IJournals: International Journal of Social Relevance & Concern
ISSN-2347-9698
Volume 5 Issue 12 December 2017

Emerging Technology for Seamless Experience in Heterogeneous Radio Environment Discovery

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ABSTRACT

Next-generation mobile network is expected to integrate wireless networks into the present cellular/Wi-Fi air interfaces. Existing personal (UWB and ZigBee series), metropolitan (WiMAX IEEE 802.16 series) and regional area networks (IEEE 802.22 series) are challenged with discovery and selection of new access system to meet intersystem handover and operation policy. Setting high-level requirements to support IP-based services to offer access for seamless mobility among heterogeneous networks, requires an equipment capability upgrade in accordance with user requirement and network condition. This research objects an infrastructure to leverage reconfiguration management for transparent information access without requiring explicit interventions. Devising an encapsulated Software-Defined Radio (SDR) and Cognitive Radio (CR) infrastructure is an emerging concept to provide for excellent performance. Using a Cognitive Pilot Channel (CPC) solution as approach to enable selection of best network flexibly is expedient within heterogeneous RATs environment. More so, data delivery over cognitive channels (CC), implementable in broadcast and/or on-demand approaches via adoption of 'CPC radio-enabler' summarily upgrades equipment for discovery and selection. Communication over CC is therefore, equipped for seamless access, continued qualitative service, demanded transmissions (uplink or downlink) of IP packets. Flexible entry schemes to enhance self-CHOP within RATs boosts distribution of cognitive-control information used for network-centric applications. Control schemes and etiquettes of the SDR equipment architecture is valid for effective autonomic computing in future generations for spectrum utilization.

***Keywords* – CPC, CRT, In-band, Out-band, RATs, Radio System, Self-CHOP**

1. INTRODUCTION

Emerging cognitive radio technology (CRT)and associated reconfiguration holds great promises in enabling unlicensed operation in licensed bands, to meet increasing demand for radio spectrum and subsequent optimization of wireless transmission routes for maintainingtraffic balances[1]. This technology has been developed to provide proximity services in line with the Third Generation Partnership Project (3GPP) of enhancing Long Term Evolution (LTE) standards. In line with developed standards for LTE public safety in 3GPP, Cognitive Pilot Channel solution in Cognitive Radio Networking (CORNET)is an emerging technology andintelligent approach to ensureinteroperability between the various access technologies and numerous service vendors. This inductively providesstimulation of competitive equipment marketing [2] because through self-management and self-diagnostic distributed computing and networking facilities, the objective is to offer user transparent information access without requiring explicit interventions.

The information technology community has been struggling to identify technical solution to autonomic computing in wireless systems. Autonomic computing emerges as a new paradigm for managing increasing complex tasks at the business, system and device level without human intervention. This is termed Self-CHOP capability, embedded in CRT via cognition and reconfiguration of cognitive networks.self-CHOP connotes *self-configuration*, *self-healing*, *self-optimization* and *self-protection*[3] in accordance with [3a] and [3b]. In like manner, autonomics concept stretches 'self-CHOP' to self-CHOPKA capabilities with additional capabilities '*KA*' denoting *self-knowledge*(ability to know status of its own resources, components and communications) and *self-adaptation*(ability to generate and enforce policy rules based on contextual information to transform both itself and local vicinity[4].

MDs equipped with Multiple Inputs Multiple Output (MIMO) technology exhibit channel diversity while collaborating with other technologies in the delivery of mobile broadband using CRT. This standard of High Speed Packet Access (HSPA$^+$) gives robust support for 4G systems in excellent delivery of public safety [5]. Although, two major issues of routing, (1) the concept of channelization and handling of dynamic variation of added dimension for route stability and (2) opportunistic performance on allocated frequency spectrum (say 2.4GHz and 5GHz) bands; and many other challenges are handled by the dynamism of multi-radio technology of cognition and reconfiguration offered in CRT.

By design and construction, MDs aspersonal communication devices includes cell phones, private digital assistants (PDA) and laptop personal computers, capable of communicatingeither locally via Bluetooth technology, a network (such as GSM, UMTS or both) using one or more radio access technologies (RATs). The *radio application*aresoftware application executing in any software defined multi-radio equipment but radio application is typically designed to use certain radio frequency band(s) and to include agreedschemes for multiple access, modulation, channel and data coding capabilities as well as control protocols for all the radio layers needed to maintain user data links between adjacent radio equipment(s), running the sameradio application. This describes the co-existence of SUs with PU.

