COMMERCE SPECTRUM MANAGEMENT ADVISORY COMMITTEE
(CSMAC)

WORKING GROUP 4
FINAL REPORT

Transition of Federal Land Mobile Radio Systems to Increase Spectrum Efficiency

December 10, 2008

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WORKING GROUP 4 (OUTLINE & DRAFT V1) REPORT:

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1. INTRODUCTION

In May 2003, the "Spectrum Policy Initiative" ("SPI") was established which called for "a comprehensive review of spectrum management policies . . . with the objective of identifying recommendations for revising policies and procedures to *promote more efficient and beneficial use of spectrum without harmful interference to critical incumbent users.*"[1] Shortly thereafter, the President also articulated a national goal — the universal affordable access to broadband technology.[2]

The SPI directed the Secretary of Commerce, after consultation with other agencies and public meetings, to prepare reports with recommendations for:

- Facilitating a modernized and improved spectrum management system;
- Identifying policy changes that would create incentives for more efficient and beneficial use of spectrum,
- Encouraging scientific research and developing methods for streamlining the deployment of new and innovative technologies, while preserving national security, homeland security, and public safety;
- Addressing the spectrum needs associated with critical government functions, such as national security, homeland security, and public safety.[3]

These reports were released in June 2004 and, among other things, recommended:

- Establishing a Commerce Spectrum Management Advisory Committee ("CSMAC") "to advise the Assistant Secretary of Communications and Information, Department of Commerce on needed reforms to spectrum policies and management to enable the introduction of new spectrum dependant technologies and services including expediting America's access to broadband services;[4]

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[1] Presidential Memo on Spectrum Policy: Spectrum Policy for the 21st Century, 39 Weekly Comp. Pres. Doc. 726, 727 (May 29, 2003) ("SPI Memo"), *available at* http://www.whitehouse.gov/news/releases/2003/06/20030605-4.html.

[2] Remarks by the President on Home ownership, Before the Expo New Mexico, Albuquerque, New Mexico (Mar. 26, 2004), *available at* http://www.whitehouse.gov/news/releases/2004/ 03/20040326-9.html.

[3] SPI Memo at § 2.

[4] *See* Spectrum Policy for the 21st Century — The President's Spectrum Policy Initiative: Report 2 — Recommendations from State and Local Governments and Private Sector Responders at B-2 (June 2004) ("Report 2").

- Creating a Test-Bed for the purpose of evaluating technologies and methods for improving spectrum sharing between federal government and non-federal government users;[5] and
- Facilitating interoperability of first responder communications and other government communications.[6]

In November 2004, the heads of executive departments and agencies were directed to implement the recommendations from the June reports. In response, the Secretary of Commerce established the SMAC and instructed the committee to focus on, among other things:

> Expediting the introduction of wireless broadband services; addressing governmental and commercial concerns regarding public safety spectrum management issues; . . . assisting in efforts to encourage the establishment of long-range spectrum planning processes; . . . gathering input on the latest technology and market trends; examining the latest radio-frequency research and development outputs; and evaluating the value of spectrum to the public and private sectors.[7]

At the February 8th 2008 CSMAC meeting, new working groups were formed. Working Group 4 was given the following mandate:

<u>Analysis and Preparation of Recommendations Concerning the Transition of Federal Land Mobile Radio Systems to Increase Spectral Efficiency</u>

Background

NTIA's Office of Spectrum Management (OSM) and Institute for Telecommunication Science (ITS) have conducted a series of reports on Federal government management and actual usage of selected Federal land mobile radio (LMR) bands. These reports led to the conclusion that significant improvements in spectrum efficiency in Federal LMR bands could be achieved by, *inter alia*, shifting to trunked rather than conventional architectures in providing service to government users. During 2007, Working Group 4 of the CSMAC undertook a broader study to identify opportunities for introducing more spectrally efficient technologies into Federal government systems that utilize radio spectrum. The focus of the effort was on providing NTIA with visibility into private sector experience in developing and deploying more spectrally efficient devices/systems. Like the more specific studies conducted by organizational units of NTIA, the interim report of Working Group 4 entitled "Government Opportunities for Government Adoption of Commercial Technologies" also concluded that Federal government radio systems could benefit in terms of spectrum efficiency and other measures by adopting certain commercially available technologies to the extent that they have not done so already.

Description

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[5] *Id;* Spectrum Policy for the 21st Century — The President's Spectrum Policy Initiative: Report 1 — Recommendations of the Federal Government Spectrum Task Force at B-2 (June 2004) ("Report 1").

[6] Report 1 at B-2.

[7] SMAC Charter at 1.

The purpose of this task is to provide the full committee with policy alternatives and supporting analyses that will allow the CSMAC to provide NTIA with policy advice and recommendations on realistic methods for transitioning Federal government LMR systems to more spectrum efficient systems while maintaining or improving on the effectiveness of the services provided to end users. This report will also discuss the evolution of LMR to wireless broadband systems. In conducting this task, the working group of the CSMAC reviewed the various studies prepared by the organizational units of NTIA as well as build upon the results of the interim report prepared by Working Group 4 during CY 2007.

2. WG4 ACTIVITIES

The committee received two written contributions:

A contribution from Motorola ("*Technology Solutions to Improve Federal LMR Spectrum Efficiency*" prepared by Bruce Oberlies, Randy Ekl, Brad Hiben, Stu Overby, Government and Public Safety business Enterprise and Mobility Solutions group, Motorola, Inc. was provided.

Written contributions from John Hoadley and Mike Lynch at Nortel were provided for Sections 4.2, 5 and 7.

Discussions were held and input was provided by staff at NTIA regarding topics in Section 3.

Material from these contributions has been extracted and summarized to form the basis for this draft report from WG4 and the suggested conclusions in the area of mobile radio systems.

3. SCOPE

This document will provide recommendations for the evolution of voice / LMR and wireless broadband radio systems that use government spectrum.

The following extract from the "Spectrum Management fro the 21st Century – The President's Spectrum Policy Initiative" March 2008, Department of Commerce outlines some of the immediate Federal voice / LMR challenges.

> **Improving Spectrum Efficiency by Narrowbanding Land Mobile Channels**
>
> NTIA recognized in 1993 that the critical land mobile communications bands of 162-174 MHz and 406.1-420 MHz were becoming congested and that future spectrum requirements would not be likely to be met under the 25 kHz channel plans.[37] NTIA concluded that the spectrum efficiency could be almost doubled if the channelization was halved to 12.5 kHz thereby enhancing the possibility of satisfying future requirements. This reduction in channel size is called narrowbanding.[38]
>
> With the advice of the IRAC, NTIA adopted 12.5 kHz channel plans for the 138-150.8 MHz, 162-174 MHz, and 406.1-420 MHz bands. For the latter two bands, conformance was required by 2005 and 2008 respectively, providing a transition period of ten years.[39] Because of fiscal and administrative constraints, not all of the Federal agencies expect to comply with these mandates. For example, narrowbanding is one of the Department of Homeland Security's (DHS) three major spectrum-related issues. New, narrowband equipment suitable for Federal missions has been slow to reach the market, and there is potential for interference from the not-yet transitioned 25 kHz systems.

