ABSTRACT
Cognitive wireless network has emerged as a promising technology for maximizing the utilisation of frequency spectrum. To improve spectrum utilisation, cognitive radio attempt to use temporarily unoccupied spectrum.

KEYWORDS

INTRODUCTION
Today’s wireless networks are characterised by a fixed spectrum assigned policy. Most of the systems are not aware of their radio spectrum environment and operate in a fixed frequency band using a specific spectrum access system. Actually not all the spectrum is utilised efficiently. Cognitive radios (CRs) are highly agile wireless platform capable of autonomously device parameters based on prevailing operating conditions. Moreover during emergency and natural disaster scenarios centralised wireless networks these cognitive radio network may not be available due to overloaded, damaged, or unpowered an access points and base stations. Distributed cognitive radio net- works can potentially establish wireless access in areas lacking an active wireless infrastructure. Cognitive radio is a revolution in radio technology that is enabled by recent advances in RF design, signal processing, and communications software [1,12]. The capability of CR has been recognized by the military and commercial sector and is now under intensive research and development by the DoD’s Joint Tactical Radio System (JTRS) program and wireless industry. Since transmitted waveform is defined by software, a CR is capable of reconfiguring RF [2] and switching to newly-selected frequency bands. From networking perspective, the emergence of CR offers new challenges in algorithm and protocol design. It is important to realize that a CR is vastly more powerful and flexible than existing multi-channel multi-radio (MC-MR) technology (see e.g., [1], [2]). MC-MR remains hardware-based radio technology: each radio can only operate on a single channel at a time and the number of concurrent channels that can be used at a wireless node is limited by the number of radio interfaces. In addition, an MC-MR wireless network typically points and base stations. Consequently, distributed cognitive radio net- works can potentially establish wireless access in areas lacking an active wireless infrastructure.
SPECTRUM UTILISATION:
Spectrum utilisation can be explained with the help of fig 1, where the signal distribution over a large portion of the wireless spectrum is shown. The spectrum usage is concentrated on certain portions of the spectrum while the significant amount of the spectrum remains unutilised. Next generation (xG) also known as the dynamic spectrum access Networks (DSNAs) as well as cognitive radio networks. Dynamic spectrum access is proposed to solve these current spectrum efficiency problems. Cognitive radio techniques are used to use and share the network in a smart way.

COGNITIVE TASKS:
Cognitive radio is a software defined radio in which the cognitive tasks are of three types, as shown in fig.2.

1. Radio- scene analysis which encompass the following.
   - Estimation of interference temperature of the radio environment.
   - Detection of spectrum holes.

2. Channel identification, which encompasses the following:
   - Estimation of the channel state information(ESI)
   - Prediction of channel capacity for use by the transmitter.
3. Transmit power control and dynamic power management:

Task 1) and task 2) are carried out in the reciever and task 3) is carried out in the transmitter.

Dynamic spectrum management required secondary users of the spectrum’s unoccupied subbands must coexist with the primary users. Interference temperature at the receiver input of each user in the network does not exceed prescribed limit. The primary requirement of the cognitive radio for spectrum sensing (unlicensed) is

- Abundance of spectra, which is available and used for spectrum sharing by secondary user (SU).
- SUs use cognitive radio techniques to avoid interfering with primary users (PU) when they are present. As explained previously, the key challenge of the physical architecture of the cognitive radio is an accurate detection of weak signals of users over a wide spectrum range. Hence, the implementation of RF wideband front-end and A/D converter is critical issues in xG networks.

ISO/OSI model for a Cognitive radio function:

This system design only covers the ISO/OSI layers one physical layer and two link layer. Higher layers will implement standard protocols not specific to cognitive radios [4]. Fig. 3 shows the main building blocks for the deployment of a Cognitive Radio system. We identify six systems functions and two control channels that will implement the core functionality.

