Wireless Innovation Forum's Comments to ITU WP-5A regarding the working document towards a preliminary draft new report ITU-R [LMS CRS2]

Cognitive radio systems [(CRS) applications] in the land mobile service

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Wireless Innovation Forum

COMMENTS REGARDING THE WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT NEW REPORT ITU-R [LMS.CRS2]

[Cognitive radio systems [(CRS) applications] in the land mobile service]

(Question ITU-R 241-2/5)

1 Introduction

At its eleventh meeting held in May 2013, ITU-R Working Party 5A (WP 5A) made progress on a working document towards a preliminary draft new Report on Cognitive Radio Systems (CRS). WP 5A plans to finalize the development of the working document during its November 2013 meeting. The Wireless Innovation Forum offers comments and modifications to the working document aiming to help finalize the development of the working document during next WP 5A meeting in November 2013

2 Proposal

It is proposed that the comments and modifications introduced are taken into account in the draft new Report ITU-R M.[LMS.CRS2] on “Cognitive radio systems [(CRS) applications] in the land mobile service”.

3 Comments

The Wireless Innovation Forum offers comments on the following topics which are specifically addressed in the working document towards a preliminary draft new report.

1. Cognitive pilot channel (CPC) /Cognitive control channel (CCC)
2. Geolocation databases
3. Applicability to different frequency bands e.g. 3.5GHz
4. Sensing – secondary user coexistence and potential fallback mechanisms
5. Receiver guidelines/specifications
6. Technology/Service neutrality
7. Blended infrastructure approach
8. Licensing models e.g. Licensed shared access/authorized shared access

In this document, the Wireless Innovation Forum is referred to as ‘the Forum’ or ‘WInnF’. WInnF comments to the editor from this point on are shown in black italicised font, sections of text referred to in the WP5A draft report are highlighted in blue, and suggested inputs to WP5A are shown in normal font.

3.1 Cognitive Pilot Channel/Cognitive Control Channel

Chapter 6 of the preliminary working document contains comprehensive material regarding CPC/CCC usage. It is noted that this concept has not gained significant traction within the wireless communications sector, that the initial projects promoting this concept, E^2R and E^3 were concluded in 2009, and the concept has not been pursued to the same extent within the research community since that time. Furthermore, the argument for CPC/CCC usage has largely been muted by a number of factors including:

- *Geolocation database approaches*

- *Complementary wireless technologies with potential for control channel type utility e.g. WiFi, LTE*
- *Shift from technology-specific spectrum usage to technology and service neutrality that can support a case against the use of a dedicated physical channel for CPC/CCC.*
- *Security issues*
  - *Not using a single dedicated physical channel/point of failure*

The Forum proposes that WP 5A reduce the focus on CPC/CCC within the draft report to reflect the changing regulatory and market environment since CPC/CCC was first developed as a concept. Distribution of control information/information relative to CRS deployments should not be restricted to a specific air interface.

However, in addressing the technical issues surrounding CPC/CCC, the Forum offers the following modifications and additions:

6.1.1 Listening to a wireless control channel

Control channels could be used for transmitting control information between two or more entities belonging to the systems which use the same spectrum resources. They facilitate more efficient CRS operation, spectrum use and coexistence of different radio systems.

To realize Dynamic Spectrum Access (DSA) functions, a CR system needs information about its operating environment and governance on how to operate. Information required by a CR to implement DSA primarily refers to radio spectrum information, e.g., what signals are present in its environment, from where are the signals emanating, to where are the signals being sent. There are numerous, different ways proposed to gain this information as described in [1], such as:

• Sensing to perform signal detection and classification, which may be cooperative to help mitigate hidden node issues,

• The use of databases based on geographical information and known primary user emitter characteristics

• Pilot channels to distribute environmental information and help the bootstrapping problem

• Direct information sharing among secondary devices and between primary and secondary systems.

To improve robustness, a combination of these techniques can be utilised.

In a contribution to the ITU regarding a response to a question on the role of cognitive radio in land mobile radio services [2], the Wireless Innovation Forum Cognitive Radio Working Group discussed some of the benefits of this technology:

A pilot channel is used to broadcast information to support the operation of cognitive radios. The term cognitive pilot channel (CPC) frequently refers specifically to the proposal developed under the E2R and E3 projects in Europe, but has since more generally referred to any channel (whether logical or physical) that is used to regularly provide overhead and control information to subscriber radios.