The long term challenge will be to ensure that the government has adequate spectrum to support both the continued use of narrowband technologies where needed and that allows it to leverage commercial technology for efficient broadband wireless services.

4. TECHNOLOGY SOLUTIONS TO IMPROVE SPECTRUM EFFICIENCY

4.1 Technology Solutions to Improve Federal LMR Spectrum Efficiency

Federal LMR users typically employ conventional systems at the agency level with little, if any, sharing of spectrum or system capacity between agencies. This mirrors the status of many of the regional and state systems a decade ago. States, counties and regional areas have made significant progress in interoperability and spectrum utilization through shared systems which are typically trunked radio communication systems.

The NTIA report on the "Assessment of Alternative Future Federal Land Mobile Radio Systems" evaluated the 100 mile area around Washington DC and concluded that the 162-174 MHz band efficiency could be improved by using trunked LMR shared systems.[8] Phase 1

[8] NTIA Report 08-451, December 2007, pg iii

Project 25 interoperable digital equipment with backward compatibility to legacy analog systems are readily available to help meet that initiative. Phase 2 of the Project 25 standards, which is still under development, will further improve this efficiency. In order to gain these efficiencies, agencies should aggregate their spectrum and system resources into shared networks. Today, 31 of the 50 states have implemented or are in process of implementing their own statewide system to support multiple agencies including state, local and sometimes federal agencies.

However, there are challenges and opportunities to move to trunking architectures in the federal LMR spectrum. Trunking architectures routinely provide their greatest benefits in an environment when the bands are organized, i.e., a standardized pairing is available, etc. However, the Alaska Land Mobile Radio system has implemented a novel solution to overcome the challenge of implementing a trunking system in the unorganized VHF band. Digital trunking systems not only improve the spectrum efficiency but also provide additional value with the option of adding dedicated data channels, improved interoperability, and expanded operational features. In addition, the promise of multi-band software defined radios on the horizon and cognitive radio technologies under development offer additional potential long term spectrum access and efficiency opportunities.

Trunking Efficiencies

Trunking radio systems are efficient system designs that allow a large number of users, whether within the same agency or across different agencies, to communicate using fewer communication channels than conventional radio systems. Trunking systems are ones that assign available channels as users initiate a call. The access control scheme will balance the calls across a fewer number of channels than a conventional system where users must wait for the channel to become available or manually hunt for an available channel. This frees up channels, providing better spectrum efficiency and generally a higher quality user experience.

An industry rule of thumb for trunked systems is that one channel pair normally supports 70 to 100 users under normal circumstances. In urban areas where the number of users is far greater, public safety entities may load 150 or so users on a channel with somewhat longer access delays, simply because they have no alternative given the lack of spectrum to expand in the band in which they are operating. Industry experience is that as the number of users approaches 175 to 200 users per channel, the delays become unacceptable to achieve their mission.

Spectrum efficiency is one element of system capacity. Systems compliant to the APCO Project 25 Phase I standard (P25 Phase I) are twice as efficient as previous 25 kHz analog conventional systems because they operate within a 12.5 kHz channel and still provide the same type of one-to-many communications capability on each channel as well as equivalent or superior range and frequency reuse distances. When the system requirements warrant 5 channels or more, P25 trunking systems will generally have more capacity than P25 conventional systems. The capacity of trunked and conventional systems can be looked at several ways. One way to quantify capacity is to consider the amount of load that result in a particular grade-of-service. A common measure of grade-of-service is the probability of a channel being available when a user wishes to initiate a call on their radio. The offered load that results in some blocking probability, say 5%, is taken as the capacity of the system. The probability of a delayed call can be calculated with the Erlang-C model of traffic theory and results in capacities given in Table 1 along with the amount that trunking improves capacity.

# of Channels	Conventional Capacity (Erlangs at 5% probability of delay)	Trunking Capacity (Erlangs at 5% probability of delay)	Trunking Factor Gain in Capacity (Trunked Capacity / Conventional Capacity)
1	0.05	0.00	n/a
5	0.25	1.15	4.6
10	0.50	4.20	8.4
15	0.75	7.15	9.5
20	1.00	10.35	10.35

Table 1, Trunking Capacity Gain

Another way to quantify grade-of-service is the average wait time when access is delayed. Load can alternatively be expressed as a given number of users given an average call length and call rate per user. Other quantities have been and are used depending on what system procurement officers are concerned about and what they know about their user needs. The different metrics may result in different capacities and different levels of capacity improvement for trunked systems.

Project 25 Phase 1 refers to a set of technical documents that collectively define Project 25 for conventional and trunked systems operation, accompanied by a set of mandatory and optional features, both of which are standardized. The P25 Phase 1 standards are complete and published. Multiple manufacturers compete with infrastructure and subscriber products, delivering a defined set of features and services for both conventional and trunked systems. The P25 Phase 1 standard has enabled public safety agencies to deploy digital systems designed for their needs which support interoperability across departments, multiple agencies and jurisdictions.

The P25 Phase 2 standard under development will further improve efficiency and overall capacity for voice systems. The proposed standard for trunked systems will support two voice paths on each 12.5 kHz channel. Rather than splitting the channel further to a 6.25 kHz bandwidth, P25 Phase 2 uses two-slot time division multiple access (TDMA) and maintains the 12.5 kHz channel to provide a 6.25 kHz equivalent efficiency. This proposed air interface standard will address the Federal Communication Commission's regulations that require a 6.25 kHz efficiency capability in VHF/UHF equipment certified after January 1, 2011 and in the 700 MHz band after January 1, 2014. P25 Phase 2 equipment is also expected to be used voluntarily in the 800 MHz band.

A relatively new standardization activity, the responsible P25 and TIA committees are projecting completion of a series of documents defining the P25 Phase 2 standard in the late 2008 or early 2009 time frame. New system deployment is anticipated beginning approximately twelve to eighteen months from completion of those documents. Upon completion of the two-slot 12.5 kHz air interface, based upon user requirements and market demand, additional work may commence to develop a four-slot 25 kHz air interface.

Both the completed P25 Phase 1 standard and the P25 Phase 2 standard under development align with the current NTIA 12.5 kHz channel plan. Systems being planned to utilize trunking architecture can increase efficiency with Phase 1 and further improve the capacity by moving to the Phase 2 standard in the future. The TDMA approach in the Phase 2 standard brings the additional benefit of improving battery life for portable users because the transmitter is transmitting half the time during voice calls. However, while some interest has been expressed in TDMA for conventional operation, no current standard activity is in place.

The recently completed NTIA study on "Assessment of Alternative Future Federal Land Mobile Radio Systems"[9] investigated three alternative trunked LMR system architectures within 100-mile radius area centered in Washington DC in 162-174 MHz Federal band. The study found that fewer channels are required for all three system architectures than what is required for the existing conventional systems. Moving to P25 Phase 2 TDMA standard equipment will double the number of available channels while providing improved user value.

Shared Networks Case Studies

The organized system design that a trunking system provides gives greater flexibility in provisioning the users into talk groups. This flexibility also allows multiple agencies to be hosted on a trunking system providing the required intra-agency communication for day to day communications while allowing for critical interoperable inter-agency communication when the need arises. This enables the concept of shared system architecture for first responders, especially in a regional or statewide geography, bringing state agencies, local county and municipal first responders as well as federal agencies together onto a common network for shared voice and data services. These benefits are available today with P25 Phase 1 and are being carried forward as well with P25 Phase 2.

