Cognitive Radio in Public Safety and Emergency Applications

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***Abstract*— During disaster and emergency conditions traditional communication facilities get impaired but it is important to have communication between all the first responders. In such situations wireless technologies offer a suitable way for communication. The emergency communications and disaster relief works create high traffic load and which in turn leads to congestion also network capacity and coverage are the major drawbacks of traditional wireless technologies. As it is known that the spectrum is partitioned and allocated for different purposes, not all the spectrum is used in particular space or time and the unused spectrum can serve the demand in need. "Cognitive radio" which is an intelligent wireless communication system can find spectrum holes (unused spectrum bands) and uses them for communication there by facilitating the effective use of spectrum. So this paper discusses the application of cognitive radio as a solution for communication in Public Safety services and Emergency Communications.**

***Keywords*— Cognitive Radio, Ad hoc Network Architecture, Emergency Communications, Network Coverage Extension.**

I. INTRODUCTION

Cognitive radio can be considered as a key technology for future wireless communications. There are diverse wireless technologies that support Internet access and other traffic services, these different wireless networks/systems can be integrated and any one of them can be used appropriately based on the communication environments and application requirements. This integration can be made through cognitive radio which is a new model in wireless communications that ensure better services for public safety, emergency and military etc. Cognitive Radio improves the spectrum utilization and hence when there is congestion or failure of certain existing technologies at times of emergency and disaster, this new technology can be used to meet the user's needs.

Cognitive radio is an intelligent wireless communication system that can perceive their environment, learn behavior and environmental patterns and appropriately adapt themselves to satisfy the immediate needs of the user, network, and radio environment. In other words, once cognitive radios can find the opportunities using the "spectrum holes" for communications, cognitive radio networking to transport packets on top of cognitive radio links is a must to successfully facilitate useful applications and services. A mobile terminal with cognitive radio capabilities can sense, detect and monitor the surrounding communication environments like spectrum holes, geographic location, and available wire/wireless communication systems/networks then reconfigure their own operating characteristics by adjusting the system parameters to best match those communication environments.

II. NETWORK ARCHITECTURE

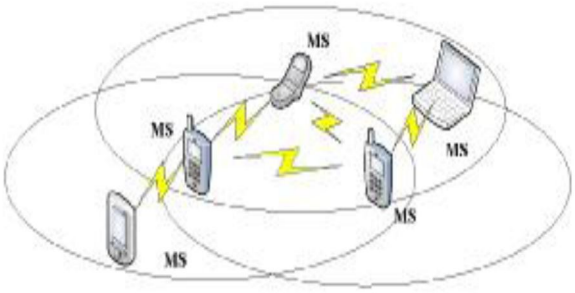
A cognitive radio in Cognitive Radio Network (CRN) can sense available networks and communication systems around it. A Cognitive Radio Network (CRN) is thus not just another network to interconnect cognitive radios. The CRNs are composed of various kinds of communication systems and networks, and can be viewed as s sort of heterogeneous networks. The heterogeneity exists in wireless access technologies, networks, user terminals, applications, and service providers. The design of cognitive radio network architecture is toward the objective of improving the entire network utilization, rather than just link spectral efficiency. The network utilization means the users can always fulfill their demands anytime and anywhere through accessing CRNs.

The CRNs can be deployed in Ad hoc, and mesh architectures. The basic components of CRNs are Mobile Station (MS), Base Station/Access Point (BSs/APs) and Backbone/Core Networks.

A. Ad-hoc Architecture.

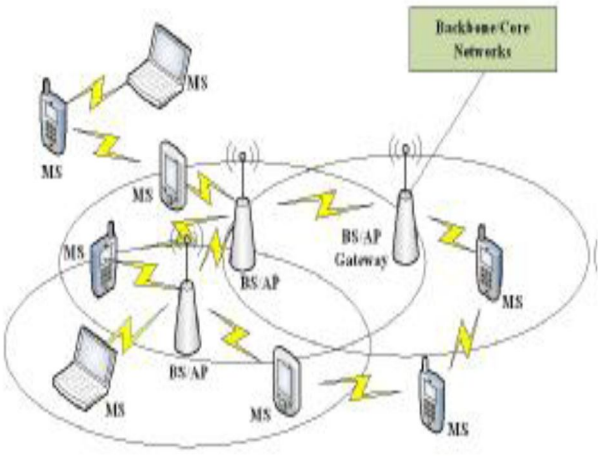
Ad hoc networks are composed of Cognitive Radio devices that are self organizing and can be deployed without any infrastructure present. If a Mobile Station (MS) with Cognitive capabilities recognizes that there are some other MS or cognitive users nearby they can set up a link through certain communication protocols and thus form an ad hoc network. Each MS or Cognitive user forms a node of the ad hoc network. The links between nodes may be set up by different communication technology. Each Cognitive user decides its action based on a local observation and with cooperation schemes the observed information can be exchanged among other users to become aware on the network. Thus the cognitive users can communicate with other cognitive users through the

existing communication protocols (e.g. WiFi, Bluetooth) or dynamically using spectrum holes.