Conversely, wireless systems have become highly congested due to increasing number of users and access to most applications via the Internet. These existing infrastructures can no longer deliver required services continuously. Although, most users are increasingly being equipped with wireless laptops, handheld computers, iPADs, iPhones with video cameras etc., service degrades as collaboration techniques for quick access to qualitative services remain as great challenge [6]. As radio system consists of a number of radio equipment(s) using at least one common radio access technology(RAT), Software Defined Multiradio (SDM) technology enables multiple radio technologies coexist to share wireless transmission and/or reception capabilities regulated and operated under common software system [7].

More importantly, terminal-centric configuration requirement in heterogeneous radio context enables selection of a single RAT or multiple RATs to camp on while roaming. Any mobile device (MD) is capable of detecting anyof the heterogeneous wireless frameworks, includingthe cellular systems (Wi-Fi), wireless local area networks (WLAN),wireless personal area networks (WPAN) and wireless regional area networks (WRAN).

2. THEORETICAL ANALYSIS OF RELATED WORKS

Cognitive Radio Technology (CRT) evolved from Software Defined Radio (SDR) as an implemented technology to increase spectrum usage [7] while network users are enabled to dynamically use additional spectrum provided for Television White Spaces (TVWS). The WRAN defined by the Institute of Electrical Electronics Engineers (IEEE) specified IEEE 802.22 standard as the technology to enable interoperability with lower standards. This is the standard guiding the CR technology.

CRwireless system senses its operational environment by periodical scans to adjust operating parameters to modify system operation autonomously for system and user needs. CR control processes permits full leveraging on situational knowledge and intelligent processing for autonomous adaptation. CR technology,guided by IEEE 802.22 meets the specification for Wireless Regional Area Networks (WRANs) and for convenience in small and large business,IEEE defined another standard, IEEE 802.20 as specification for mobile broadband wireless access [8]. So as CR senses its operational environment by periodic scans, it adjusts operating parameters, modifies system operation to autonomously suite user applications[9].

Reference [10] described CR as intelligent system, which implements artificial intelligence techniques to offer Dynamic Spectrum Access (DSA) tofacilitate interoperability with lower IEEE standards. This technology alleviates spectrum scarcityfaced by wireless communications while an earlier description in [11] specified CR as an integral agent to software defined radio (SDR) communications.

As broadband wireless technology continues to evolve and 4G technology of HSPA$^+$ is being applied to emerging technologies, the promise of higher speed wireless networks' focus on data and multimedia streaming is achievable. Though, the immediate benefit of mobility in wireless network isevidently characterized with massive scalability and improved reachability, existing wireless systems' aim and offerof higher data rate applications to numerous users at same time and practical constraints of excessive traffic requests has imposed scarce resource bottleneck on the networks[12].

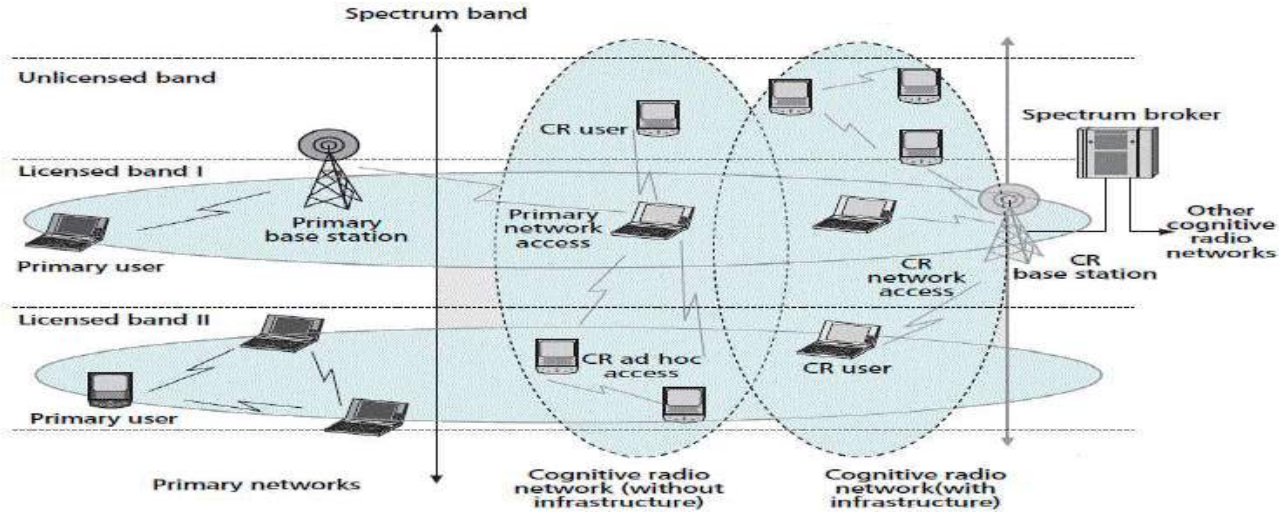
Software Defined Radio (SDR) being a radio that provides *software control* of a variety of modulation techniques, wideband or narrowband operation, communication security functions and waveform requirements of current and evolving standards over a broad frequency range. As multi-band, multi-standard, multi-service and multi-channel device, cognitive radio waveform functionality is reconfigurable through software and each CR device is configurablefor many functions[13]. In the long term, SDR proposed by SDR Forum (Wireless Innovation Forum) is becoming the dominant technology in radio communicationsbecause thesoftware defined antennas can also be featured as 'radio enablers'within the CRT.