The State of Michigan has taken a leadership role in supporting interoperable communications with the deployment of the Michigan Public Safety Communications System (MPSCS)[10]. The MPSCS began in 1984 when the Michigan State Police formed a committee to evaluate its existing two-way radio system. In June of 1994, the Michigan Legislature approved the funding for the new system. In September 1995, the state broke ground on Phase One construction which was officially completed in 1997. The project was completed in November 2002.

The Michigan Public Safety Communication System is the largest, most technologically advanced statewide 800 MHz Project 25 digital communications system for public safety use in the United States. It provides reliable digital mobile radio coverage to 97%[11] of the state for over 500 state, local and federal agencies and serves more than 27,000 users.

State agencies include the Michigan State Police, Department of Natural Resources, Department of Corrections, Attorney General, Emergency Management Division, Military Affairs, and DHS. Federal agencies include Border Patrol, ATF, Customs, FBI, DEA, and US Forest Service. Local entities include public safety agencies in over 25 counties, as well as tribal police operations. The MPSCS also serves as the primary communications system for the public safety

[9] NTIA Report 08-451, December 2007

[10] http://www.michigan.gov/mpscs

[11] http://www.michigan.gov/mpscs/0,1607,7-184-25394-71408--,00.html

responders in Michigan's border areas. The City of Detroit, Macomb County, St Clair County and Chippewa County all use the MPSCS.

Local agencies have the option of customizing the coverage of the system to meet their needs for in-building coverage. Genesee County, Monroe County, City of Detroit, Macomb County, City of Battle Creek, City of Ionia, Berrien County, Kalamazoo County, Livingston County, and Mason County have all added to the system infrastructure to meet their coverage requirements. As an example, the city of Detroit has deployed its own trunking system that was integrated into the MPCSC. The network control centers are mutually backed up on the two systems. Agencies that are not ready to buy a new system can link their existing radio systems to the network.

The State of Alaska's Alaska Land Mobile Radio (ALMR) network is the United States first statewide digital trunked radio network that combines state, federal and local resources. The system implementation starts with coverage for the road system where 80% of the population is concentrated, it will grow to cover the entire state. Fifty-six state, federal and local agencies are operating on the system. State agencies include Alaska State Troopers, Alaska Fire Service, and Alaska Defense Service. Federal agencies ATF, Customs & Border Protection, DEA, FBI, US Army Alaska, US Forest Service, US Marshals, UAF PD.

In March 2003, a training exercise called Northern Edge was held. The ALMR system handled over 17,500 calls in 12 days for 1,500 participants across federal (Army, Air Force, Navy, and Coast Guard), state, and local (Valdez police and fire, EMS, and Valdez Community Hospital).

These two state networks are examples of the recent trend towards regional, multi-jurisdictional and multi-disciplinary LMR communication systems. This trend is fuelled by challenges common to the federal LMR radio systems: agencies operating on different aging communication systems and frequency bands, with a need to interoperate across a growing complex communication environment when funding for communication systems is difficult. These networks allow agencies to operate more cost effectively while providing agency autonomy. Since these networks are IP based, new agency systems can be added expanding the capacity and/or enhancing the coverage area of the network. These systems expected to evolve into interstate communication networks.

The Public Safety Wireless Network (PSWIN) program released a report identifying best practices for the approaches to improve interoperable communications. The "State and Local Interoperability Assistance Support-Statewide Strategy Best Practices"[12] report analyzed the approaches used by Mississippi, Tennessee and West Virginia as part of the interoperability assistance that PSWIN provided to the states. While the report identifies the best practices for state-wide interoperability strategies, both Mississippi and West Virginia were looking at shared state-wide communication solutions. "The actionable best practices derived from the analysis of the strategy-based assistance provided to these states included –

- Comprehensively develop political and stakeholder support

[12]http://www.safecomprogram.gov/SAFECOM/library/interoperabilitycasestudies/1068_statewidestrategy.htm

- Centralize coordination among multiple agencies through a formal committee
- Formalize coordination committees through executive orders, charters, or memorandums of understanding
- Emphasize coordination, partnership, and asset sharing
- Conduct detailed analysis of current needs and capabilities while planning future developments
- Prepare and provide a wide range of educational materials to stakeholders and decision-makers
- Sponsor communications and interoperability forums where officials can learn about current challenges and plans, provided input into the process, or learn how to get involved
- Solicit input from all interested parties or entities throughout the coordination, planning, and project processes
- Examine the successful strategies of similar states or regions."[13]

Regional and state-wide communication networks have shown the capability to provide both day to day mission effectiveness operability and incident response interoperability when needed for multiple federal, state, county, and city agencies. The best practices identified by PSWIN should be utilized to develop regional shared communication networks for federal use. The ALMR network is unique because it utilizes both federal NTIA frequencies as well as state FCC frequencies making it easier to overcome the challenges of trunking in the unorganized VHF and UHF spectrum. We recommend that NTIA work with all of the stakeholders including federal agencies to seek out opportunities to emulate this successful spectrum usage model with state and local entities in additional areas.

Technology Transition Challenges and Opportunities

Large regional and statewide communication systems require significant effort to identify and analyze the frequencies to be utilized across the service area considering the frequencies available, interference sources, propagation of the frequency band and minimum combiner separation issues. This becomes especially challenging when considering a trunking system architecture to provide improved spectrum efficiency in the non-organized VHF and UHF bands.

The 700 MHz and 800 MHz bands were planned for FDMA operation and are often called an "organized band plan" meaning that the transmit (TX) frequencies and receive (RX) frequencies are grouped into bands that are separated by, typically, tens of MHz. Figure 1 depicts an FDMA band plan showing a TX to RX frequency separation. Two key frequency selection considerations during system design are the transmitter to receiver frequency offset and the potential for intermodulation (IM) interference. The FDMA fixed TX to RX offset simplifies the base station and subscriber radio design as well as the system and site design. The base receiver must be capable of filtering out the power from its own base transmitter to avoid receiver overload and the base transmitter must filter it's transmit spectrum to keep its out-of-band

[13] "State and Local Interoperability Assistance Support-Statewide Strategy Best Practices", pg ES-1

emissions from interfering with its own receiver. Maximizing the TX to RX separation simplifies the filters needed for this. Practical filters support a minimum of 1.25MHz required separation between base station transmitters and receivers. The fixed TX to RX offset of organized bands allows standard turnkey solutions. The 3rd order IM interference potential is determined by the difference in the maximum and minimum transmitter frequency that will enter the receiver. If the TX/RX separation is greater than this separation 3rd order IM will not be an issue and if twice the difference 5th order IM will not be a problem. This is true for both the 700 and 800MHz LMR bands.

Figure 1, Organized FDMA Band with RX / TX Separation

Figure 2 depicts a typical VHF or UHF band that is being laid out for a large regional or statewide area. Note the lack of a clear separation between the transmit and receive bands. This makes the system and site design much more difficult. Each site will require unique combiners and multi-couplers which significantly complicates turn key solutions. Also, in order to avoid 3rd order interference in the system, fewer channels will be actually usable, impacting spectrum efficiency. Therefore, steps NTIA is taking for new systems to utilize a consistent 9 MHz Transmit/Receive pairing at 406-420 MHz should be beneficial.

