



Wireless Innovation Forum Top 10 Most Wanted Wireless Innovations

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Preface

In 2010, The [Wireless Innovation Forum](#) initiated an ongoing project to identify major innovations that would be required to create the foundation of the next generation of wireless devices. These innovations, either technical, business or regulatory, if realized, would address various shortcomings in existing wireless communications from the point of view of the different stakeholders in the wireless industry value-chain, including users, radio or platform manufacturers, software and hardware component providers, operators and service providers, spectrum regulators. These innovations don't necessarily need to result in patents or intellectual property, but they would serve to help the community in addressing emerging wireless communications requirements through improved performance of deliverables, reduced total life cost of ownership and the responsive and rapid deployment of standardized families of products, technologies, and services.

To create this innovation roadmap, the Forum's Spectrum Innovation Committee sought participation from the different stakeholders to identify perceived or real shortcomings in the wireless domain and or to propose innovations that could potentially address these shortcomings. From the input received, the Forum's Spectrum Innovation Committee selected the following as the revised "Top 10 Innovations" that have the most potential of improving the wireless communications experience:

1. Innovation #1: Techniques for Efficient Software Porting Between Heterogeneous Platforms and Generic Development Tools for Heterogeneous Processors
2. Innovation #2: Certification Process for Third Party Waveform Software
3. Innovation #3: Receiver Performance Specifications
4. Innovation #4: Low Cost Wide Spectral Range RF Front-End (Multi-octave Contiguous) (Tx,Rx)
5. Innovation #5: Techniques to Minimize Power Amplifier Spectral Regrowth in Non-contiguous Spectral Environment
6. Innovation #6: Increase Communications Time on Battery Charge by an Order of Magnitude
7. Innovation #7: Context Aware Cognitive Radio
8. Innovation #8: Interference Mitigation Techniques
9. Innovation #9: Standardized Computer Interpretable Policy Language for Cognitive Radio
10. Innovation #10: Flexible Regulatory Framework for Temporary, Cooperative and Opportunistic Access

In support of the Forum's [Strategic Plan](#), the Spectrum Innovation Committee will maintain this list, adding or subtracting innovations as required to serve the overall needs of the advanced wireless community. The intention of the Forum is to promote this list across the advanced wireless community, and to support research and development activities addressing the targeted innovations both within the Forum membership and in partner organizations.

Wireless Innovation Forum

Top 10 Most Wanted Wireless Innovations

1 Innovation #1: Techniques for Efficient Software Porting Between Embedded Heterogeneous Platforms and Generic Development Tools for Heterogeneous Processors

1.1 Executive Summary

To reduce development time and cost, it is important that the software written be “easily” portable from platform to platform. SDR development processes today are mostly informal or ill-defined; standards for exchanging information between different steps in processes are not mature; tools do not use standard interchange formats and are not interoperable. An area of emphasis should be on the development of tool interchange standards and the development of end-to-end processes and tools to support the development of SDR applications, components, and platforms.

Software architecture and design paradigms must evolve to integrate the software design model with the physical radio architecture to address platform-specific requirements and differences in the current versus the target radios that impact software porting.

1.2 Application

The implementation of software to represent the waveform is often hampered by the fact that the waveform specification is not clearly stated and the target platform is composed of multiple processors, each one interacting with one another. Developers need to use multiple tools to achieve their project but the lack of standards makes the integration very challenging.

The benefits of achieving greater portability between heterogeneous platforms will benefit a broad range of user communities including:

1. *Waveform Application Developers:* More efficient waveform porting will enable waveform developers to develop component-based waveform implementations that can be ported to other radio systems. This reduces the waveform development cost.
2. *Radio Developers/Integrators:* As a radio developer/integrator, more efficient waveform porting enables a wider selection of waveforms that may be ported and deployed on their radio systems, within the physical limits of the radio.
3. *End Users:* Ultimately, the end user community benefits through lower costs of radios and the waveforms and applications that run on the radio. This applies to both commercial and government users. This end cost benefit is realized because one of the side effects of more efficient software is a more product-based development, resulting in

wider range of products and a more competitive environment. wider range of products and a more competitive environment.