A. Physical Layer Functions

1) Spectrum Sensing

The main function of the physical layer is to sense the spectrum over all available degrees of freedom (time, frequency and space) in order to identify sub-channels currently available for transmission. From this information, Secondary User Links can be formed from a composition of multiple sub-channels. This will require the ability to process a wide bandwidth of spectrum and then perform a wideband spectral, spatial and temporal analysis. Sub-Channels currently used for transmission by SUs have to be surveyed at regular intervals – at least every transmitter to detect Primary Users activity on those Sub-Channels and if there is activity then those Sub-Channels must be given up. It will be necessary for the SUs to exchange and merge their local sensing information in order to optimally detect presence of PUs and avoid the hidden terminal problem. This cooperation between SUs within a communicating group will be important to realize adequate accuracy of interference activity. Spectrum sensing is best addressed as a cross-layer design problem since sensitivity can be improved by enhancing radio RF front-end sensitivity, exploiting digital signal processing gain for specific primary user signal, and network cooperation where users share their spectrum sensing measurements.
2) Channel Estimation
In order to set up the link, channel sounding is used to estimate the quality of sub-channels between SUs that want to communicate. The transmission parameters (transmit power, bit rate, coding, etc.) are determined based on the channel sounding results. After the setup, the physical layer continuously estimates the quality of sub-channels analyzing the data packets received during ongoing communication.

3) Data Transmission
CR’s optimally uses the available spectrum as determined by the spectrum sensing and channel estimation functions. Therefore it should have the ability to operate at variable symbol rates, modulation formats (e.g. low to high order QAM), different channel coding schemes, power levels and be able to use multiple antennas for interference nulling, capacity increase (MIMO) or range extension (beam forming). One possible strategy would be based on an OFDM-like modulation across the entire bandwidth in order to most easily resolve the frequency dimension with subsequent spatial and temporal processing.

B. Link Layer Functions
1) Group Management
We assume that any secondary station will belong to a SU Group. A newly arriving user can either join one of the existing groups or create a new one through the Universal Control Channel.

2) Link Management
Covers the setup of a link in order to enable the communication between two SUs and afterwards the maintenance of this SU Link for the duration of the communication. The link layer will initially choose a set of Sub-Channels in order to create a complete SU link subject to the considerations described previously.

3) Medium Access Control (MAC)
As long as it can be assured that all Sub-Channels are used exclusively, i.e. all Sub-Channels used by one SU Link cannot be used by any other SU Link this problem comes down to a simple token-passing algorithm ensuring that only one of the two communication peers is using the link[11]. However, when considering a multi-group, multi-user system, which may not be centrally organized, making the assumption of exclusively used Sub-Channels is not realistic. So the MAC has to provide means to concurrently access a SU Link by SUs or even to manage the concurrent access of individual Sub-Channels by different connections of different SUs. A generic architecture of a cognitive radio [4] is as shown in Fig. 3.main components of the cognitive radio transreceiver are the radio front end and the baseband processing unit. Each component can be reconfigured via a control bus to adapt time varying RF. In the RF front-end, the received signal is amplified, mixed and A/D converted. In the baseband processing unit, the signal is modulated/demodulated and encoded/decoded. The baseband processing unit is similar to existing transceiver unit. However the cognitive radio is the front end. The novel characteristic of cognitive radio transceiver is a wideband sensing capability of the RF front-end. This function is mainly related to RF hardware technologies such as wideband antenna, power amplifier and adaptive filter. RF hardware for the cognitive radio should be capable of tuning to any part of a large range of frequency spectrum. Also such spectrum sensing enables real-time measurements of spectrum information from radio environment [4]. Generally, a wideband front-end architecture for the cognitive radio has the following structure as shown in Fig. 3(b) [5].
The components of a cognitive radio RF front-end are as follows:

- **RF filter**: The RF filter selects the desired band by bandpass filtering the received RF signal.
- **Low noise amplifier (LNA)**: The LNA amplifies the desired signal while simultaneously minimizing noise component.
- **Mixer**: In the mixer, the received signal is mixed with locally generated RF frequency and converted to the baseband or the intermediate frequency (IF).
- **Voltage-controlled oscillator (VCO)**: The VCO generates a signal at a specific frequency for a given voltage to mix with the incoming signal. This procedure converts the incoming signal to baseband or an intermediate frequency.
• Phase locked loop (PLL): The PLL ensures that a signal is locked on a specific frequency and can also be used to generate precise frequencies with fine resolution.

• Channel selection filter: The channel selection filter is used to select the desired channel and to reject the adjacent channels. There are two types of channel selection filters. The direct conversion receiver uses a low-pass filter for the channel selection. On the other hand, the superheterodyne receiver adopts a bandpass filter.

