BeyoDynamic spectrum access moves to the forefront

The Department of Defense spectrum problem is access not capacity. What is needed is a dynamic spectrum access network that allows military frequencies to be accessed automatically and dynamically without interference to other legacy radios using the same frequencies. This article describes a next-generation (XG) radio system that uses dynamic spectrum sharing technology to determine locally unused spectrum, and then operates on these channels without causing interference to the existing "non-cooperative" users.

By Salvador D'Itri and Mark McHenry

With the last large spectrum auction at 700 MHz almost behind us, the current spectrum supply and demand model threatens to constrain not only our appetite for new broadband applications but also restrict innovative companies from launching new wireless services. Enter a new approach known as dynamic spectrum access (DSA) that was first demonstrated in 2006 by the Defense Advanced Research Projects Agency (DARPA) and Shared Spectrum Company (SSC) of Vienna, VA. DSA software technology enables users of virtually any modern radio device to utilize dynamic spectrum access techniques and thereby dramatically improve spectrum efficiency, communications reliability, and deployment time. Fundamentally, a device running DSA software dynamically senses and adapts to its radio frequency (RF) environment to maintain reliable communications with other DSA-enabled devices, and it does so without interference with non-DSA-enabled systems (i.e., non-cooperative or legacy radios). Furthermore, a DSA-enabled radio operates within prescribed policy constraints, which may vary depending upon geographic location, frequency band, time of day, legacy radio activity and other anticipated or unanticipated factors. DSA presents a real opportunity to harvest licensed, underutilized spectrum to enhance everything from mission critical wireless access to consumer wireless consumption. DSA technology can change our use of spectrum assets the way the IP protocol changed our use of traditional switched network communications[5].

Spectrum depletion vs. actual usage

The U.S. Government has long been concerned about spectrum depletion of available spectrum in communities assigned stovepiped frequencies from a larger frequency pool. For example, the Federal Aviation Administration (FAA) has estimated that its VHF spectrum will be exhausted by 2015 due to growth in spectrum usage[1]. The White House has been concerned enough to start a Presidential Spectrum Policy Initiative and create a multi-agency Federal Government Spectrum Task Force[2] to focus on interagency initiatives to use spectrum better and more efficiently. This calls attention to the fact that spectrum is a finite resource of great economic value. National Science Foundation (NSF)-funded spectrum usage measurements have shown that the actual amount of spectrum used, averaged over time, space, and frequency, is about 14%, with about a 2-3% swing depending on the location measured[3,4]. This is the busy-period percentage during the day, when wireless traffic is at its peak, and is true in the SSC has taken spectrum measurements at several major U.S. cities and determined that at times some licensed bands are rarely used at all. This means that spectrum can be re-used in real time if radios were sufficiently nimble and well designed, and if re-use protocols could be developed that could take advantage of the remaining 86%.

Government initiatives--DARPA XG

On Aug 15-17, 2006, Shared Spectrum Company and the U.S. Department of Defense's Defense Advanced Research Projects Agency (DARPA) demonstrated, for the first time, a multinode network of neXt Generation (XG) radios capable of using spectrum over a wide range of frequencies on a secondary basis. The cognitive radios making up several formations of XG networks sensed radio signals over 225-600 MHz and adapted frequencies automatically to prevent interfering with existing military and civilian radio systems. The XG networks were tested on a military test range at Fort A.P. Hill in Bowling Green, VA, in front of an audience of more than one hundred military and government spectrum management agency representatives from the Army, Navy, Air Force, Coast Guard, Joint Spectrum Center, the Federal Communications Commission and the National Telecommunications and Information Administration[5].