1.3 Description

One of the benefits of software radios is the ability to reuse parts or all of the software implementation to a different radio hardware platform. However, this is not a trivial problem because SDR platforms often contain multiple processors of different types, e.g. General Purpose Processor (GPP), Digital Signal Processor (DSP), Field Programmable Gate Array (FPGA), as well as evolving processor architectures together with other reconfigurable components and devices.

To reduce development time and cost, it is important that the software written be “easily” portable from platform to platform. In order to achieve this objective, software architecture and design paradigms must evolve to encompass multiple programming languages such as C, C++ and HDL, multiple design approaches such as multi-threaded applications on GPP or concurrent state machine designs for an FPGA and integrate the software model with a systems model of the physical radio architecture to address platform-specific requirements and differences in the current versus the target radios that impact software porting.

There are several key elements that are required to realize this innovation. These encompass the range of technology, engineering disciplines, systems engineering practices and process, common representation standards and intra-company process changes. New technology is required to enhance and extend the expressiveness of current design and modeling tools to encompass a heterogeneous waveform design. However, in addition to waveform design, the tools must also be capable of modeling the hardware elements of a radio system and being able to represent the constraints and capabilities of the platform in such a form that enables the analysis of a waveform design with respect to the target hardware on which it is to be deployed. This encompasses multiple engineering disciplines including digital design, electrical engineering and software engineers. Furthermore, these disciplines must evolve to operate in a more cohesive and integrated manner that promotes collaborative architecture and design across all engineering disciplines. This is a fundamental difference in mindset from most current practices and processes which are typically hardware focused through the systems discipline with the software engineering aspect typically not joining the process until after the hardware architecture has been largely decided.

2 Innovation #2: Certification Process for Third Party Waveform Software

2.1 Executive Summary

The ability to certify software implementations of waveforms for use on various radio computing platforms promises to significantly reduce development cost and time to market of software based radios.

2.2 Application

Similar to entertainment or work-related applications being uploaded on smartphones or personal computers, third party software implementations of communications waveforms should be available for software defined radios. A process to verify the conformity of these implementations and their performance on the various radio platform types must be defined.

2.3 Description

One of the main benefits of software defined radios resides in the ability to decouple the signal processing software from the radio hardware, enabling a multiplicity of communications protocols to run on the same radio. Currently however, the radio manufacturer is still the one who implements the software on its own hardware. Unlike the personal computer domain, third-party-written communications protocol software is rare in SDR. While the heterogeneous nature of the platforms and liability of the manufacturer for the performance of the radio can be finger-pointed for this barrier, a certification process that would enable third-party software to be used across multiple platforms would significantly reduce development cost and time to market.

3 Innovation #3: Receiver Performance Specifications

3.1 Executive Summary

The growing movement to encourage spectrum sharing will be a significant enabler for cognitive radio systems. However, existing spectrum users have a reasonable expectation that their systems operation will not be impaired by new in-band and adjacent band users. Historically, this has been managed through a variety of standards and regulations primarily focused on transmitter parameters, sometimes with unexpected consequences. The Forum believes that long term the entire range of both transmitter and receiver characteristics must become an integral part of spectrum regulation and management. Specifically, adding focus on regulating receiver performance can bring much benefit in terms of spectrum efficiency through such regulation while at the same time reducing risk for new market and new technology entrants.

3.2 Application

- Identification of the critical receiver parameters required in order to enable spectrum sharing systems in existing bands.
- Capability of current and future receiver front end technologies
- The standards required to support the regulation of receiver specifications.

3.3 Description

The critical receiver parameters required in order to enable spectrum sharing systems in existing bands must be developed looking at a historical view of how receiver performance has impacted spectrum regulation. Potential examples from the US include the 800MHz Public Safety rebanding and Lightsquared terrestrial LTE at 1.5GHz.