• Automatic gain control (AGC): The AGC maintains the gain or output power level of an amplifier constant over a wide range of input signal levels. In this architecture, a wideband signal is received through the RF front-end, sampled by the high speed analog-to-digital (A/D) converter, and measurements are performed for the detection of the licensed user signal. However, there exist some limitations on developing the cognitive radio front-end. The wideband RF antenna receives signals from various transmitters operating at different power levels, bandwidths, and locations. As a result, the RF front-end should have the capability to detect a weak signal in a large dynamic range. However, this capability requires a multi-GHz speed A/D converter with high resolution, which might be infeasible. The requirement of a multi-GHz speed A/D converter necessitates the dynamic range of the signal to be reduced before A/D conversion. This reduction can be achieved by filtering strong signals. Since strong signals can be located anywhere in the wide spectrum range, tunable notch filters are required for the reduction. Another approach is to use multiple antennas such that signal filtering is performed in the spatial domain rather than in the frequency domain. Multiple antennas can receive signals selectively using beam forming techniques [6].

SYSTEM ARCHITECTURE:
In our system model, SUs form Secondary User Groups (SU Groups) to coordinate their communication. Members of a SU Group use a common control channel for signaling and might communicate with each other in a distributed ad-hoc mode or through a centralized access point. In either mode we assume only a unicast communication, either between a pair of SUs or between a SU and the access point. Direct point-to-point communication between Secondary Users from different SU Group’s or broadcast is not supported [7].

The traffic pattern for the SUs will be initially assumed to have the following characteristics:

1. Centralized, infrastructure based where there has to be a base station or access point providing connection to a backbone connection, as typically found in Internet access networks.

2. Ad hoc networking covers all kinds of ad-hoc traffic that does not assume any infrastructure. Main purpose is to communicate with each other and exchange information within a SU Group.

To support this traffic Cognitive Radio for
Virtual Unlicensed System (CORVUS) [5] operates over a Spectrum Pool, which could cover from tens of MHz to several GHz creating a “virtual unlicensed band”. It is not necessarily a contiguous frequency range and Spectrum Pools of different SU Groups may overlap which implies that SU Groups will compete for the available resources. Each Spectrum Pool will be further divided into N Sub-Channels, which will be the basic resolution used for sensing and transmission. Figure 2 shows the principle idea of a Spectrum Pooling system in CORVUS. Primary Users own different parts of the spectrum but may not be active at a particular time. The shaded frequency bands indicate that the PU is currently using its spectrum and consequently this frequency band cannot be used by any SU. The figure also shows three different active Secondary User communications. For each communication a pair of SUs picked a pattern of sub-channels to form a Secondary User Link (SU Link). The number of sub-channels in a SU link may vary depending on the quality of the sub-channels, the bandwidth of a single sub-channel and QoS requirement for that connection. Sub-channels selected to create a SU Link should be scattered over multiple PU frequency. This principle has a double significance. On one hand it limits the interference impact of a SU on a re-appearance of a PU, while on the other hand if a PU appears during the lifetime of a SU Link it would impact very few (preferable one) of the Sub-Channels used by the SU Link. The communication peers using that link would have to immediately clear the affected sub-channel and find a new free sub-channel. In order to maintain QoS, SUs should always have a redundant number of sub-channels for their SU Link. Within CORVUS, SUs use dedicated logical channels for the exchange of control and sensing information. We envision two different kinds of logical control channels, a Universal Control Channel and Group Control Channels. The Universal Control Channel is globally unique and has to be known to every SU operating in the relevant frequency bands, since access to that channel is pre-requisite for initiating communications. The main purpose of the Universal Control Channel is to announce existing groups and to give the relevant transmission parameters to enable newly arriving users to join a group. Additionally SUs, which want to create a new group can request the local primary user footprints on that channel. Although globally unique the communication range should be locally limited as SU Groups are limited to a local area. In addition to the Universal Control Channel each group has one logical Group Control Channel for the exchange of group control and sensing information. Control channels will carry a limited load of low-bit rate signalling which could be located in:

a) Dedicated spectrum for this purpose
b) An unlicensed band such as the ISM/UNII bands
c) Unlicensed UWB (Ultra Wide Band)

We believe the UWB option is especially attractive if we are considering use of the 3-10GH band. UWB control channels would be unlicensed.
but with low impact on other types of communication and with the possibility to operate independently using different spreading codes. There are severe limitations on the power of UWB emissions limiting its range, but the control channel requires very low data rates, so spreading gain will increase the range to be adequate for most applications (more than 10,000 times lower data rate than the commercial UWB systems being envisaged in this band). Note that the Universal Control Channel and the Group Control Channels are logical concepts, which might even be mapped to a single physical channel broker can be connected to each network and can serve as a spectrum information manager to enable coexistence of multiple xG networks [6,7,8].