Thus a pilot channel may provide registration, location, policy, spectrum assignment and other overhead information not normally required by registered telecommunication devices. An example of this is the data overhead associated with database updates.

The CPC is generally focused on bootstrapping cognitive radios to have the information required to be aware of local spectrum, policy and networks characteristics. The information broadcast on a cognitive pilot channel can be either continuous broadcast, periodic broadcast, hierarchical broadcast, or on demand to include the broadcasting of policy information (e.g., public safety systems will constrain when a radio can transmit via messages broadcast over control channels), specified transmission characteristics for devices (as is done in IEEE 802.16), aid in the bootstrapping of network association (e.g., Flash symbols in Flash-OFDM), or information about relevant operational information.

Cognitive networks enable the introduction of the cognition radio concepts and technologies in a multi-RAT environment, such as the CPC. The availability of reconfigurable base stations in the networks in conjunction with cognitive network management functionalities could give the network operators the means for a globally efficient way of managing the radio and hardware resource pool, with the aim to adapt the network itself to the dynamic variations of the traffic offered to the deployed RATs and to the different portions of the area

As part of its review of the CPC considered as a proposed scheme for distributing information related to a radio's operating environment to reduce end user device complexity and simplify policy management, several security concerns and suggested mitigation techniques which can and should be generalized to other control channel schemes were raised in [3]. These points can be summarised as follows:

• If adopted, the CPC should not be essential for operation and should primarily be used to enhance awareness of information that terminals could learn by other means. This will reduce the impact of a malicious attack or network failure.

• Embedding cognitive pilot signals in strong fixed signals (such as radio or TV broadcast) would reduce the impact of jammers.

• When deployed as private CPC, logical channels should be used to make jamming and spoofing more difficult.

• Introducing redundancy to CPC functionality would reduce the impact of jammers.

• The CPC should include authentication measures e.g. digital certificates, digital signatures, Extensible Authentication Protocol (EAP), and 802.1x.

• The requirement for autonomous initial location determination should be eliminated so the system does not fail if GPS is jammed or the terminal is located where the satellites are not visible. However, having this function as an optional feature may be beneficial.

CPC/CCC should be considered as a complement to geolocation databases. The complementary characteristics could include point to multipoint node broadcast and push/pull notifications.

The CPC/CCC concept should be further considered in terms of leveraging existing deployed technologies e.g. Long Term Evolution (LTE), WiFi, where general control channel capability using existing deployed technology could be utilised.

3.2 Geolocation databases

Section 6.1.3 of the draft working document concerns geolocation databases. Geolocation databases can facilitate the unified active management of spectrum (terrestrial / air / space /

maritime) to maximize spectrum utilization. The use of spectrum access databases is one important tool to enable increased sharing and thereby increase the dynamic nature of spectrum management.

[ITU Editor's note: the rationale for focusing on sensing and database should be explained. Also other CRS technologies should be addressed.]

To help address the editor's question regarding the rationale for focusing on sensing and databases, the Forum offers the following input:

The term geo-location database emerged from the early development of TVWS. The database is part spectrum manager, part policy manager, and part coexistence manager.

In the context of shared spectrum usage through a geolocation database approach, the database deals with spectrum usage policies, which may have nothing to do with actual spectrum use. Examples include national quiet zones and satellite earth receiver stations, which don't involve transmission so a sensing radio can never identify them. This is the starting point for a geolocation database. A policy is in a database has an added advantage in that it can be modified, whether through improvements to understanding or algorithms or because the demands for the spectrum (applications and services) change over time.

Networked and synchronized databases accessed with device location information have therefore emerged as a critical technology for enabling and managing spectrum access e.g., 700MHz TVWS and 3.5 GHz Notice of Proposed Rule Making and Orders (NPRM) [4, 10, 20]. A geolocation database is a critical component of CRS but it is not fully enabled, and therefore spectrum is not efficiently utilized, unless it is in conjunction with sensing and frequency/bandwidth agility e.g. using CRS. A database is a necessary starting point for policy management but the most effective outcomes are realised through the combination of geolocation database and spectrum sensing.

Basing management and policy decisions in networked and synchronized databases allow regulations and services to adapt over time and vary by band while protecting incumbent users [5]. Networked databases provide access to information beyond what is immediately observable by a radio, thereby mitigating hidden node problems in spectrum sharing scenarios. They provide a simpler mechanism for managing upgrades to spectrum management and dynamic access schemes by updating rules in a small set of databases rather than in millions of individual radios.