The current and expected receiver performance criteria for existing systems must then be evaluated for effective protection. This requires a survey of existing systems across the

government, public safety, satellite and commercial markets. A roadmap of receiver performance then needs to be developed, as well as an evaluation of the potential impact of evolving communication systems on incumbent solutions.

4 Innovation #4: Low Cost Wide Spectral Range RF Front-End (Multi-octave Contiguous) (Tx,Rx)

4.1 Executive Summary

Small, low cost transmit and receive front-ends are critical to enable viable wireless solutions in spectrum that is being opened by regulatory bodies to improve spectrum utilization and meet the broadband needs of their citizens.

4.2 Application

An RF front-end, capable of transmitting and receiving over a very wide spectral range. An example is the challenge of devices for TV Whitespaces that are allowed to operate in unoccupied TV channels 2-51 (54-698MHz) but must do so in the presence of strong adjacent and alternate TV transmitters.

4.3 Qualifiers

Transmit and receive, low cost, occupies small surface area, multi-octave operation, very linear

4.4 Description

Regulatory bodies around the world are looking for opportunities to improve spectrum utilization and provide more broadband service for their constituencies. Often, the spectrum “white-spaces” that are becoming available are not contiguous and are located in harsh RF environments. An example is TV whitespace where there could be one or more unoccupied 6MHz channels from 54-698MHz with the presences of strong adjacent or alternate TV transmitters. A viable product solution using this spectrum needs to be low cost, operate over this broad frequency range because the unoccupied channels vary by geographical area, and have a receiver that can tolerate a high power TV broadcast signal on the adjacent or alternate channel. The receiver design must balance the insertion loss of a narrow tunable pre-selector with the linearity of the receiver front end. For reference information, see section 6 on TVWS in “Public Safety Interference Environment – Raising Receiver Performance Requirements” <http://groups.winnforum.org/p/cm/ld/fid=88>, December 3, 2009, Session 3.2)

5 Innovation #5: Techniques to Minimize Power Amplifier Spectral Regrowth in Non-contiguous Spectral Environment

5.1 Executive Summary

Techniques (algorithms, software, hardware, or mixed technique) that significantly reduce spectral regrowth (target of -70 dBc) when a wideband (≥ 20 MHz), but non-contiguous, signal is passed through a nonlinear transmitter.

5.2 Application

In many secondary spectrum deployment scenarios, it will be difficult to find contiguous wideband spectrum due to primary users. Thus to achieve sufficient communications bandwidth for high data rate applications, it will be necessary to combine together multiple smaller pieces of contiguous spectrum which would ideally be transmitted from a single transmitter. In such a scenario, it is vital that the primary user signals are protected from interference.

5.3 Description

Simply filtering or nulling the transmitted signal energy in the intermediate subbands at baseband will not provide sufficient protection to the primary users due to transmitter nonlinearities leading to spectral regrowth in the primary users' bands. Likewise, while narrower bandwidth signals can be used that eliminate the possibility of spectral overlap, this narrow bandwidth is often insufficient. Similarly, significantly increasing guardbands can improve primary user protection, but this is highly inefficient use of spectrum. Ideally techniques should mitigate this spectral regrowth in unused bands in transmissions over non-contiguous spectrum without increasing guardbands to achieve suppression that yields -70 dBc signal level in protected bands.

5.4 Qualifiers

Single band (e.g., TV bands) is acceptable. Multiple transceiver chains to multiple antennas are not desirable for this topic. Can be a software, hardware, or mixed signal solution. Many different techniques have been proposed, including predistortion and subcarrier manipulation techniques, but these techniques normally achieve suppression at least 20 dB less than the desired 50 dB.