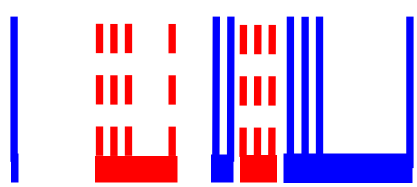


Figure 2, Unorganized Band with no RX / TX Separation

The previously discussed Alaskan Land Mobile Radio system had a novel solution to allow better utilization of the VHF spectrum. The ALMR system uses a spectrum-sharing agreement that calls for the federal government to donate VHF channels for the mobile and portable units, while the fixed infrastructure transmits signals over state-owned spectrum.[14] Figure 3 depicts the system frequency band with a TX/RX channel spacing of over 11 MHz and transmitter frequency difference of less than 3MHz preventing any 3rd or 5th order IM interference. If independent state and federal systems were to be developed using the existing sites 45% more channels would have been required.

[14] http://mrtmag.com/mag/radio_trailblazers/index.html, April 1, 2006

Figure 3, ALMR Frequency Plan

The ALMR system is a unique joint system arrangement between federal and state agencies, sharing spectrum and communication infrastructure. Moving the spectrum sharing model to the rest of the United States has challenges. In the high population states, the VHF spectrum is very crowded and shared across agencies making channels difficult to secure. There are also policy hurdles and agency exclusive-rights philosophies that must be overcome. For example it took the FCC two years to approve the ALMR agreement. [15] However, we believe there is value in emulating this successful spectrum use model where possible and encourage the NTIA and FCC to take steps that could shorten the time for approvals.

There is additional value when systems move from conventional to trunked systems besides just spectrum efficiency gains because the legacy communication system is typically a voice-only system. Most of the regional and state wide systems follow the Project 25 standards and several states are actively involved in upgrading their current networks to Project 25. The Project 25 standard includes a 9600 bps data service that can be implemented on dedicated data channels, as integrated voice and data channels on conventional systems, or allocated on an as-needed basis on trunked systems. The freed channels from implementing a trunking architecture typically go toward additional voice channels required by new users that are often added to the new shared system and/or to dedicated data channels that add new capability to the users.

These trends toward trunking and shared regional and statewide systems add significant additional value for the new system and increase the efficiency of the spectrum. However, these steps do not provide additional spectrum needed for long term growth of narrowband operations or new system capabilities such as broadband data and video which require much wider channels and significantly greater capacity.

Long Term Technology Solutions

Smart Antenna Technology

Multiple antenna systems that are embrace in the term Spatial Diversity Multiple Access (SDMA) technology have been proven to offer important improvements in spectral efficiency

[15] http://mrtmag.com/mag/radio_trailblazers/index.html, April 1, 2006

with concomitant reduction in deployment, maintenance, and engineering cost. SDMA includes such terms as MIMO, smart antennas, adaptive arrays, interference cancellation, and others. SDMA technology is presently deployed in hundreds of thousands of base stations serving many tens of millions of subscribers worldwide. Ironically, one example is a broadband system operating in Sioux Falls, S.D. today using SDMA technology in a system shared with local law enforcement agencies.[16] The spectral efficiency of an SDMA system used by Redwood Wireless Broadband Internet in Sioux Falls is sufficiently high that the combined use of commercial and law enforcement agencies does not tax system capacity even during emergencies. While this may not be true in larger communities, it is fundamental to such systems that governmental agencies could be provided priority over commercial service to any desired degree by merely throwing a software switch.

The improvements offered by use of SDMA technology are incremental to those introduced by trunking (as discussed above) and by cellular technology. For example, in the trunked systems data discussed earlier, it is possible, in a SDMA enhanced system, to conduct simultaneous transmissions between two or three users so long as the users are in separate locations. Effectively, this means achievement of two or more Erlangs. When cellular technology is added to such trunked systems (all cellular systems are, in fact, trunked) the improvement in spectral efficiency becomes markedly greater since all channels can be used in every cell in contrast to non-SDMA systems where re-use patterns of 7 are typical.

For reasons stated above, SDMA technology is now an inherent requirement in such emerging standards as mobile WiMAX (IEEE Standard 802.16e) and LTE.

Software Defined Radio and Cognitive Radio

Software Defined Radio (SDR) and Cognitive Radio (CR) technologies are maturing and will over time enable more efficient use of spectrum. SDR technologies, specifically multi-band technologies, will first provide an additional technical solution to enable and advance interoperability. As multi-band radios designed to meet the rigorous operational demands of local, state or federal agencies become more widely available they can help resolve some of the technology challenges discussed above. Cognitive Radio technologies will provide the next step forward beyond Software Defined Radios by enabling communication systems to utilize the "white spaces" in the spectrum under certain circumstances. The NTIA spectrum sharing test bed will provide a mechanism for the industry to better understand and mature these technologies.

Multi-band SDR subscriber radios will become available in the next several years that operate across several LMR bands operating in conventional and trunked modes. Local, state or federal public safety users can carry one radio to cover two or more bands, instead of multiple radios. Therefore a user could have greater built in capability to communicate to multiple agencies or levels of government who operate on different bands.

As the multi-band technology matures improving cost and performance they could become a useful tool to overcome the challenge of finding available channels with sufficient separation.

[16] http://www.redwoodwireless.com/index.php?cont=about.php#

Current generation trunking systems utilize IP technology across the core to the sites and thus only the sites are frequency dependent. Multi-band SDR radios could enable future regional and state-wide systems to leverage these IP anchored communication networks with frequency plans utilizing transmit and receive frequencies on different bands. While simplifying the system designer's challenge of identifying spectrum, this does not come without hurdles. The spectrum bands have different propagation properties creating a challenge to keep the link margins balanced. Agencies at local, state and federal levels with legacy radios also must be considered to insure interoperability.

Many studies have shown when analyzing segments of spectrum in both the time and frequency domains that portions are not used, often called "white spaces". For example, the television broadcast band has significant amounts of spectrum that are not used in a given location. The amount of whitespace spectrum varies within the TV band depending on the geographic location. However, due to the relatively large blocks of white space spectrum in the TV band where each vacant channel is 6 MHz and the relatively static nature of the TV band, it is relatively straightforward to deploy cognitive radio technologies that protect incumbent operations and allow viable access to the unused white space spectrum. CR technologies are currently being developed to utilize these white spaces enabling more efficient use of spectrum. CR techniques can protect the primary user through various mechanisms, such as Geolocation and sensing.

Geolocation functionality utilizes the known information of the potential white space user, as well as information on the incumbent system location and coverage area to establish viable frequencies for operation at a given location. The CR pulls this data from a database and applies service contour formulas (or simulations) to determine which frequencies can be used in a geographic area and which frequencies can not be used, as they may cause interference to the incumbent users. Geolocation techniques are robust and low risk, given that the correct transmitter / receiver repeater data is in the database.