![Figure 4: Spectrum pooling idea](image)

![Figure 5: Cognitive radio network system.](image)
The reference xG network architecture is shown in Fig. 6, which consists of different types of networks: a primary network, an infrastructure based xG network, and an ad-hoc xG network. xG networks are operated under the mixed spectrum environment that consists of both licensed and unlicensed bands [7, 8]. Also, xG users can either communicate with each other in a multihop manner or access the base-station. Thus, in xG networks, there are three different access types as explained next:

- **xG network access:** xG users can access their own xG base-station both on licensed and unlicensed spectrum bands.
- **xG ad hoc access:** xG users can communicate with other xG users through ad hoc connection on both licensed and unlicensed spectrum bands.
- **Primary network access:** The xG users can also access the primary base-station through the licensed band. According to the reference architecture shown in Fig. 6, various functionalities are required to support the heterogeneity in xG networks. We describe the xG network functions to support the heterogeneity of the network environment.

### xG network functions

As explained before, xG network can operate in both licensed and unlicensed bands [9, 10, 11]. Hence, the functionalities required for xG networks vary according to whether the spectrum is licensed or unlicensed. Accordingly, in this section, we classify the xG network operations as xG network on licensed band and xG network on unlicensed band. The xG network functions are explained in the following sections according to this classification.

- **xG network on licensed band:** As shown in Fig. 1, there exist temporally unused spectrum holes in the licensed spectrum band. Hence, xG networks can be deployed to exploit these spectrum holes through cognitive communication techniques. This architecture is depicted in Fig. 7, where the xG network coexists with the primary network at the same location and on the same spectrum band. There are various challenges for xG networks on licensed band due to the existence of the primary users. Although the main purpose of the xG network is to determine the best available spectrum, xG functions in the licensed band are mainly aimed at the detection of the presence of primary users. The channel capacity of the spectrum holes depends on the interference at the nearby primary users. Thus, the interference avoidance with primary users is the most important issue in this architecture. Furthermore, if primary users appear in the spectrum band occupied by xG users, xG users should vacate the current spectrum band and move to the new available spectrum immediately, called spectrum handoff.

- **xG network on unlicensed band:** Open spectrum policy that began in the industrial scientific and medical (ISM) band has caused an impressive variety of important technologies and innovative uses. However, due to the interference among multiple heterogeneous networks, the spectrum efficiency of ISM band is decreasing. Ultimately, the capacity of open spectrum access, and the quality of service they can offer, depend on the degree to which a radio can be designed to allocate spectrum efficiently. xG networks can be designed for
operation on unlicensed bands such that the efficiency is improved in this portion of the spectrum. The xG network on unlicensed band architecture is illustrated in Fig. 8. Since there are no license holders, all network entities have the same right to access the spectrum bands. Multiple xG networks coexist in the same area and communicate using the same portion of the spectrum.

Fig. 6 xG network on licensed band.

Fig. 7 xG network on unlicensed band.
Intelligent spectrum sharing layered algorithms can improve the efficiency of spectrum usage and support high QoS. In this architecture, xG users focus on detecting the transmissions of other xG users. Unlike the licensed band operations, the spectrum handoff is not triggered by the appearance of other primary users. However, since all xG users have the same right to access the spectrum, xG users should compete with each other for the same unlicensed band [11]. Thus, sophisticated spectrum sharing methods among xG users are required in this architecture. If multiple xG network operators reside in the same unlicensed band, fair spectrum sharing among these networks is also required.

CROSS OPTIMIZATION LAYER:
In wireless distributed networks, conventional networks will encounter disturbances and performance degradation many times occur due to unstable noise, interference levels and topology changes[12]. Variations in noise and interference levels, together with the distance changes among nodes, will result in fluctuating signal-to-interference-and-noise-ratio (SNR) values at the receiver. The SNR values and the modulation schemes together can be used to determine the bit error rate (BER) at the receiver and sent back to the transmitter via overhead channel. Moreover, the requirements on the BER may vary when employing different error correction schemes and transmission applications. In a wireless network, besides the above dependencies among layers, there are dependencies between link layer and other layers also. The cross-layer optimization engine uses operating parameter information from the various network layers, as well as environmental parameters external to the wireless platform, in order to decide on an appropriate device configuration. This configuration is applied to the network layers of the platform. Routing stability and link availability depend on the BER and positions of nodes, and the hop number and congestion over a route determines the delay value for the transmission application. Performance objectives depend on the several performance parameters such as center frequency, bit rate, transmitter power, and subcarrier bandwidth of the network. Due to the numerous dependencies between the operating parameters and the performance objectives of the system, it is more efficient to configure across the traditional layers in order to better utilize the available resources. The general layout of cross-layer optimization architecture is shown in Fig.8. Each node has a cross-layer optimization engine that takes as input a set of internal and external parameters obtained either by sensing environment or via overhead channels. The engine is responsible for deciding on a set of internal operating parameters across the different layers of the wireless device in order to avoid contention with other users and to satisfy user requirements with as little resource as possible. We are not focusing on incorporating many layers in this work, although this basic framework can be extended to include higher layers.
3. Optimization framework for distributed cognitive radio networks