6 Innovation #6: Increase Communications Time on Battery Charge by an Order of Magnitude

6.1 Executive Summary

The use of battery powered communications devices requires the user to carry either extra batteries or have frequent access battery recharging facilities. For some user scenarios it imposes a significant burden to carry additional batteries since the user must operate with out access to battery charging facilities for extended periods of time. These users constantly have to trade the frequency of communications and what they communicate with its impact upon battery life. Battery life is generally quantified in hours given a ratio of a talk time and idle time; or percent transmit, percent receive, percent idle.

6.2 Application

For military, mobile users, firefighters in remote areas and others the extension of communications time on a battery charge by an order of magnitude would reduce the amount of batteries they would need to carry as well as allow them to communicate more frequently. For those users in remote areas for extended periods of time they must make tradeoffs between food,

water, and other mission essential equipment and the amount of batteries that will be needed to power their communications devices.

6.3 Description

There are many different technical approaches to increasing the communications time on a battery charge such as reducing processor power consumption, increasing power amplifier efficiencies, signal processing techniques, improving battery chemistries to get more energy per kg.. There might be constraints in terms of size and weight.

7 Innovation #7: Context Aware Cognitive Radio

7.1 Executive Summary

Methods, tools, architectures, and languages need to be developed to enable cognitive radios to incorporate contextual reasoning into their decision processes. By adapting to dynamic contexts, cognitive radio algorithms can be automatically matched to changing conditions, wireless network performance can be significantly improved, end user experience enhanced, and network management time and costs reduced.

7.2 Applications

By incorporating context awareness into cognitive radio processes, the following will be feasible:

- Automating communications leader communications resource management in a way that recognizes and facilitates reaction to the dynamic nature of major incident/disaster responses. This generalizes to disrupted context scenarios where the communications network was planned to accommodate assumptions (pre-defined contexts), but a radically different and rapidly evolving environment (contexts) is encountered.
- Enabling smartphones to automatically adapt their wireless behavior based on what other users are nearby, what services the smartphone is trying to support, time-of-day, location, calendar information, and models of user intentions.
- Improving spectrum sharing, management, and co-existence of cognitive radios by incorporating a better understanding of the changing capabilities, constraints, and goals of radio systems.
- Increasing the market-size, applicability, and robustness of wireless devices by incorporating a context-aware software module (possibly with additional software defined radio capabilities) that adapts the behavior of the communications assets to the varying needs of different customers and changing situations
- Simplifying the deployment and configuration of self-organizing networks (small-cells) in existing cellular bands and considered spectrum sharing bands (e.g., 3.5 GHz) by having radios automatically detect and monitor their operating context and adapting accordingly.

7.3 Description

Context refers to

- a) information associated with a message that is not directly communicated with the message that influence the message's meaning
- b) a set of relationships that one object has with other objects.

While most cognitive radio literature considers the context inferable from a wireless chipset, a context-aware cognitive radio should have a wider scope of information to draw upon in its decision processes, including what the radio should be trying to do, what it is doing, what messages it is conveying, or the meaning of data in accessible databases.

Examples of valuable contextual information to cognitive radio processes include the following.

- Locations, trajectories, and patterns of movement of radios and their users
- Relationships between the users of radios
- Characteristics of the radio users, such as their changing goals and objectives, calendars of activities, and general preferences
- Services provided by and receiver characteristics of other radios and networks in the area
- Current and intended activities and applications of the users of the radios
- Meaning, and urgency of messages being carried over communications networks
- External environment conditions, such as RF load density, general propagation and interference characteristics, weather conditions, time-of-day, and sensor data
- Platform specifics such as power consumption, calculation and measurement precision, permissible operating environments and policies.
- Metrics commonly used by cognitive radio designs such as RSS, BER, end-to-end delay, and packet loss rate.

Understanding the following three types of context will be particularly valuable to further development of cognitive radio applications.

Operational context

Operational context refers to the object relationships pertaining to the operation of the radio. This includes information such as what a user is trying to do, where the radio is located, the current needs of the situation, and the changing relationships with other users and radios. Understanding operational context is critical to automating communications resource management.