Furthermore, this approach has additional foreseeable benefits in that it starts the community down a path towards gathering real-time spectrum information and awareness from many distributed users, thereby helping to achieve the real-time spectrum dashboard vision [5, 6]. It also simplifies the integration and application of non-spectrum domain information into spectrum management decisions, and such a solution should scale well over time.

Databases could be made an integral part of a coexistence architecture given their visibility into the locations and operational states of many different radios from disparate wireless networks. Such a solution would need relatively rapid database responsiveness to account for changing environmental conditions. This could be helped by adopting a hierarchical architecture of databases with local caching.

However, managing spectrum access in such a manner should account for the following considerations:

- The possibility of a catastrophic single-point of failure implies that the system should have redundancies built in.

- The possibility of disparate information leading to conflicting and potentially difficult to trace decisions means that these multiple redundant databases should be well-synchronized.

- Spectrum sharing systems leveraging networked databases have a greater need for secure communications and authentication due to the potential for impacting a large number of systems.

- Furthermore, as with all databases, there exists the possibility of incomplete or erroneous information.

Thus there is value to incorporating fail-safe mechanisms, such as spectrum sensing, which could provide a mechanism for assessing the presence of protected users independently of databases.

Furthermore, current trials have shown that the use of networked and synchronized databases accessed with device location information can be a critical technology in maximizing incumbent protection by enabling and managing real time access to this spectrum by secondary users on a geographic and temporal basis [7, 8, 9]. Basing management and policy decisions in networked and synchronized databases allow regulations and services to adapt over time and vary by band while protecting incumbent users. Networked databases provide access to information beyond what is immediately observable by a radio, thereby mitigating hidden node problems in spectrum sharing scenarios. They provide a simpler mechanism for managing upgrades to spectrum management / access schemes by updating rules in a small set of databases rather than in millions of individual radios [10].

3.3 Applicability to different frequency bands

In Section 5.1 of the draft document, the use of the 5GHz band as a radio local area network (RLAN) is outlined as an example of where dynamic frequency selection is used.

The FCC Notice of Proposed Rule-Making and Order on the use of small cells in the 3.5GHz band offers an additional example of a multi-tiered licensing and usage framework where usage models and power levels depend on the geographical deployment area. The under-utilisation of spectrum is not a band-specific problem; spectrum is underutilized in several frequency bands where these bands also have the potential for spectrum sharing through CRS means [11].

3.4 Sensing – secondary user coexistence.

Spectrum sensing is address in Section 6.12 of the draft working document. The Forum suggests that the following text be considered for integration into this section:

The use of spectrum sensing technologies to better enable cooperative, opportunistic access should not be discounted in future regulatory and system planning [12].

A spectrum sensing device intelligently detects whether a band of electromagnetic spectrum within radio frequencies is currently in use. Technologies for spectrum sensing include both non-cooperative (e.g. matched filters, energy detection, cyclostationary analysis, wavelet analysis, and covariance detection) and cooperative sensing. Cooperative sensing helps to improve detection by providing readings from multiple users who collaborate with each other to refine non-cooperative spectrum sensing devices. Cooperative sensing provides both users and network administrators an appropriate spectrum context for implementation and optimization of policy based spectrum management. Multiple independent observations may be useful in identifying hidden nodes, minimizing false alarms, and may provide more accurate signal detection.

3.5. Receiver guidelines/ receiver specifications

Regarding Section 7 where the characteristics and high-level operation and technical requirements are discussed, the Forum suggests the following input for integration into this section:

The use of receiver characteristics should be included as part of the analysis of spectrum allocations. The traditional regulatory focus on transmitter emissions is insufficient to properly operate a cognitive radio system within and across band allocations. Defined protection approaches are a function of the receiver parameters such as sensitivity, blocking and protection ratios. By including receiver characteristics into the CRS solutions, improvements in flexible spectrum usage will be enabled [13].

The specific form of these receiver characteristics will vary on the service and type of CRS being considered. For example, database driven CRS systems that are sharing spectrum with well defined fixed users may be able to pre-compute protection zones as a function of frequency and location based on the transmitter and receiver performance characteristics. This would not require communications of the receiver characteristics to all users of the band. Dynamic CRS systems that just share among other cognitive users may be able to use adjacent channel protection limits or harm thresholds based on adjacent user receiver characteristics to evaluate their usage impact. Highly dynamic systems could potentially sense and evaluate all of the links in the system based on detailed receiver characteristics and optimally form their communications to minimize impact. Regardless of the method used, all of these CRS systems would need to have access to the fundamental receiver characteristics for adjacent and co-incident users.