SDR equipment operates in the same kinds of networking environments as today's MDs[14]. Both licensed and unlicensed frequency bands remain in use while SDR equipment userterminals within operators' networks feature as peer equipment either in short range, personal or ad hoc networks, specifically MANETs[15]. Radio and TV broadcasting stations and other geo-positioning satellites could also be used as distant communication peers of SDRequipment.Unlike conventional radio, both SDR and CR dynamically support multiple variable systems using various protocols and interfaces [16].Furthermore,SDR'reconfigurability is a proof of software prototyping and upgrade approach to provide for faster/cheaper process of improving technology than the usual hardware high-level designs [17].

3. CORNET ARCHITECTURE FOR CPC DESIGN

CORNET architecture presented in fig. 1 consists of cognitive radio (CR) base stations (BS), access points (AP) and CR users (terminal) elements. With the configurationshown as three-tier architecture consisting of licensed bands I, II and unlicensed band defined to provide service to licensed and unlicensed users respectively, CPC enables the conceptual delivery ofproximity services.Licensed users are called *primary user (PU)* of CORNET licensed channels while other users of the network becomes *secondary users*(SUs).

With the notion described in[18], CRT enables *SU* co-existence on the channels as CR senses and adapts the *SU* to communicate on detected white spaces (idle band/channels) while not interfering with the *PU* activity. CR terminals have access to both licensed and unlicensed channels/bands. This access to wide area coverage is an operation on CPC out-band, provided for CR terminal via a new radio interface (Wi-Fi, WSN, WiMAX or CRT) or an adaptation of legacy technology with appropriate characteristics. As speculated in [19], the out-band CPC is not provided by bearers from a RAT in any operator's legacy system but the in-band CPC is enabled to use channels of existing RATs as provided by the bearer of an operator's network.



, Fig. 1 Cognitive Radio Network Architecture (adapted from Akyildiz *et al.*, 2011)

AP data broadcast allow *PU* terminal selects a network within the heterogeneous access environment, implementing procedures defined in the flowchart described in fig. 2. The Out-band information refers to any physical channel outside the component radio access technologies while the in-band information specifies the logical channels within the component radio access technologies. The out-band CPC information, obtained between Bands I and II or between Bands II and Unlicensed is used as the start-up information while the in-band CPC information (within Band I) provides the intelligence taken as ongoing information.

3.1 Proposed model of combined CPC information approach

Where several technologies are possibly provided by several operators, network management is controlled by meta-operator regrouping the several operators using more detailed context information such as policies for reconfiguration management [19].