Communications context

Communications context refers to information associated with a message that is not directly communicated with the message that nonetheless influence the message's meaning. Much operational context can be inferred from the meaning of messages conveyed by the communications system. Further, an understanding of communications context can lead to better cognitive radio decisions, new forms of encryption (by withholding context from unintended recipients), and more efficient communications (by understanding the context of intended recipients so that less contextual information needs to be transmitted).

Data context

Data context refers to the provenance, reliability, and relationships of data made accessible to cognitive radios, such as is envisioned for white space databases. This includes meta-data about the provenance and reliability of data, relationships with other data, and the objectives of the system. Understanding data context can help address Big-Data-like problems in the RF space, such as synthesizing and extrapolating meaningful patterns of behavior from accumulated sensor measurements.

As a new field, realizing context-aware cognitive radio will require the development or adaptation of several supporting technologies and innovations, including the following.

- Extensible languages and tools for modeling and reasoning on contextual information drawn from a diverse and changing set of sources.
- Mechanisms for automating the creation and updating of context models from observations and data shared from other sources and internal reasoning processes.
- Algorithms for improved contextual pattern recognition to reduce ambiguity and rapidly determine the applicability of existing solutions.
- Processes for innovating new solutions and interfacing with users when existing solutions are determined to be inappropriate to the determined context.
- Programming languages (paradigms?) that allow end-users to easily specify how their communications assets should behave under varying scenarios.
- Improved interfaces and processes for translating data (e.g., from sensors or online databases) into formats suitable for contextual reasoning
- Methods and paradigms for interfacing with users to provide contextual information to the user and corrective feedback to the systems when ambiguous or erroneous contexts are identified
- Big Data tools applicable to RF problems (i.e., Big RF) for collecting, correlating, weighting, and reasoning over disparate pieces of information in a timely, precise, verifiable, and accurate fashion at varying degrees of granularity
- A flexible regulatory framework that will support the kinds of temporary, cooperative, and opportunistic applications that will emerge from context aware cognitive radio.

8 Innovation #8: Interference Mitigation Techniques

8.1 Executive Summary

Better mechanisms are needed to reduce destructive interference on the communications signal, and thus improve the signal's quality of service and/or communications range.

8.2 Applications

Interference can take the form of intentional jamming, as often occurs in military communications, or non-intentional interference often resulting from misused of equipment (wrong frequency settings, misplaced of towers) or power spillover in other bands. In either case, the interference decreases the signal to interference plus noise ratio at the receiving end of

the communications path and, if of sufficient level, will substantially degrade or obliterate voice quality in a voice system and data throughput in a data system.

8.3 Description

Innovations are sought that deal with how Software Defined Radio (SDR) and/or Cognitive Radio (CR) might alter the system design tradeoffs of primarily either to enable better rejection of interference without the exponential cost growth associated with more traditional solutions. Such innovations might include, but are certainly not limited to, the ones listed below. It is realized that many of these techniques are already used in some advanced communications systems, but not used in others because design tradeoffs or other factors may not have favored their deployment. It is recognized that cognitive radio techniques, whereby the frequency plans could be modified to operate in non-interfering bands, might be a solution, but the implementation cost of such techniques would be prohibitive for many applications. In the present cases, other techniques are sought. A few examples are given here:

- Power control throughout the communications system, using only enough power to maintain communications at the minimum acceptable level. In fact, for low priority communications paths, the power could even be set for degraded voice quality relative to the paths with the highest priority to reduce interference.
- Adaptive beamforming to maximize antenna gain in the direction of the communications path and minimize gain in the interference direction.
- Adaptable data rate to the minimum rate needed for the communication and/or according to priority of the operator.
- Adaptive frequency control to increase frequency separation of the interference sources from the desired radio path
- Adaptive receive filtering to provide better rejection of the interference balanced against possible sensitivity loss.
- Improved roaming algorithms (Change sites or systems to one that has a better Signal to Noise plus Interference ratio.
- Change channel coding algorithms to relax the required signal to interference plus noise ratio at the expense of more data overhead