Since contention greatly impairs network performance, cooperation and optimization across several network nodes can be employed in order to minimize the occurrences of these events. In a distributed network, performance optimization and resource utilization is a more challenging task when compared to a centralized network due to the increased number of variables and the need for increased coordination between nodes. Approaches using a “super node” in order to take care of all optimization activities within the network rely on the ability and stability of the super nodes.

3.2. xG network applications

xG networks can be applied to the following cases: Leased network: The primary network can provide a leased network by allowing opportunistic access to its licensed spectrum with the agreement with a third party without sacrificing the service quality of the primary user [9]. For example, the primary network can lease its spectrum access right to a mobile virtual network operator (MVNO). Also the primary network can provide its spectrum access rights to a regional community for the purpose of broadband access.

Cognitive mesh network: Wireless mesh networks are emerging as a cost-effective technology for providing broadband connectivity. However, as the network density increases and the applications require higher throughput, mesh networks require higher capacity to meet the requirements of the applications. Since the cognitive radio technology enables the access to larger amount of spectrum, xG networks can be used for mesh networks that will be deployed in dense urban areas with the possibility of significant contention. For example, the coverage area of xG networks can be increased when a meshed wireless backbone network of infra-structure links is established based on cognitive access points (CAPs) and fixed cognitive relay nodes (CRNs). The capacity of a CAP, connected via a wired broadband access to the Internet, is distributed into a large area with the help of a fixed CRN. xG networks have the ability to add temporary or permanent spectrum to the infrastructure links used for relaying in case of high traffic load. Emergency network: Public safety and emergency networks are another
area in which xG networks can be implemented. In the case of natural disasters, which may temporarily disable or destroy existing communication infrastructure, emergency personnel steer areas need to establish emergency networks. Since emergency networks deal with the critical information, reliable communication should be guaranteed with minimum latency. In addition, emergency communication requires a significant amount of radio spectrum for handling huge volume of traffic including voice, video and data. xG networks can enable the usage of the existing spectrum without the need for an infrastructure and by maintaining communication priority and response time.

**Military network:** One of the most interesting potential applications of an xG network is in a military radio environment. xG networks can enable the military radios choose arbitrary, intermediate frequency (IF) bandwidth, modulation schemes, and coding schemes, adapting to the variable radio environment of battlefield. Also military networks have a strong need for security and protection of the communication in hostile environment. xG networks could allow military personnel to perform spectrum handoff to find secure spectrum band for themselves and their allies.

**SUMMARY:**
Cognitive wireless network is studied along with cognitive radio operation in detail. We have studied how efficiently frequency spectrum utilisation is achieved by using cognitive radio network system. This technology that will deal with this increasing complexity. This paper presented the first investigation into the critical design decisions that engineers need to trade off when architecting a cognitive network. These critical design decisions were used to analyze a cognitive network for maximizing the lifetime of a multicast tree in a wireless network, providing insight into the effectiveness of the features used in the cognitive process. Cognitive Radios are capable of sensing their spectral environment and locating free spectrum resources. In CORVUS, these radios perform local spectrum sensing but Primary User detection and channel allocation is performed in a coordinated manner. This collaborative (either centralized or distributed) effort greatly increases the system’s ability in identifying and avoiding Primary Users.

In the CORVUS architecture, a group of Cognitive Radios forms a Secondary User Group to coordinate their communication. Each member of this group senses the Spectrum Pool, which is divided into sub-channels. A pair of Secondary Users picks a set of sub-channels spread over multiple Primary User frequency bands to form a Secondary User Link. Sub-channels are picked based on estimated channel gain of a sub-channel and the user’s QoS requirements. These are important issues for designers to analyze and evaluate when researching and implementing future cognitive networks.

**REFERENCES:**


