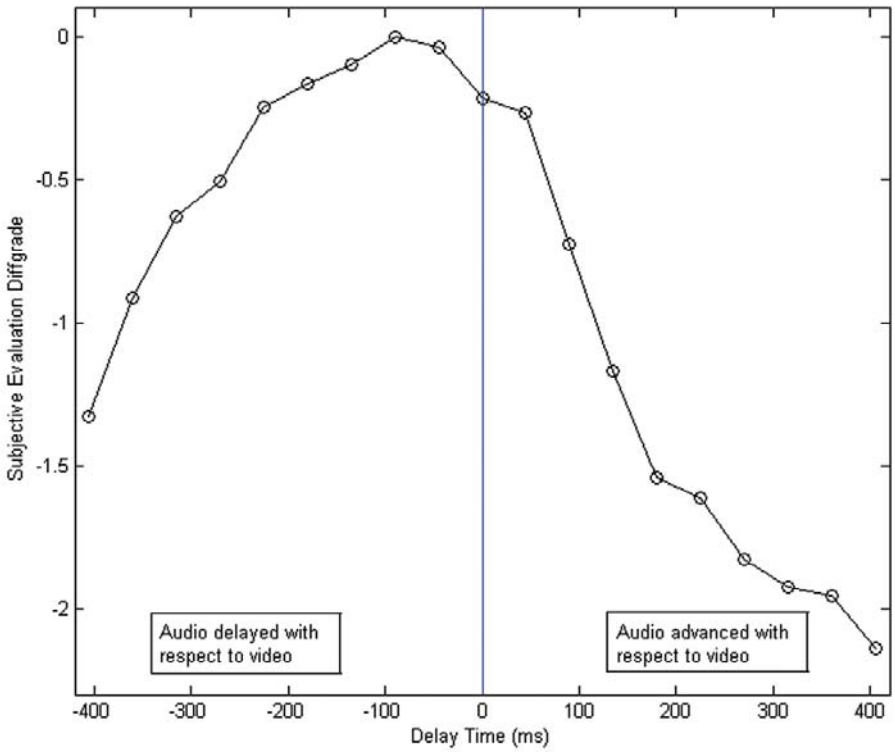

Figure 2. Effect of audio and video desynchronization on overall multimedia quality.

A second multimedia subjective test was begun to quantify the effect of audio and video desynchronization on the quality as perceived by the viewer/listener. Figure 2 shows a plot of the preliminary results of this second experiment — the subjective quality versus the amount of desynchronization between the audio and video signals. Note that the perceived quality degradation is not symmetric about zero desynchronization (delay time). These results are consistent with other tests conducted in the field.

Subjective testing plays an important part in ITS efforts to develop voice and video quality assessment methods. For multimedia research, subjective testing is no less important. Objective quality assessments are based on data derived from subjective quality experiments. A series of multimedia subjective tests will be executed to explore the relationships between the quality parameters for audio, video, and audiovisual synchronization. This will provide the data needed for the development of an integration function that will estimate the overall audiovisual quality from measurements of audio quality, video quality, and audiovisual synchronization.

This work is being done in conjunction with projects underway in the Video Quality Experts Group (VQEG) and the ITU-T Joint Rapporteur Group on Multimedia Quality Assessment (JRG-MMQA). The JRG-MMQA is an official body of the International Telecommunication Union and is formed from members of ITU-T Study Groups 9 and 12.

In FY 2009 this project will continue to develop tools and conduct research into the Hybrid Perceptual/Bitstream models in conjunction with projects in progress in VQEG and the JRG-MMQA. ITS will continue to work on the development of a multimedia quality assessment model. Additional tests measuring the effects of audio/video desynchronization will be completed in FY 2009. HDTV audiovisual tests will be performed to explore the effects high resolution video has on multimedia quality.

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Wireless Network Measurement Methods

Outputs

- SDR test instrument technologies.
- Wireless channel measurement techniques for high speed data networks.