DARPA, recognizing the convergence of radio technology advances with increased need for better use of spectrum, developed the XG radio communications program[5], which focused on the transformation of spectrum assignment technology for DoD applications through dynamic spectral use. The burden of sharing spectrum falls on XG radios, which must detect legacy radio systems (who are "primary" users of the frequencies in terms of regulatory priority) and not interfere with them, without a priori knowledge of the legacy radio waveform, MAC layer protocol, radio positions, transmit powers, or receiver sensitivities. Since legacy radio systems have primary access rights to the spectrum, many were not designed to cooperate or interoperate with secondary users like the XG radios; hence, these legacy radios are often referred to as "non-cooperative [5]." The program is currently in the Phase III transition stage and SSC is working with Harris Corporation and Thales Communications to test and integrate Dynamic Spectrum Access into their widely deployed Harris PRC152 Falcon III handheld and Thales PRC148 JTRS-enabled MBITR radios.

How DSA works

The SSC dynamic spectrum access solution is a radio software solution comprising the core components depicted in Figure 2. The key features of how dynamic spectrum access both learns and adapts are grouped into four key categories: frequency detection, spectrum management and neighbor discovery and channel maintenance.

Frequency detection: DSA software uses information from the radio detector(s) and/or the policy subsystems to manage spectrum usage. DSA maintains reliable communications while avoiding interference and ensuring compliance with the existing constraints. Ultra-high sensitivity detectors are used for a variety of different bands of interest. In cases where detectors are not sufficient or prohibited DSA software uses geo-location and group-sensing techniques. The scalability and seamless integration into existing network architectures is achieved through the frequency topology module that combines the detector information, network information as well as policy information to continuously track networks of interest in frequency.

Spectrum manager: The spectrum manager module uses information from both the detector and the spectrum policy module to dynamically manage spectrum access to maintain reliable communications while avoiding interference and ensuring compliance with prescribed policy constraints.

Channel maintenance and neighbor discovery modules: The channel maintenance and neighbor discovery modules establish an operating channel by determining and negotiating an operating frequency for a particular network of DSA-enabled radio nodes. In this process, the radios establish a means of rendezvous when one or more DSA-enabled radios are impacted by frequency interference.

Dynamic spectrum access

The main emphasis of the dynamic spectrum access framework is to overcome two types of concerns: harmful interference caused by a malfunctioning device and harmful interference caused by a malicious user. In tandem with signal-detection-based interference avoidance algorithms employed by software-defined radios, a set of policy-based components, tightly integrated with the accredited kernel on the radio, avoids potentially harmful interference caused by a malfunctioning device. The policy conformance and enforcement components ensure that a radio does not violate policies, which define regulatory and other stakeholders' goals and requirements, and which are encoded in an abstract, declarative language[6].

Policy-system architecture is based on a several key areas that involve both the policy