B. Mesh Network Architecture.

This architecture is a combination of Infrastructure and Ad-hoc architectures. This consists of back bone/core networks and also several cognitive radio devices. The Mesh Network enables the wireless connections between Base Station/Access Point (BSs/APs), which is similar to the Hybrid Wireless Mesh Networks. BSs/APs work as wireless routers and form wireless backbones. Cognitive Radio devices/ MSs can either access the BSs/APs directly or use other MSs as multi-hop relay nodes. Some BSs/APs may connect to the wired backbone/core networks and function as gateways. Since BSs/APs can be deployed without necessarily connecting to wired backbone or core networks, it is more flexible and less costly in planning the locations of BSs/APs. Here BSs/APs also have cognitive radio capabilities so they communicate by sensing and borrowing a free space. Due to potentially lots of spectrum holes available, the capacity of wireless communication links among cognitive radio devices and BSs/APs may be enough to serve as wireless backbone.



III. Applications

A. Public safety services

Cognitive Radio with its advantage of efficient spectrum utilization will have significant impact on society with its broader wireless applications and services. CR devices can work on the white space that is not of any use in the frequency spectrum of the transmission channel and can provide solutions to the problems of Public Safety Communications.

One aspect Public Safety Services need to deal with is an interoperability issue among first responders (police, fire, paramedics and safety departments). Interoperability is the important issue because first responders need to be able to communicate during disasters. In any rescue situation, the network consists of different types of network nodes, such as emergency workers, vehicles, helicopters etc. Each of them has different physical layer requirements and disparate hardware which makes incompatible to share information and hence cannot work collaboratively. Hence Cognitive Radio can address this interoperability issue in an effective manner.

Another aspect can be the development of applications that will lead to communicate, locate and reach victims who are stuck in harassed conditions or more critically inside buildings in and around crisis staging area.

Mobile therapies and Wireless medical networks can also be developed with Cognitive Radio Networks. With the integration of on-the-body sensors patients can be monitored for vital signs such as temperature, pressure, blood oxygen and electrocardiogram (ECG). Mobile therapies can become more efficient if the output of the data is in the audio form. A Person can check mood, by fixing a wireless ECG detector on the person's body which detects changes in stress levels as measured by deviations in heart rate variability and triggers mobile therapies and as a result the result is outputted in the audio form.

This audio output methodology can be implement on various aspect of our day to day life and during the emergency and public safety applications like in forest fire, hurricane etc. Sometimes the rescue team working in a building may need a map of a building which can be uploaded to the cognitive device of a worker from the control room, thus enabling even video streaming also.

B. Emergency communications

During emergencies, like a natural calamity, a terrorist attack or war zone scenarios the importance of communication systems becomes clear. These communications systems include the wireline and wireless telephone networks, radio, Public Safety Land Mobile Radio, satellite systems and increasingly the Internet. If a major disaster takes place, the existing public network is often gets overloaded by concerned citizens and calls for help within a very short time. Even though special emergency channels are allocated for the to prevent the emergency services from being too dependent on the public network, but they too often gets crowded with the calls as they have a limited bandwidth. If emergency services also want to communicate via video in the future, or want to

send data on a patient to the hospital, more bandwidth will be needed. Although our communications systems are the most advanced, extensive and defined, unusual conditions like limited bandwidth and heavy congestion can put a strain on them. So with the Cognitive Radio capabilities of sensing and detection of white spaces in the spectrum, the available free space can be accessed to make an emergency call. In this way the unused spectrum in the existing networks can be put to the best use.

Cognitive radio can identify all transmitting and receiving possibilities in the vicinity and utilize them to the full. With the ad-hoc architecture a network of cognitive radios can be built even without a basic infrastructure. All the Radios of the emergency responders with the cognitive capabilities can jointly form the nodes of a temporary ad hoc network where the information can be reached to the destination over these nodes by hopping.

In the same way an ad hoc network of cognitive radio devices can also be used by the war field soldiers. With the advent of advanced communications and jamming technologies it is difficult to maintain connectivity in modern war fields. Cognitive radio can be a counter to jamming technology. The soldiers can carry a cognitive radio device which has capabilities of sensing other cognitive devices and form the nodes of the network and share vital information.

This does require a totally new approach to the radio spectrum: instead of the current highly channeled approach, cognitive radio tries to borrow bandwidth in other bands for example white spaces in TV bands, GSM network etc without disturbing the users of these bands.

C. Network Coverage extension

There may be a scenario where communication between the first responders fails as the radios are otherwise cut off from their main infrastructure due to a disaster or an attack. Cognitive capabilities could provide more efficient and effective communications in these situations.

Cognitive radio technology could be implemented to reconfigure responders' radios to create an extension to the existing network. This network extension would allow transmissions to be passed back and forth from the incident site along a network of individual responder radios operating in peer-to-peer mode to a radio which can communicate with the main radio system/network. A radio would be positioned where it could maintain connectivity with the main network infrastructure and function as a repeater to bridge between the otherwise disconnected radios and the infrastructure. Depending on distribution of radios in the site, additional radios could also be automatically reconfigured to act as repeaters among the disconnected radios.

Communications is enabled between personnel who can communicate with the main network to dispatch and emergency management centers, but not from responders at the site. The concept of the network extension capability is reflected in the additional links that could be established automatically among responders otherwise cut off from communication with the main network. This provides immediate restoration of communications for all users without requiring additional equipment at the scene.

IV. Conclusion

In this paper, the Network architecture of cognitive radio is referred for the Applications discussed in case of Public Safety and Emergency scenarios. Also the potential use of cognitive radio technology for Extension of existing network coverage when individual radios move outside the coverage of the communication system is discussed.

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