The August, 2006 report "Federal Land Mobile Operations in the 162-174 MHz Band in the Washington, D.C. Area"[17], which focused on the phase 1 study of Agency Operations in the Washington DC area, discusses some of the same topics as above. Most specifically, it discussed the Government Master File (GMF) and determining the useable and non-useable channels per geographic area, based on models that they used. In essence, this is the Geolocation technique, and would lead to increasing geographical frequency reuse, and increasing the number of users on a given frequency over an area, especially as more exact models are developed.

The geo-location database, in this case, could be the Government Master File (GMF). The GMF contains records of the frequencies assigned to all US Federal Government agencies in the US and its possessions. It also includes non-Federal authorizations coordinated with NTIA for the bands allocated for shared Federal and non-Federal use. The GMF includes transmitter power, antenna location, frequency, bandwidth, and user, along with possibly other information and is updated daily.[18]

[17] NTIA Report 06-440, August 2006

[18] Department of Commerce, Office of Radio Frequency Management, Main page - http://www.orfm.noaa.gov/

The database updates can be distributed in a timely manner. An extension to the GMF would be to have it include hours of operation for a particular system, so that other users would have full access to that frequency during the off-hours. However, because the GMF database is classified and therefore inaccessible by non-federal users, so today, as a practical matter cognitive radio applications would be limited to additional federal users. Any use of these cognitive radio techniques across local, state and federal users will require that NTIA tackle ways to make at least some portion of the information in the GMF more available. Releasing all unclassified information within GMF database could accelerate the use of cognitive radio techniques.

Ray tracing can be used to determine the appropriate transmit power to avoid co-channel and adjacent channel interference. This would give more accurate results than “flat” contour-determining formulas. Contour formulas are a conservative, possibly overly protective of incumbents, whereas ray tracing is more aggressive and would lead to greater spectrum access. If any interference issues are discovered post-deployment, then the database can be updated and/or models and formulas can be adjusted to resolve the interference issues.

A second technology used for Cognitive Radio is Spectrum Sensing. In particular, sensing is done for two reasons, first, to determine if an incumbent is in the area, and second, to determine the general activity (noise) on a particular channel. If an incumbent is sensed, then the channel that the incumbent is using would be avoided. In this context, an incumbent can be a permanent primary user or an indicator, such as a beacon signal, that the channel is being used temporarily.

Sensing techniques, as they are solely RF-based, are not flawless. They inherently have problems which effect RF signals, those being other interference, obstructions causing hidden node problems, fading, and so forth. However, sensing can achieve a high degree of reliability, especially for higher power, narrower bandwidth signals in open areas and when beacons are properly designed. Geolocation generally provides a lower risk of interference than sensing-only technologies, and combining the two techniques would give the highest degree of reliability.

While white space operation may be viable in the TV band, using similar approaches in bands used for mobile operations requires additional examination. The NTIA / FCC spectrum sharing test bed will examine using CR techniques, including Geolocation and Spectrum Sensing, to investigate better utilization of NTIA and FCC spectrum. In addition to these techniques, the test bed will allow participants to exhibit other techniques to prove business viability, such as channel aggregation. Channels could be opportunistically aggregated, so that more data can be transmitted when more channels are determined to be available. The result of sending more data earlier, when possible, is that channels are not utilized for as long of a period of time. This would be an end user measure of efficiency, i.e. the overall time to transmit a fixed amount of data is decreased. Different mechanisms could be used for the aggregation, but opportunistically aggregating channels together using OFDM technology based on spectrum availability shows the most promise at the present time.

Summary Technology Solutions to Improve Federal LMR Spectrum Efficiency

Regional and state communication systems have shown the ability of supporting and attracting local, state and federal agencies to provide day to day operability and incident response interoperable mission critical communications. These systems are expected to evolve into interstate communication networks. The efficiency of federal LMR spectrum will be improved by following this trend and implementing Project 25 trunking systems that can serve more users, whether in the same agency or across multiple agencies. P25 Phase 1 trunked systems that are readily available and proven in the public safety environment offer a spectrum efficiency gain over 2X that of a conventional 25 kHz channel analog system. Future migrations to Phase 2 Project 25 TDMA standard can provide an additional two-fold increase in efficiency, with products expected to be available in the 2010 – 2011 timeframe. Typically these shared systems not only include voice channels but utilize dedicated data channels to enhance the productivity of the users while providing additional value and increasing the efficiency of the spectrum.

Most federal LMR spectrum is not organized under a standard transmit/receive pairing, which can impact the potential spectrum efficiency gains in regional communication system designs. Steps NTIA is taking for new systems to utilize a consistent 9 MHz Transmit/Receive pairing at 406-420 MHz should be beneficial. Also, the Alaska Land Mobile Radio communication network utilized both federal NTIA frequencies as well as state FCC frequencies to overcome this challenge. This has enabled this network to use 31% fewer channels than otherwise would have been required.

In the long term, software defined radios and cognitive radios will enable further spectrum efficiency. Multi-band SDR radios will help overcome the inefficiencies caused by the non-organized spectrum by separating the trunking receiver and transmitter frequencies across different bands. However, the system design to keep the link budget balanced across the bands will be a challenge.

Cognitive radio technologies hold the promise of using spectrum white spaces as a secondary use. The NTIA spectrum sharing test bed will provide a mechanism to test and mature cognitive radio technologies such as geo-location and spectrum sensing to protect incumbent primary users of the spectrum.

4.2 Evolution to Terrestrial Wireless Broadband Communication Technologies

This report would be remiss not to discuss the future requirement for government wireless broadband communication applications, solutions and spectrum. Widely used, cost effective government wireless broadband applications are not available today however, it is clear that wireless browsing, collaboration and video applications will significantly improve the efficiency and effectiveness of many government employees.

As the previous WG4 CSMAC report titled, “Opportunities for Government Adoption of Commercial Technologies” - Issued February 25, 2008 stated, the cost and innovation advantages of basing government radio solutions on mainstream commercial technology are overwhelming. The need to select a limited number of government wireless broadband technologies is critical to ensure that users can roam (inter- region activities) and the government gains scale of economy and cost benefits.

Fortunately, the existence of a well defined set of commercial 3G and future 4G wireless broadband standards means the government selection process is simplified.

This report recommends that the government deploys interagency shared, national wireless broadband solutions. A single 3G technology for initial broadband wireless should be deployed. The two commercial 3G technologies that can provide wireless broadband are EV-DO Rev A / eHRPD (3GPP2 standards) and HSPA (3GPP standards). These standards are already deployed in volume regionally by the leading commercial wireless operators. Teaming with the commercial wireless operators will allow the government to enjoy the benefits of wireless broadband in a cost effective manner. This allows the government to avoid the massive fixed costs (towers, base station site construction, network sites & buildings, maintenance & operation staff) of a dedicated wireless network. This should allow the government users to pay a price that is closer to the incremental cost of the 3G service.

For the sake of operational efficiencies and roaming, it would be advantageous for the Federal government, if they could gain access to the 700 MHz D block spectrum. This would require the same regional and national technology approach and recommendations for the 700 MHz D block.

For 4G wireless broadband government service, this report recommends that the use of either LTE or Mobile WiMAX (802.16e). Both of these technologies implement SDMA / OFDM. A single 4G commercial standard should be adopted by the government as the base for all of its 4G broadband requirements. It is recommended that the government selects either LTE or Mobile WiMAX based upon the determination of which has the greatest commercial support over the next 10 or more years. LTE or Mobile WiMAX standardization is recommended to ensure roaming capabilities, scales of economy and interoperability.