Regulators should leverage the work of standards and certification bodies to develop the methods of capturing, sharing and certifying receiver performance characteristics for their represented industries, with regulators encouraging the formation of broader groups of spectrum stakeholders to enable this information to be useful to CRS systems in shared bands.

The role of receiver parameters in standards and their related consideration in spectrum engineering should receive greater prominence in order to enhance spectrum efficiency and to help maximize value to the economy and society.

- Significant potential benefit can be achieved in terms of spectrum efficiency through this approach while at the same time reducing risk for new market and new technology entrants [14].

- Receiver parameters play a fundamental role in flexible spectrum usage and management because the defined protection approaches are a function of the receiver parameters e.g. sensitivity, blocking, and protection ratios

- Improvements in technology and manufacturing processes have greatly reduced the costs for components designed to improve receiver performance. It is therefore more feasible that there is little or no economic penalty for improving receiver performance in new products.

- Furthermore, the protection of an existing wireless communications system with a poor receiver performance could hamper the introduction of a new technology.

- Receiver parameters included in harmonized standards would have an impact on equipment specifications, which would improve the performance of existing radio applications and further support the deployment of new wireless communications products and services.

3.6. Tech/Service Neutrality

We note that the draft report does not appear to address the technical aspects regarding on ongoing push towards technology and service neutrality with regards to spectrum regulation. We therefore propose that a new section and the following additional text be considered for inclusion in the draft report:

Technology and service neutrality is required to further enable innovative and efficient use of spectrum. While supporting a regulatory framework of dedicated, licensed spectrum, increased neutrality with respect to the specific uses of licensed spectrum could result in increased innovation in wireless applications. For example, mandating specific technology restrictions negatively impacts continued use of second-generation commercial wireless technology. In some jurisdictions, regulations still require that commercial wireless operators use Global System for Mobile Communication (GSM) in certain bands. However, no reason exists today for precluding operators from using other air interfaces within these bands such as LTE, IEEE 802.11af or proprietary air interfaces. SDR base station technology can support multiple technologies using the same hardware, dynamically assigning channels in a manner that avoids any interference between them [15].

Allocating spectrum with licenses adapted towards a spectrum usage rights method that has the minimum necessary technical restrictions to provide adequate protection against harmful interference. Optimal use of radio spectrum is more likely to be secured if the market, and not the regulator, decides what technology or service should be provided in a particular frequency band. The increase in users' flexibility and ability to respond faster to changing market and deployment conditions will enhance the ability to increase spectrum usage efficiency. Licenses should not necessarily restrict the technology or application. [16,17].

3.7 Blended infrastructure approach

The draft report does not specifically address blended infrastructure. This consideration for a blended infrastructure directly impacts Sections 8 (CRS performance and potential benefits) and 9 (Factors related to the introduction of CRS technologies and corresponding migration issues) of the draft working document. We propose that the following text be considered for inclusion in the report:

A blended infrastructure approach will increase in dominance over the coming years. It is unlikely that a single technology/standard will be able to provide sufficient capacity and coverage within the land mobile sector. The use of CRS should therefore be considered as a complement to existing network deployments e.g. LTE, and how best to leverage the advantages of cognitive radio systems in this context.

This blended infrastructure is illustrated in Figure 1, where RF mesh and TVWS technologies complement a core cellular network technology e.g. LTE, for capacity and high data-rate delivery, and 2-3G cellular technologies for coverage. WiFi will continue to play a strong role in home area networks and as part of operator data-offload strategies. Short range devices e.g. ZigBee and Z-Wave will dominate the in-building control sector. The role of CRS should be considered against this backdrop as a complement to existing technologies and also how to leverage the advantages of an existing WiFi network or short range wireless sensors for new CRS use cases for example.