Broadband wireless data systems incorporate significantly greater operational mode complexity than legacy voice systems. In analog voice radio systems, a continuous signal is transmitted, and reception often depends primarily upon the amount of signal power available to the receiving device and the noise power that the system must overcome at the receiving site. Relatively simple power-versus-frequency measurement methods suffice to determine the availability and quality of received signals.

By contrast, digitally modulated wireless data systems utilize higher system complexity to achieve higher capacity in the radio channel. The digital modulation itself is a case in point. Sampled digital RF modulation techniques quantize the signal in time as well as in some other parameter – frequency shift, phase, amplitude, etc. The time quantization leads to synchronicity issues. A receiver must ensure that it is synchronized at the RF level, often in both frequency and phase, as well as at the symbol level, i.e., the receiver carries precise information about the start and end time of a symbol. Loss of synchronicity at either level results in signal errors whose cause may be difficult to characterize.

Modern technologies like Wi-Fi, Wi-MAX, and LTE (Long Term Evolution) also embody a notion of rate-adaptive error correction and modulation. These devices change their error correction strength and modulation methods on the fly based on sensed information about the current conditions of the radio channel. In general, this includes the concept of closed loop control – messaging passing between mobile nodes and the base station that provides information about the local radio environment.

In turn, control messages imply control protocols. Systems of this type rely on proper adherence to well specified protocols for control and messaging. These systems are often said to be "stateful" — they have precisely defined states that respond only to certain messages. Messages that are correct in content but incorrectly sequenced will cause network failure, as will incorrect or incorrectly formatted messages.

All of these different mechanisms lead to a much broader error tree for current wireless networks than has been the case in the past. At the physical layer, historical concepts of signal power and signal to noise thresholds still apply. However, digital modulations create possible failure modes due to channel timing constraints that lead to intersymbol interference and excessive transmission retries, as well as errors in receive timing synchronization at either the RF carrier or the symbol level. The closed loop nature of current networks as well as their stateful nature means that errors may stem from confusion about modulation type or error correction level. Finally, protocol errors may cause system failure if messages are incorrectly formed or exceed timeout thresholds, or if optional proprietary parameters are included in messages meant for devices from the same manufacturer that are instead received by different manufacturers' systems.

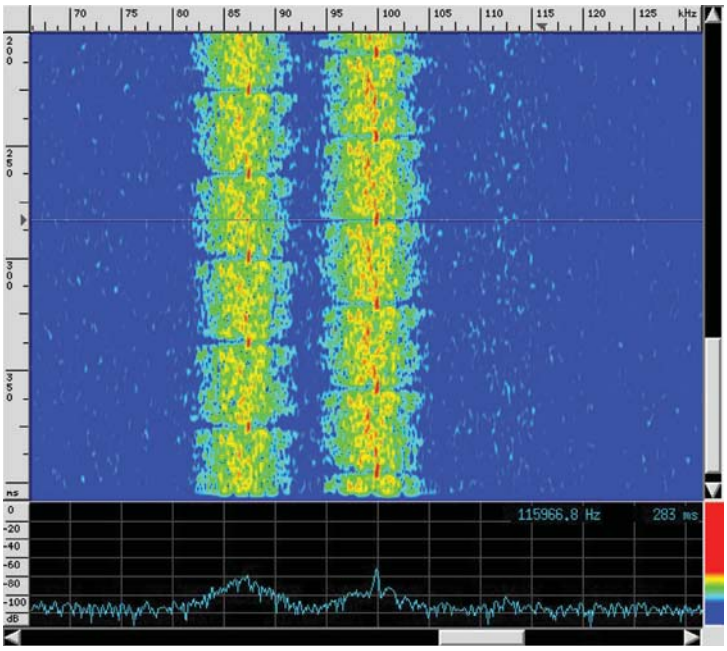

Figure 1. Spectrogram of SDR P-25 trunking control channel capture.