At present, it appears that the LTE and WiMAX 802.16e standards will dominate the commercial wireless broadband market. This provides a unique opportunity for the government to adopt and leverage commercial 4G technology early in its technology lifecycle. LTE is the consensus 4G technology for most global carriers Verizon Wireless, AT&T, US Cellular , TMO, Vodafone, China Mobile, Orange, NTT DoCoMo, KDDI ... LTE has established itself in standards as the 4G evolution for both EV-DO (3GPP2) and HSPA (3GPP) thus ensuring interworking with the recommended 3G government wireless broadband technologies. Mobile WiMAX should also be considered since its is earlier to market than LTE and has the support of Clearwire (Sprint, Comcast, Time Warner…) and many international incumbent and start-up operators in developing countries.

It is recommended that the government continues to monitor the global adoption and support for both LTE and Mobile WiMAX and mandates a single 4G standard prior to government deployments.

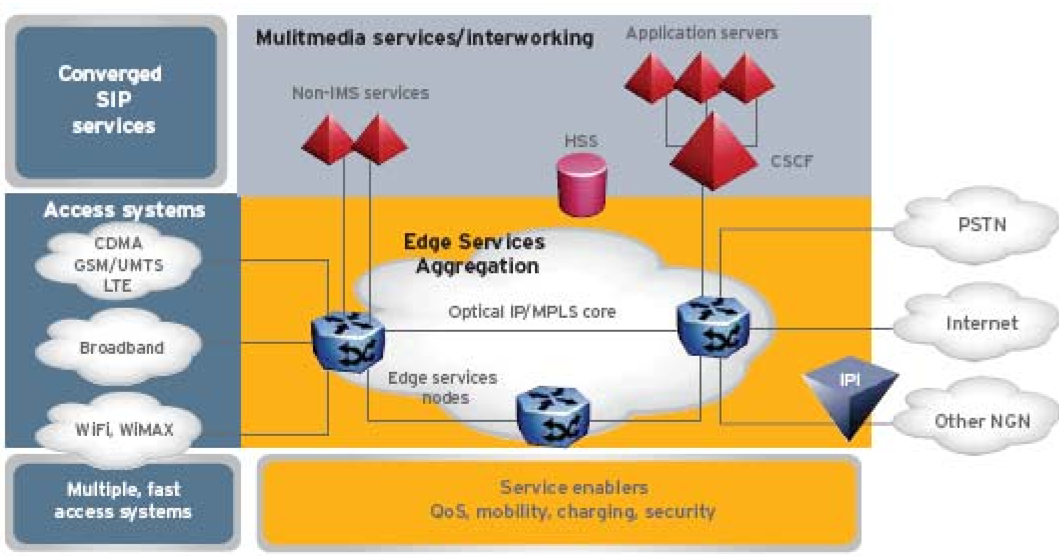
Terrestrial Wireless Broadband Communication Solutions

With commercial wireless networks, there is an expanding requirement from a growing pool of 3G wireless users that can be satisfied with next-generation / 4G networks. Key government 4G services will include video streaming, real time video, browsing, and collaboration. These applications are starting to gain traction in commercial networks and can be adapted for government needs, such as emergency response, surveillance etc. 4G networks will also provide the capacity to support a growth in demand for connectivity from a new generation commercial devices tailored to those new mobile applications.

This report recommends that the government plays an active role evaluating and contributing to both the LTE and WiMAX 802.16e standard. With these new 4G technologies, the government can have significant impact upon adding special government features and requirements. The initial WiMAX 802.16e standard was published in late 2005 and an ongoing process exists to publish WiMAX standard revisions. The 3GPP Release 8 LTE specification is expected to be completed by the end of 2008. Many enhancements including support for emergency services are to be added in Release 9, which is scheduled for the end of year 2009 publication. It is easier for government to add new requirements in Release 9 than trying to retrofit deployed systems. As an example, early government involvement in 802.11 WiFi standards would have avoided many security challenges that were encountered later.

LTE and WiMAX 802.16e encompass the following pillars of next-generation networks:

- **Broadband wireless as the new access reality –** High-throughput, low-latency mobile access based on OFDM/MIMO, efficiently delivering unicast, multicast and broadcast media.
- **Convergence of technology and networks –** A single applications domain serving customers across multiple networks and devices.
- **Intelligence at the services edge –** Implementing policy enforcement and decisions at the network edge, in an access-agnostic but access-aware framework.
- **Technology shift to all-IP –** Simplifying the network, improving scalability and deployment flexibility, and enabling consistent access-aware policy enforcement.
- **Embedded security –** A multi-layer, multi-vendor approach to security is critical to ensure that security is endemic to the network and not just focused on point solutions.



4G Wireless Access: Using LTE as an Example

The challenge for next-generation wireless networks is to provide wireless broadband performance better that that achievable with wireline broadband technologies, while maintaining seamless mobility, service control and maximizing network capacity with limited spectrum resources.

Specific requirements addressed by the LTE and WiMAX 802.16e standards are:

- Low-latency and high-throughput
- Efficient always-on operations, with instantaneous access to network resources
- Support for real-time and non-real-time applications
- Flexible spectrum allocations
- Re-use of existing cell site infrastructure
- High spectrum efficiency for unicast, multicast and broadcast data

In addition to the requirements above, there is a set of minimum performance requirements defined by the 3GPP LTE studies. These objectives include:

- **Increased spectral efficiency and capacity –** LTE is expected to deliver three to five times greater capacity than the most advanced current 3G networks.
- **Lower cost per bit –** Increased spectral efficiency combined with the operational benefits of an all-IP network will reduce the cost per bit compared to 3G solutions.
- **Improved quality of experience (QoE) –** One of the benefits LTE/SAE will bring is a reduction in latency time, which will enhance the behaviour of time-sensitive applications, such as VoIP, thus improving the user experience. For example, the latency time, expressed as the time for a 32-byte Ping, is expected to reach 20 ms (compared with 120 ms for a typical 3G network).

Two key enabling technologies will help to meet and exceed the 4G performance objectives:

- **Orthogonal Frequency Division Multiplexing (OFDM)** is intrinsically able to handle the most common radio frequency (RF) distortions without the need for complex equalization techniques, and scales easily to fit different bandwidth requirements.
- **Multiple Input/Multiple Output (MIMO)** increases peak throughput by transmitting and receiving multiple streams of data with the same spectrum. MIMO exploits the multi-path effects typical in wireless environments.

The combined use of OFDM and MIMO will improve the spectral efficiency and capacity of the wireless network, and will prove to be a very valuable asset in maximizing usage of scarce spectrum resources.

OFDM is already an extremely successful access technology currently deployed in a number of wireless and wireline applications. These applications include broadcast (Digital Audio Broadcast or DAB, and Digital Video Broadcast or DVB), wireless WLAN (IEEE 802.11a and IEEE 802.11g), WiMAX (IEEE 802.16) and wireline Asynchronous Digital Subscriber Loop (ADSL/ADSL2+). OFDM is widely accepted as the basis for the air-interface necessary to meet the requirements for next-generation mobile networks.