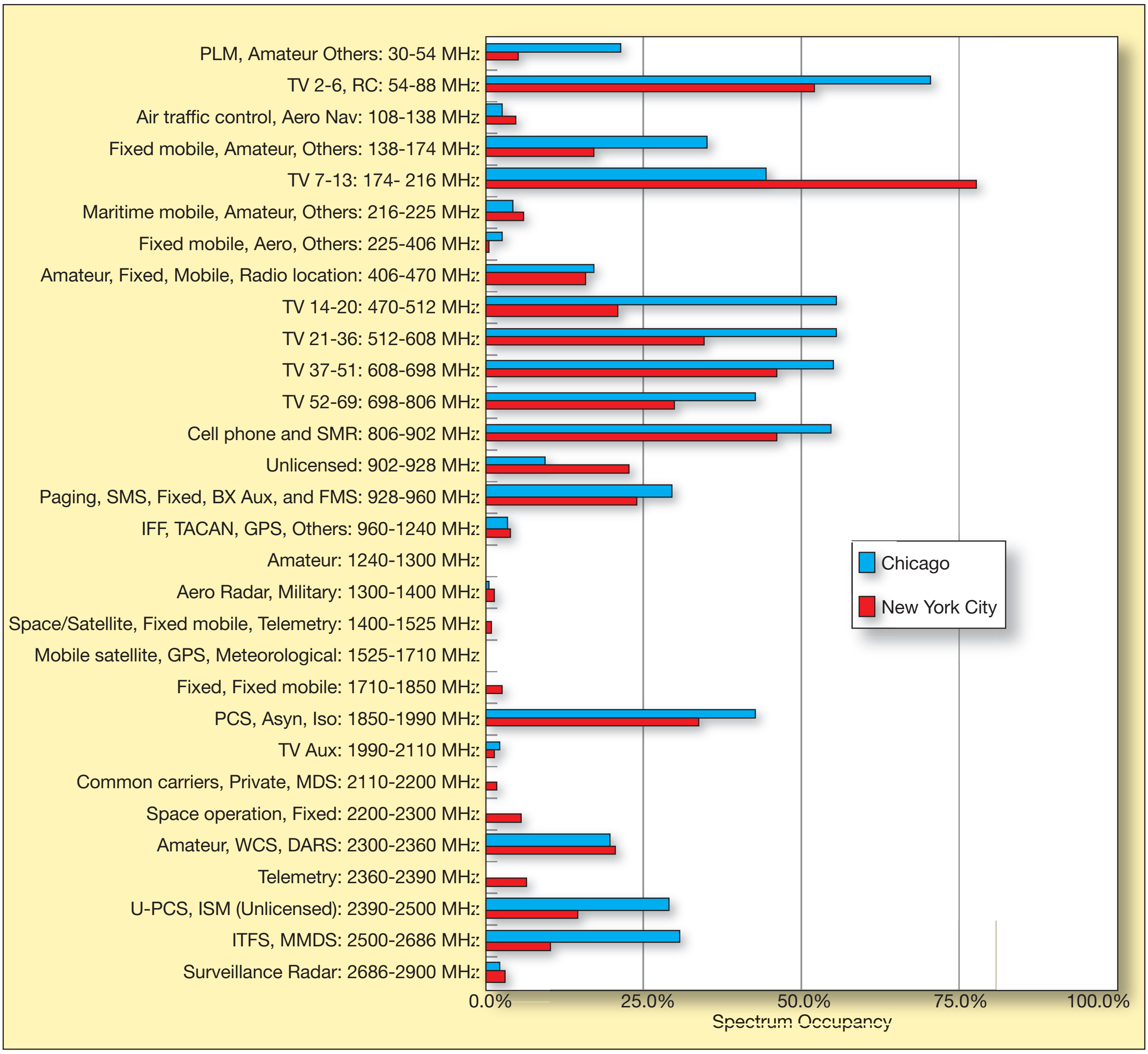

Figure 1. Spectrum measurements in New York City and Chicago conducted by Shared Spectrum.

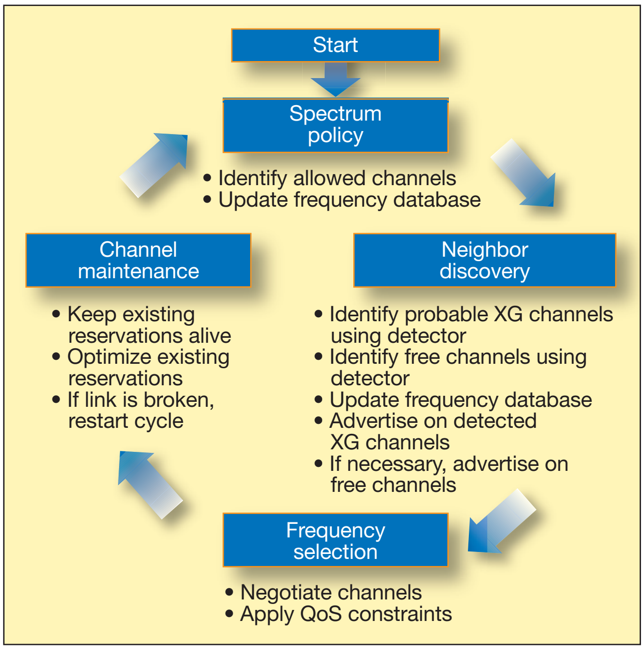

Figure 2. Dynamic spectrum access component s and data flow.

author and the software-defined radio. The core components are depicted in Figure 3 and Table 1.

Software upgrade

The DSA software is provided to the radio manufactures as compiled code. The code is implemented in the software-defined radio (SDR) as a new waveform. The software-defined radio does not require any hardware modifications to operate.