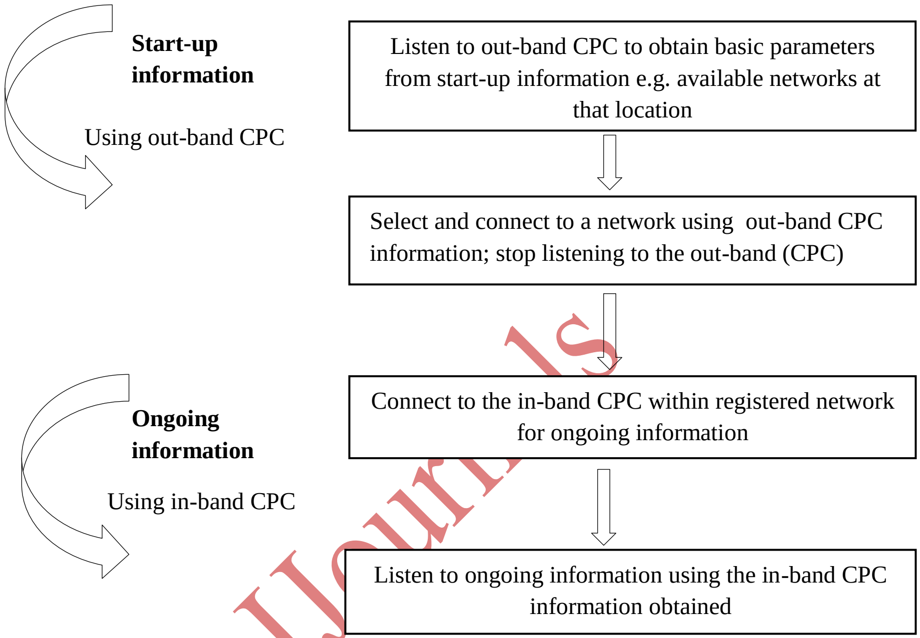


Fig. 2 Flowchart combining out-band and in-band CPC operations

The CPC combined informationapproach of both in-band CPC and out-bands CPC requires some form of harmonizationbetween the two distinct phases of start-up and ongoing strategic implementations. This harmonization is termed Harmonized band. Once the start-up information is obtained via out-band CPC operation, the device will switch to the in-band CPC to obtain ongoing information while the different bearers adapt to smaller 'CPC cells' to provide a higher bitrate and more likely provide downlink and uplink information transfer.

For CR nodes to periodically scan and identify available channel(s)within selected frequency spectrum made available for SU transmission/reception for reasonable amount of time without interference with PU activities, some layer-2 configuration problem needs to be resolved before establishing network-wide communication. This is handled by SDR where the configuration is implemented in abstracted centralized (or peer-to-peer) communication paradigm as illustrated in fig. 3. This special characteristic of CRT encapsulates SDR and CR to offer self-CHOP capabilities and autonomic computing described in [3].

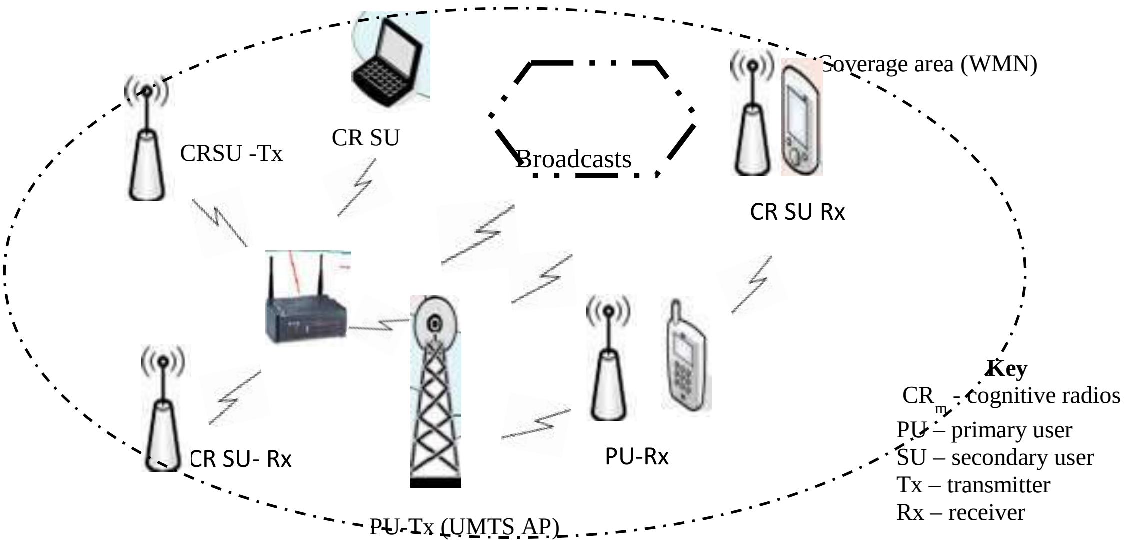


Fig. 3 CORNET configuration (adopted and modified from Ghosh *et el*, 2014)

Automation and dynamic scaling of CORNET parameter is realizable and validated by virtualization through implementation of SDR of software defined networks [20]. SDR model also implementssupervisory control and data acquisition (SCADA) technique to dynamically shape network trafficto realize a centralized CORNET architecture depicted in fig. 3 to establishrequired orthogonality computationfor two signal functions x_q and $x_k$respectively representingPU and SU. These users are orthogonally defined over interval $[a,b]$as specified inthe expression given in (1).

$$\langle x_q \cdot x_k \rangle = \int_a^{bU} x_q(t) \cdot x_k(t) dt = \begin{cases} 1, k = q \\ 0, k \neq q \end{cases} \quad (1)$$

Thisassociation between PU and SU is zero for any combination except for $x_q(t) = x_k(t)$,thus coexistence of both PU and SU activity/session on same spectrum band simultaneously without interference is established in [9] andalso proved in [21].