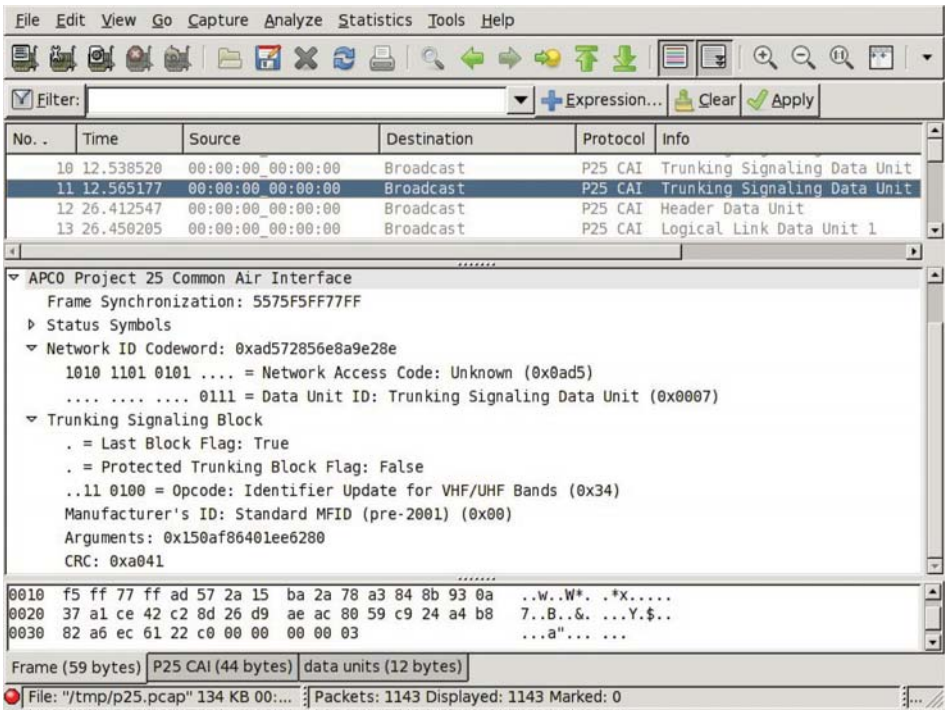

Figure 2. Network trace from P-25 trunking control channel.

This complex testing environment makes great demands on test instruments. In many cases the testing device can no longer be a passive receiver, but must respond with correct protocol and control information to bring the system under test into the desired state for the test to proceed. In other instances, the test instrument must intentionally provide incorrect responses to the target system, to determine if error sensing algorithms in the system under test are operating correctly.

Software defined radio (SDR) systems offer a possible solution to the demands of this complex testing regime. They typically allow a high degree of configuration flexibility, and some current development platforms include multiple receivers and transmitters on the same motherboard, allowing software control of transmission and reception on multiple frequencies simultaneously. ITS investigations into test instrumentation capabilities of this technology have demonstrated applicability in multiple tasks, from acting as an RF recorder/retransmitter and spectrum analyzer to potential use as an inexpensive sensor system for MIMO (multiple input multiple output) research. A spectrogram from one experiment using an inexpensive SDR platform is shown in Figure 1.

In this series of experiments, an SDR platform was configured as an APCO Project 25 trunked radio control channel receiver. A software plugin with the ability to decode the control message protocol was devised to enable the use of a standard digital network trace tool to evaluate the control messages being sensed by the SDR platform. A screenshot from this operation is shown in Figure 2.

As wireless data systems become more heavily used by multiple Federal and civilian agencies, the ability to rapidly configure specialized test instrumentation for unusual test cases becomes more important. The availability of low cost SDR development platforms that are easily programmed to respond to various radio protocols and offer a high degree of modulation flexibility may be crucial to future work on state of the art high speed data systems. Future systems promise to become even more complex than present technology — the use of low cost SDR based test instrumentation is an important tool to help ensure that Federal wireless systems remain on the cutting edge of the technology.

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