MIMO employs multiple transmit and receive antennas to substantially enhance the air interface. It uses space-time coding of the same data stream mapped onto multiple transmit antennas, which is an improvement over traditional reception diversity schemes where only a single transmit antenna is deployed to extend the coverage of the cell. MIMO processing also exploits spatial multiplexing, allowing different data streams to be transmitted simultaneously from the different transmit antennas, to increase the end-user data rate and cell capacity. In addition, when knowledge of the radio channel is available at the transmitter (e.g. via feedback information from the receiver), MIMO can also implement beam-forming to further increase available data rates and spectrum efficiency.

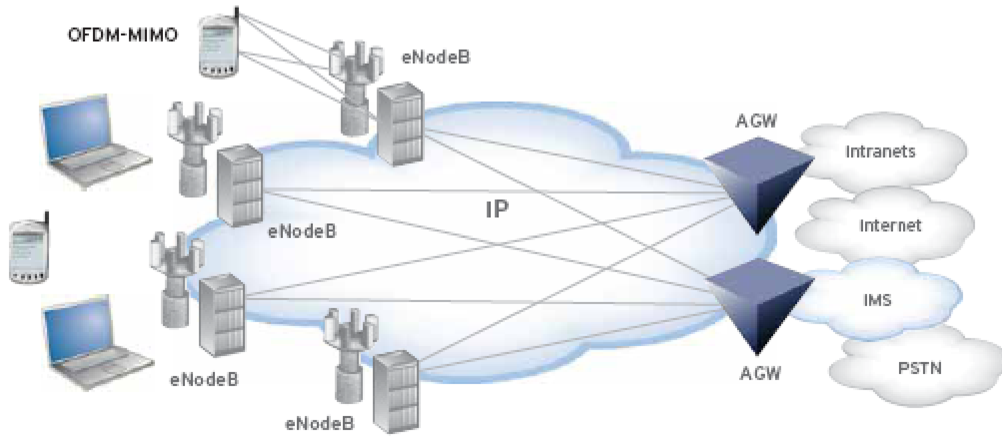
It has been shown that OFDM-MIMO with beam-forming **–** or Spatial Division Multiple Access (SDMA) **–** can provide a higher order of magnitude capacity on the downlink than current 3G deployments. It has also been shown how multiple antennas could be deployed on the user equipment, an especially challenging requirement with severe space constraints.

Simplified architecture: Using SAE as an Example

To meet the technical and performance requirements noted previously requires a reduction in the number of network nodes involved in data processing and transport. The flatter network architecture implemented by both LTE and WiMAX 802.16e lead to improved data latency (the transmission delay between the transmitter sending data and the receiver receiving it) and better support of delay-sensitive, interactive and real-time communications.

Using LTE as an example, a typical LTE/SAE network will have two types of network elements supporting the user and control planes.

- The first is the enhanced base station, so called **"**Evolved NodeB (eNodeB)**"** per 3GPP standards. This enhanced BTS provides the LTE air interface and performs radio resource management for the evolved access system.
- The second is the Access Gateway (AGW). The AGW provides termination of the LTE bearer. It also acts as a mobility anchor point for the user plane. It implements key logical functions including MME (Mobility Management Entity) for the Control Plane and SAE PDN GW (SAE Packet Data Gateway) for the user plane. These functions may be split into separate physical nodes, depending on the vendor-specific implementation.



Comparing the functional breakdown with existing 3G architecture:

- Radio Network elements functions, such as Radio Network Controller (RNC), are distributed between the AGW and the eNodeB.
- Core Network elements and functions, such as SGSN and GGSN or PDSN (Packet Data Serving Node) and routers are distributed mostly towards the AGW.

Standards are expected to be finalized by the end of 2008.

Convergence and services edge

Key requirements focus on user quality of experience, service innovation and network simplification and evolution. Specifically these include:

- Service-oriented architecture supporting diverse service classes
- Content-based charging
- Operator policy control of services and networks
- End-to-end QoS
- Service and network roaming support
- Technology co-existence
- Open interfaces
- Scalable, evolvable network elements

Adoption of a Service-oriented Architecture (SoA) is desirable in order to reduce the time spent from service creation (or development), to deployment, to execution, and therefore improve service innovations. SoA facilitates cost-effectiveness and acceleration of the time to move from conception to execution.

Content-based charging, operator policy control, QoS and roaming support are important concepts in order to sustain the value of key strategic assets (e.g. spectrum licenses, cell site infrastructure) over the long term, and under roaming scenarios. They also contribute to improving end-user quality of experience.

All-IP flat networks

Using IP networking as the foundation for services delivery provides maximum flexibility, decouples the user and control planes to simplify the network and improve scalability, and allows the wealth of existing IETF standards to be leveraged. Specific requirements include:

- Optimal routing of traffic
- IP-based transport
- Seamless mobility (intra- and inter-Radio Access Technologies)
- Simplification of the network

Security

The security challenge with IP networks is one of the most significant factors that slow down the further adoption of network technologies. Operators and enterprises recognize the clear productivity improvements and cost savings of converging their communication technologies on a single infrastructure and enabling universal connectivity for users. However, they are hesitant to adopt technologies that may compromise their privacy and put their critical operations at risk.

An end-to-end system approach to security is required in next-generation wireless networks, including:

- Platform hardening
- User/operator authentication, authorization and auditing
- Secure protocols, communication and data storage
- Software and configuration integrity
- Secure network management, control and signalling
- End-point compliance
- Network perimeter protection and interior protection
- Unsolicited traffic protection

LTE and WiMAX 802.16e provide this necessary security.

Commercial operators will launch commercial WiMAX 802.16e service in late 2008 and will be trialing LTE through 2009 and launching service in 2010. Therefore the government should being reviewing the WiMAX 802.16e and LTE standards and developing any adaptations of the commercial WiMAX 802.16e LTE standards needed for federal public safety broadband requirements.

5. REALISTIC USE OF COMMERCIAL WIRELESS NETWORKS FOR A GOVERNMENT OR PUBLIC SAFETY ENVIRONMENT

The use of commercial wireless networks for government agencies has been a matter of discussion for a number of years. Indeed during the work prior to WRC-2003 then ITU-R WP8A, in developing a report (ITU-R. M.2033, Radiocommunication objectives and requirements for public protection and disaster relief), considered the possibility that commercial wireless networks, including IMT-2000, could meet the needs of agencies involved with Public Protection and Disaster Relief (PPDR). At that time it was agreed that such wireless networks could meet most, if not all, of the needs of government agencies in support of their critical PPDR activities. By extension, it may be that those same types of wireless networks can meet the needs of other government agencies.

While there are different types of commercial wireless networks that may be appropriate for use by government agencies one that was discussed in the WP8A deliberations is in Canada and uses a technology (iDEN) that is also widely used in the USA and elsewhere. The intent here is not to promote a technology type but to highlight that a government agency’s requirements can be met by commercial wireless networks. It would also seem likely that the cost of user terminals and user fees should be reduced by the inherent economy of scale that such networks have. It will be difficult or impossible for custom or purpose built wireless networks to achieve those cost savings. Additionally it is fair to expect that commercial networks, using technologies such as those employed in 2G, 3G, beyond 3G and 4G can be expected to be very spectrally efficient.