9 Innovation #9: Standardized computer interpretable policy language for cognitive radio

9.1 Executive Summary

The ability to operate legally and agilely across multiple bands and in multiple different places using policies as a means to check whether you're legal and eligible constitutes policy awareness. The policies can include regulatory and system specific policies. Hard/soft-wired policies can determine when spectrum is considered as opportunity as well as providing constraints on using these spectrum opportunities. Future innovations are required to (1) allow regulatory policies and rules for dynamic policy based radio control to be automatically interpreted and executed and (2) extend the core ontology as defined in the Forum's Modeling Language for Mobility and make it capable to express the use cases and support the policy based radio control.

9.2 Applications

- A declarative language with computer processable semantics can support a number of problems identified by the Wireless Innovation Forum that require innovations. Some of the problems that could be dealt with using such a language are listed below.
- Interoperability: Communication nodes can use ontologies to interoperate and control their functionality because they can understand each other (radios speak a common language). This applies to the military (coalition interoperability), public safety (among various agencies, services and emergency responders) and commercial.
- Run time reconfigurability: Communication nodes can understand requests for reconfiguration and implement the requested functionality (e.g., a waveform) according to the specification (expressed in MLM) provided by another node.
- Validation: Formalization allows one to detect inconsistencies and formally validate functionality.
- Self-awareness: Communication nodes can describe their own structure and capabilities, and tell others about it.
- Flexible querying: Communication nodes can query other nodes about their functionality and capabilities.
- Communication economy: No need to transmit information that can be inferred locally at the receiver node.
- Radio certification. Formal specifications of the structure and the functionality of particular communication systems can be utilized in the process of certification. Only the components that are modified will need to be certified.
- Support Dynamic Spectrum Access: Policies for dynamic spectrum access can be expressed in MLM and then automatically interpreted by the Inference Engine running on either a base station or a handset. The policy decisions then can be enforced by the device.

9.3 Description

MLM is a future language for communication nodes to exchange information – both object (data) information and process (control) information. The use of MLM includes the following steps: 1. Exchanging (send/receive) messages. 2. Interpretation of messages by a local Inference Engine that also includes the use of a local Knowledge Base. 3. Planning a reaction to the received message. 4. Continuation of information exchange as in point 1.

MLM should have the expressive capability of describing at least the following aspects of communications:

- Capabilities of the nodes (e.g., frequency bands, modulations, MAC protocols, access authorizations, etiquettes, bandwidths, and interconnections).
- Networks available to a user (parameters, restrictions, costs).
- Security / privacy (capability, constraints, policies).
- Information types (an emergency call vs. just a “how are you” message).
- Local spectrum situation (spectrum activity, propagation properties).
- Network to subscriber & subscriber to network control (policies).

- Manufacturer matters (hardware and software policy).
- Types of users (authority, priority, etc.).
- Types of data (Async., Isoc., narrow band, broad band, etc.)
- Local regulatory framework (e.g., policies at a given geo location, time of day, emergency situation, etc.)
- Time of Day (at both ends of session and important points in between).
- Geographic Location (in three space, surrounding geography/architecture).

10 Innovation #10: Flexible Regulatory Framework for Temporary, Cooperative and Opportunistic Access

10.1 Executive Summary

A new flexible regulatory framework is needed to enable the operation of advanced wireless devices and systems that meet certain reconfigurability requirements across multiple bands and wireless services on a temporary, cooperative or opportunistic basis.

10.2 Applications

This innovation will lower regulatory barriers to entry and promote technological innovation through easier and faster access to spectrum, enabling incumbents and entrepreneurs to pursue new business opportunities throughout the wireless value chain.