While the policy enforcer, policy manager and policy conformance reasoner are loaded onto the SDR radio, the policy-authoring tools (policy administrators, system strategy reasoner) are loaded into a server attached to the network. The policy authorer uses the GUI and policy software to create and push the policies down to the radio.

Military applications

Military exercises and campaigns create an environment of constrained and highly coordinated access to spectrum. Technologies like policy-based DSA will increase flexibility and timeliness of mission planning. Troop radios are enabled by policy to find available frequencies for communication when impacted by intentional or unintentional frequency interference. To control the operating parameters of the software-defined radios, the local or regional spectrum manager establishes the policies. Beyond handheld radios, DSA technology enables greater control over unmanned systems by closing long-link ranges and adapting to the changing RF environment without disrupting communications. The impact is greater use of small UAVs and tactical robots to improve surveillance and keep soldiers out of dangerous situations.

Public safety initiatives

SSC has been awarded a grant from the National Institute of Justice (NIJ) to develop and demonstrate a multiband cognitive radio system that will help optimize spectrum access for public safety agencies. This project focuses on creating a spectrum management subsystem on radio networks that controls the individual radios with spectrum access

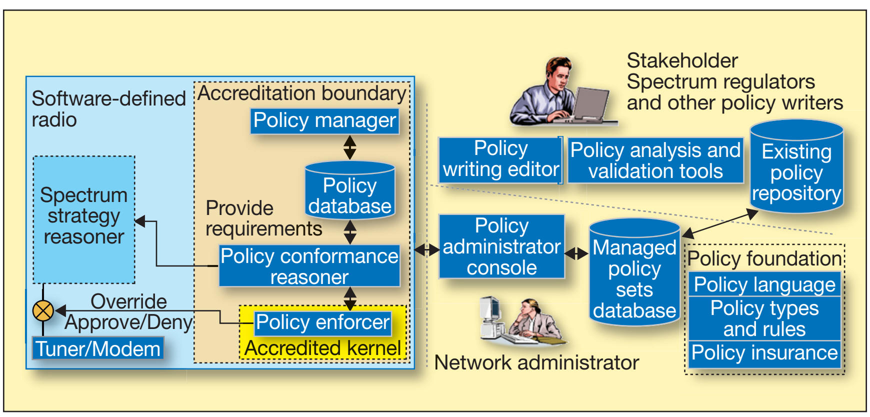

Figure 3. Distributed policy-based spectrum access control architecture. The SDR includes a localized policy enforcer responsible for controlling spectrum access based on requirements provided by regulatory and other stakeholders. The radio is managed by a network administrator who relies on stakeholders for providing up-to-date policies.

Key Components	Function
Policy Manager	Manages local policies and responds to remote commands
Policy Conformance Reasoner	Analyzes and reasons over policies and device-provided evidence
System Strategy Reasoner	Adjusts and selects the device's operational modes
Policy Enforcer	Governs the radio by permitting only allowed transmission requests
Policy Administrators	Secure interactive method for operators to remotely modify the state of the radio

Table 1. Key components of the DSA-based policy architecture

"policies" that allow better use of available spectrum frequencies. This subsystem, called cognitive radio access and management (CRAM), will lead to the creation and dissemination of a wide range of spectrum access and priority rules, including trusted security measures to avoid unauthorized access and operations. It will also provide for logging of transmissions to monitor usage and quickly remedy interference. This is one of the first steps at providing a dynamic spectrum environment needed during rapid deployment situations where multiple government agencies are responding to a situation.

Conclusion

Access to spectrum is an immediate problem for military and public safety users. After the 700 MHz auction, access to needed blocks of spectrum will require adoption of new communications tools to harvest existing spectrum. Dynamic spectrum access technology is available now to provide the critical link through a wireless software suite comprising policy-based rules and database engines that drive algorithms for frequency agility and cognitive decision-making. The entire suite enables an environment for users to adopt DSA and begin to address spectrum challenges and enable innovation and growth in wireless solutions. **DE**

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