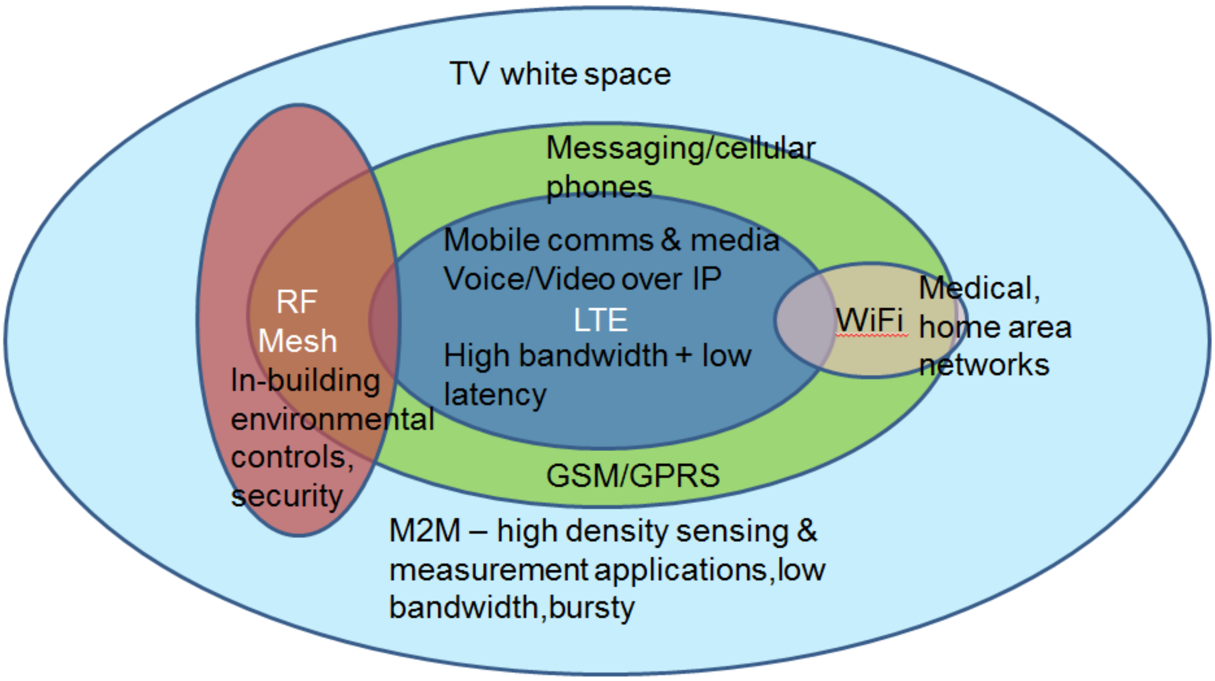

Figure 1: Blended technology approach with LTE at the core for capacity, GSM/GPRS for coverage, RF mesh used as part of bridging between the core networks and user devices, WiFi for home, office, and operator data offload, and TV whitespace & CRS for longer range/building penetration use cases

3.8 Licensing models

The draft report does not appear to address the technical implications associated with emerging licencing models. The Forum therefore suggests that the following text be considered for inclusion in the draft report:

In further consideration of the technical requirements and performance evaluation of CRS, the need for dedicated spectrum for essential and critical communications will remain. Dedicated spectrum is critical to the development and operation of essential and critical communications systems to support, for example; first responders, state and local public safety communities and federal Homeland Security networks. The need for immediate and prioritized access to spectrum, in emergency/crisis situations, can only be met by exclusively authorized (licensed or assigned) spectrum [18].

Commercially operated communications systems require similar dedicated access to exclusive-use spectrum to build the necessary business case for predictable service delivery to prospective consumers. Without a business case, founded on dedicated spectrum, commercial operators will not be able to make the large investments necessary to deliver national broadband wireless services as called for by regulators [19].

Regulatory models should include combinations of licensed and unlicensed, sharing and hierarchical, cooperative and co-existent domains for the optimal utilization of spectrum. This approach will also permit the use of spectrum that is currently unavailable due to warehousing or is no longer used though the license remains active. While exclusive-use spectrum is a necessary regulatory condition, it is insufficient to ensure that national spectrum resources are optimally leveraged to maximum benefit. The integration of unlicensed access models and establishment of new spectrum sharing regulations, including increased tolerance of nominal levels of interference where appropriate, coupled with effective interference resolution processes are critical.

Assessment of the impact of spectrum sharing on unique legacy system that are unable to augment their systems performance must be addressed by regulatory agencies. An example of such a system is the National Science Foundation (NSF) National Radio Astronomy Observatory at Green Bank West Virginia; they may need an increase in their radio exclusion zone to mitigate the impacts.

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