3.2 Defined rules for opportunistic channel access by cognitive elements

Taking APs as PUs and MDs as SUs, co-existence of PU and multiple SUs is enabled on assigned channels with defined RATs (e.g. IEEE 802.11) under the following conditions:

Let N be a set of channels where frequency range = $1 \ldots n$;

Let J be the set of access technologies within the heterogeneous networks captured by any operator m;

Let M be a set of cognitive radios (APs) competing for opportunistic access on the N channels allocated to a PU using any of $j = 1 \ldots J$;

M cognitive radio pairs sense from a set of N channels using J RATs.

On data broadcast, a CR's throughput of locating information is affected by other CR's success in finding a vacant channel (frequency range) usable as well as by PU activity. This results in fairness of resource allocation.

For a SU (MDs) to select a good channel and also co-exist efficiently with other SUs, the Stochastic Multi-channel Load Balancing (SMLB) algorithm is implemented.

With PU and SUs co-existence on discovered and selected channel and allotted RAT, the potential of learning embedded in routing enabled intra-SU collaboration and co-operation. This is essentially provided via CRC in-band operations. Conversely, information availability at any mesh location within the geographical area covered by transmission (AP broadcast coverage) is achieved via CPC out-band operation.

Required seamless experience is obtained as defined in algorithm I s depicted in fig. 4.

Algorithm I

Mesh #i: Location information for SU
Operation #1
RAT #1
Frequency Range #1
.
.
.
Frequency Range #n
RAT #j
Frequency Range #n
SU
Operator #m

Fig 4:Algorithm I

4. DISCUSSION

Each AP, equipped with wireless interface of *J* RATs act as gateway to provide connectivity to the Internet. As each APbroadcasts connectivity advertisements relayed by multi-standard CR neighbour, every MD needs no farther than two hops from gateway to the Internet. Also, the CR MDs act as intermediate hosts and routers in agreement with [22] and [15]. CR u*ser* terminals in CORNET exhibit smart and micro-intelligence capabilities. Combining in-band and out-band information management help achieves autonomic computing to enhance discovery and selection of access networksthat provides seamless experience. In addition, the technology offer an equipment upgrade capability to meet pressing needs of wireless users whereby mutual co-existence of multiple CRs on same channel(licensed or unlicensed) will facilitate spectral usage efficiency where multi-radio application sessions characterized with reduced service disruption is featured [5].

Proximity services of either (i) network assisted discovery of users (*user equipment to network relay)*or (ii) direct communications between users (*user equipment to user equipment relay*) is facilitated by CORNET to promote public safety communication in areas outside network coverage. In effect, the WRAN architecture provide support for TV-Band devices, Geolocation/Database applications,Spectrum Sensing technology as well as Wireless Cellular and Public Safety Networks, Smart Grid, Wireless Medical Networks (WMNs) and other Wireless Mesh Networks (WMNs) [23].Technically, CRT and CPC formulation, aided by OFDMA and WiMAX technique eliminates allhidden node problems of ordinary wireless systems (Jinadu, 2016).

5. CONCLUSION

Equipment upgrade achievable with cognitive pilot channel information management as CORNET offer as major paradigm for heterogeneous next generation mobile system enables SDR/CR exploitation. Communication nodes and other network elements are therefore equipped with autonomic decision making and elf-management (self-CHOP) capability. Additional capability of self-knowledge and self-adaptation is conversely provided as a way-to-go from the telecom-initiated functions to flexibly-governed systems. Besides existing radio technologies, new radio technologies and frequency bands will become available to SDR equipment, CR terminal nodes and mobile devices.

Therefore, design of SDR/CR equipment architecture for adoption by new frequency bands and radio systems, especially, the ones supporting cognitive radio systems is usable on cognitive channels (CC) profitably. More flexible schemes to use available radio frequencies profitably will emerge by refined spectrum sensing techniques discussed in [1]. In addition, the flexibly co-ordinated distribution of cognitive control information and its use of commonly-agreed spectrum etiquettes enhance efficient utilization of spectrum scarce resource. From the SDR equipment architecture point of view and implementation of CC, both network-centric control schemes and autonomously operating MDs are very valid in future spectrum utilization cases desired for interoperability with lower IEEE standards. This is specially facilitated by the flexible access offer by SDR/CRscheme for improved self-CHOPKA capabilities and autonomic computing. These features are expedient for performance in future wireless generations.

6. ACKNOWLEDGEMENTS

Special thanks to the Tertiary Education Fund (TETFund) of Federal Republic of Nigeria for providing support for research and the Polytechnic community for providing an enabling environment to carry out research in diverse fields of study.

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