At the time that WP8A was completing their PPDR report, prior to WRC-2003 the above Canadian iDEN network was reporting an availability of 99.99% and was expected to handle 33 million user minutes in 2003. It included all standard iDEN features such as group mode, private calling, data and interconnection.

There are other models and modes of operation that could allow government agencies to use commercial wireless networks for some, if not all, of their needs. One can be wireless priority service (WPS) to allow enhanced access to existing commercial wireless networks. This could be combined with an “affiliate” network where, in areas of low population density, the commercial network is built out to serve government agency needs. This could not only provide access for government agencies but allow citizens in those same areas to have access to wireless networks. The latter would help to defray the overall cost of the affiliated network.

Commercial wireless networks cover the majority of the population. It is entirely feasible that commercial wireless network operators and government agencies can work together to provide strong and reliable communications using a combined public and private/affiliate network.

The USG needs to leverage public networks as a complement to current NB systems and gain the advantages that public systems offer:

- Economies of scale: A high-volume, thriving market with many vendors
- Extensive coverage
- Evergreen evolution without significant new capital investment
- Access to leading edge capabilities and platforms using open, standardized interfaces as they become available
- Ability to adapt the solution to fit the needs of different agencies

6. CREATING INCENTIVES FOR TRANSITIONS

Incentives / Funding to Upgrade Equipment to Improve Spectral Efficiency

After a review of the other reports, it is apparent that two issues are already being studied:

- valuing spectrum when new spectrum is being assigned (WG5 Report – A-11 Circular)
- creating incentives and funding when relocation is needed (WG3 Report, Section 4, Recommendation E).

However, the creation of incentives for government agencies to upgrade continually to spectral efficient systems has been not yet been addressed within the CSMAC. This topic does not focus on the initial spectrum assignment. This topic addresses the efficient use of the spectrum over the lifetime of the system or equipment's mission. This is an extremely important issue since improved spectral efficiency could allow for spectrum to be returned for other government or commercial uses and will ensure that the utility of the spectrum will be maximized over a 10, 25, 50 … year mission lifetime.

Data from NTIA indicates that some agencies are very slow to adopt spectral efficient LMR equipment: In 2008:

- For the 162-174 MHz band24% of federal assignment are totally narrowbanded 50% of the federal assignments have combinations of 12.5 and 25 kHz use 26% are still all 25 kHz

- For the 406.1-420 MHz band, 25% of federal assignment are totally narrowbanded 50% of the federal assignments have combinations of 12.5 and 25 kHz use 25% are still all 25 kHz

Several attempts have been made to mandate the evolution of LMR equipment form the use of 25 kHz to 12.5 kHz channels. Unfortunately, spectrally inefficient 25 kHz channel LMR systems remain in service. Budget hurdles exist since the per year cost of maintaining 25+ year old equipment is lower than the cost of purchasing new equipment. The challenge is to incent and fund the evolution of systems to more spectrally efficient equipment.

WG4 examined two alternatives for providing the needed incentives:

- Intra-Government Spectrum Allocation Fees – An internal fee structure for the use of spectrum by government agencies

- "Scorecards" – An independent evaluation of the spectral efficiency practices of each agency would be completed by NTIA and recommendations for "best practice" improvements would be made to each agency. New spectrum allocations would be withheld if spectrum efficiency recommendations were not followed and spectrum efficiency practices were not adequate.

It is recommended that NTIA makes a full evaluation of each option.

This report concurs with the recommendation from the September 19, 2008 CSMAC meeting that CSMAC, as part of its next charter, that NTIA develop a new management structure for federal spectrum that emphasizes spectrum sharing and examines economic incentives that foster more efficient use of spectrum. And that NTIA begin developing a new management structure for federal spectrum that includes improved sharing arrangements. In addition, the this report recommends that, as part of its next charter, the CSMAC examine economic incentives, including fees, as a possible way to improve efficiency

Several considerations should be reviewed thoroughly before an intragovermental fee structure is recommended and implemented.

- The methodology and the level at which fees are set

- The possible split payment of fees when spectrum is shared by agencies

- Initial budgeting challenges and the possible need for agency budgets to be increased by the estimated aggregate fee

- Funding mechanisms to upgrade equipment

The use of "scorecards" was viewed unfavourably by some of the committee members due to past unsuccessful experiences. However, the use of scorecards should be further studied.

7. SUMMARY OF RECOMMENDATIONS REGARDING TRANSITION OF LMR SYSTEMS

- Agencies should aggregate their spectrum and system resources into shared LMR networks that maximize the use of trunking.

- NTIA work with all of the stakeholders including federal agencies to seek out opportunities to emulate this successful LMR spectrum usage model with state and local entities in additional areas.

- Actionable best practices to ensure that LMR networks are shared:
    - Comprehensively develop political and stakeholder support
    - Centralize coordination among multiple agencies through a formal committee
    - Formalize coordination committees through executive orders, charters or memorandums of understanding
    - Emphasize coordination, partnership, and asset sharing
    - Conduct detailed analysis of current needs and capabilities while planning future developments
    - Prepare and provide a wide range of educational materials to stakeholders and decision-makers
    - Sponsor communications and interoperability forums where officials can learn about current challenges and plans, provided input into the process, or learn how to get involved
    - Solicit input from all interested parties or entities throughout the coordination, planning, and project processes Examine the successful strategies of similar states or regions

- There is value in emulating the successful ALMR spectrum use model where possible and encourage the NTIA and FCC to take steps that could shorten the time for approvals.

- Smart Antenna / SDMA, cognitive radio and software defined radio solutions should be evaluated as the government evolves to broadband wireless systems.

- NTIA spectrum sharing test bed should be used to test and mature cognitive radio technologies such as geo-location and spectrum sensing to protect incumbent primary users of the spectrum. As appropriate, NTIA should consider releasing all relevant unclassified information within GMF database to accelerate the use of cognitive radio techniques.

- The government deploys an interagency shared, national wireless broadband network. A single 3G technology for initial broadband wireless should be deployed. The two commercial 3G technologies that can provide wireless broadband are EV-DO Rev A / eHRPD (3GPP2 standards) and HSPA (3GPP standards). These technologies should be evaluated and one should be selected for this nationwide network.

- For 4G wireless broadband government service, this report recommends the use of either LTE or Mobile WiMAX (802.16e). It is recommended that the government selects its 4G technology based upon the determination of which has the greatest commercial support over the next 10 or more years.

- This report recommends that the government plays an active role evaluating and contributing to both the LTE and WiMAX 802.16e standard.

- Increase government's use of commercial wireless networks for government agency needs, including PPDR activities if commercial networks are able to satisfy PPDR requirements for coverage, reliability, access, and security. Possible approaches that need to be examined are the increase use of wireless priority service (WPS) and implementation of an "affiliate" network model, in areas of low population density.

- This report concurs with the recommendation from the September 19, 2008 CSMAC meeting that CSMAC, as part of its next charter, that NTIA develop a new management structure for federal spectrum that emphasizes spectrum sharing and examines economic incentives that foster more efficient use of spectrum. And that NTIA begin developing a new management structure for federal spectrum that includes improved sharing arrangements. In addition, the this report recommends that, as part of its next charter, the CSMAC examine economic incentives, including fees, as a possible way to improve efficiency