10.3 Description

Traditional international and domestic regulatory frameworks governing access to RF spectrum are based on "static" frequency allocations and assignments. While emerging multi-band, cognitive radio and dynamic spectrum access technologies are being introduced under modern flexible, market-based regulatory policies in some countries, a new supplemental framework that can overlay existing schemes will further enable innovative technologies, and such technologies can enable innovative frameworks. This new flexible regulatory framework would apply across multiple bands and wireless services. The rules would authorize advanced wireless devices and systems that meet certain reconfigurability requirements to operate across a wide swath of frequency bands on a temporary, cooperative or opportunistic basis depending on the nature and characteristics of the existing authorized systems, to the extent there are any. The following example is derived from SSC's Comments and Reply Comments filed by Shared Spectrum Company (SSC) in ET Docket No. 10-237 (Feb. and Mar. 2011):

- Under the proposed policy-based framework, regulators would require eligible RF devices to be reconfigurable to prevent spectrum squatters and ensure that the devices can be updated (or even disabled in certain bands) after being sold to end users. Equipment authorization/certification rules would establish minimum hardware and software capabilities for such devices, but they would include only baseline operating parameters (mirroring any existing technical rules) and would authorize deviation from the baseline through policy controls managed by third-party band/database managers. The rules could also include a built-in enforcement apparatus to implement interference deconfliction

remedies (e.g., activity logs, over-the-air policy updates or time-limited access policies that would have to be renewed).

- The policies themselves would implement the service rules and any licensing conditions or incumbent/stakeholder requirements. They could also be changed to reflect newly available operating frequencies or modified power levels. Regulators would defer to industry standards organizations such as IEEE working group P1900.5 and the Wireless Innovation Forum's Modeling Language for Mobility ("MLM") working group for the development of policy languages, ontologies and architectures. Based on such standards, entities can develop policy authoring and administration tools to create and manage the policies, which can be reviewed, tested and potentially modified by the regulator and other interested stakeholders. The regulator may also want to consider requiring a policy certificate security management feature that prevents unauthorized access by validating spectrum access polices in certain spectrum bands.

The following example is derived from the European Commission's Radio Spectrum Policy Group (RSPF) Report on "Cognitive Technologies" (Feb. 2010) and the RSPG "Opinion on Cognitive Technologies" (Feb. 2011):

- A more simplified regulatory framework would focus on cognitive radio (CR) technologies that would be implemented/controlled through geo-location databases. This approach assumes that current regulatory mechanisms and models can be used as the primary basis for the introduction of CR technologies. However, new regulatory framework(s) would address the conditions/requirements that the databases and devices have to meet along with database accreditation issues. Specifications established by standards organizations would be needed for: the exchange of information between the CR devices and the database(s), to ensure that CR devices will be connected with the relevant database(s), geo-location systems, and other assurances. [See RSPG Opinion at p. 8 for "actions that would be needed for a common regulatory framework to enable implementation of geo-location-based CR devices."]

Another example of regulatory framework initiative is the European Union's project on a Techno-Economic Regulatory Framework for Radio Spectrum Access for Cognitive Radio/Software Defined Radio (TERRA)(<http://www.cost-terra.org>):

- This effort is focused on coordinating techno-economic studies for the development of a harmonised European regulatory framework to facilitate the advancement and broad commercial deployment of Cognitive Radio/Software Defined Radio (CR/SDR) systems. Specifically, COST-TERRA Working Group 3, "Economic aspects of CR/SDR regulation," will work on evaluating the economic aspects of the developed CR/SDR regulations, considering both the attractiveness of rules suggested by studies in Working Groups 1 and 2 and the development of any new regulatory paradigms based on economic (market-based) policies. Such studies would identify critical factors that have significant impact on economic benefits and viability of the proposed regulatory regimes for CR/SDR. Working Group 4 on "Impact assessment of CR/SDR regulation" will work on carrying out impact assessment for identified combinations of techno-economic sets of

CR/SDR deployment rules with the aim of identifying the most attractive combinations to form the basis for the ultimate CR/SDR regulatory framework with any variations therein.