A Survey on Localized and Distributed Channel Assignment Framework for Cognitive Radio Networks

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***Abstract* - Cognitive radio (CR) technology allows the observation of the network conditions to dynamically discover available and underutilized spectrum. A cognitive network is the framework that uses the CR to take advantage of underutilized spectrum. The availability of using multiple interfaces and channels with cognitive radio abilities in wireless devices is expected to alleviate the capacity limitations that exist in traditional single channel wireless mesh networks. Although having multiple radio interfaces and available channels can generally increase the effective throughput, a problem arises as to what is the best strategy to dynamically assign available channels to multiple radio interfaces for maximizing effective network throughput by minimizing the interference. This paper presents a survey on distributed and localized interference-aware channel assignment framework for multi-radio wireless mesh networks in a cognitive network environment.**

Keywords - CR,localized interference-aware

I INTRODUCTION

Wireless network applications have increased dramatically over the last decade.
Many wireless standards have been introduced during this period including Wifi, Ultra Wide Band (UWB), Bluetooth, and WiMax.Increased usage of these applications is encouraged by technology advocates, but a limiting factor of these applications is that they must coexist within a fixed amount of spectrum. This creates a spectrum underutilization problem which can be defined as the inefficient reuse of the available physical spectrum within a particular environment. A main source of limited spectrum arises from the traditional wireless network hardware that is used to support these applications. In traditional wireless hardware predetermined analog operating parameters are utilized to assign the spectrum to facilitate the operation of these applications. With an increased saturation of wireless devices, the fixed spectrum usage strategy has been shown to strain the available spectrum. This strain of available spectrum is not because of a physical limitation of usable spectrum, it is conversely the result of inefficient partitioning of the spectrum space. There have been studies [1] that have verified large
underutilization of spectrum.

II CONGNITIVE NETWORKS

To better utilize available spectrum, suggestions have been given to design network hardware and protocols that are able to adapt to the environment. A network that can dynamically adapt to the environment and use the available spectrum effectively will alleviate the spectrum limitation problem. These smart and adaptive networks have been generally known as cognitive networks. A cognitive network has been defined as a cognitive process that can perceive current network conditions, and then plan, decide and perform actions based on those conditions. The network can learn from these adaptations and use them to make future decisions, all while taking into account end to-end goals [2]. Network operators and networks user's perspectives end-to-end goals should also be taken into account. Dynamic and intelligent switching of frequencies at a radio interface requires the use of many technologies namely a software defined radio, signal-processing and machine-learning procedures. In addition, dynamic and intelligent cross-layer design of the network stack is needed to implement a cognitive network.

2.1 Traditional Networks vs. Cognitive Networks

The design and operation of cognitive networks differs in a number of ways than that of a traditional network. Differences are usually realized through the adaptive characteristics, including the ability to react to network stimuli, of a cognitive network. An excellent example of the adaptive characteristics of a cognitive network is the cognitive radio. A key difference between traditional radios and cognitive radios is the ability for the cognitive radio to sense the radio environment and dynamically switch to a particular frequency. Traditional radios are typically assigned a specific set of frequencies that are shared among its users. IEEE 802.11b has 11 channels in the 2.4 GHz spectrum, 3 of which are orthogonal, and IEEE 802.11a has

13 orthogonal channels in the 5 GHz spectrum [3]. Using only the set of predetermined channels the radios of wireless devices are assigned channels to facilitate communication. This assignment of channels could be preconfigured or dynamically assigned through protocols. An issue with this type of channel selection is the limitation of only using the predetermined channels. If all of the channels experience heavy interference then the network performance can be degraded.On the other hand a cognitive radio would have the ability to adapt to the situation through sensing the environment and detecting "better" channels that can be used for communication. Another important difference between cognitive and traditional networks is the network layer stack design. Traditionally, networks are designed using the layered protocol model, where each layer performs its function independently. An issue with the layered protocol model design is that each layer can only respond to network conditions with which it has visibility. This situation means that problems or adjustments usually can only be made within the scope of the particular layer. These modular modifications at each individual layer may not lead to the best possible network performance.Alternatively, cognitive networks are envisioned as having a highly cross layer design, especially at the lower layers. Using network conditions as seen from of multiple layers,protocols can be designed to fully explore the best performance in an end to end fashion.

2.2 Spectrum Opportunities and Cognitive Radio

Issues with spectrum underutilization have lead to the concept of spectrum holes. Spectrum holes have been defined as a band of frequencies assigned to a licensed user,but, at a particular time and specific geographic location when the band is not being utilized by that user [5]. A licensed user or primary user is defined as an entity that has a high priority in a given frequency band. For example a primary user can be a cell phone provider, TV station, or emergency services. The primary user has the rights to this spectrum because the primary has exclusive usage of the spectrum. Primary users may be aware of unlicensed users aware, but they are typically unaware. Spectrum holes appear as useable channels to unlicensed users with respect to the licensed band in question. An unlicensed user or secondary user is an entity that can benefit from unused spectrum opportunistically, but departs when a primary user begins to transmit. For a secondary user, given its locations, a set of spectrum holes can be available at a given time. Such a set of available channels are referred to as the spectrum opportunity (SOP) of the secondary user. Note that there will be no change in the primary users' architecture in the existence of secondary users. As shown in Figure 1-1, spectrum holes can appear temporally, in frequency, power and other parameters. The secondary user can dynamically select and use these SOPs for its own communication.

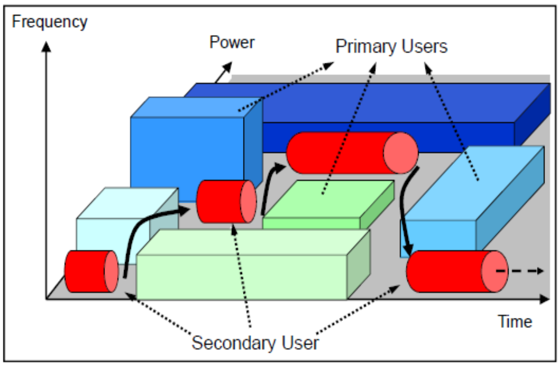

Figure 1-1: Spectrum opportunities

In order to leverage those SOPs or holes for enhancing the effective network throughput, as perceived by the secondary users, it is necessary to develop mechanisms for dynamic spectrum opportunity/channel assignment to the secondary users interfaces.Cognitive Radio is the technology that enables a radio interface to change its transmitter parameters based on sensing and interaction with the environment in which it operates.The cognitive radio is the basis for the cognitive network. A cognitive radio, for example,can sense the available spectrum opportunities and their corresponding interference, and offer a set of suitable channels (spectrum holes). Afterwards using this information a cognitive layer can analyze and decide what best strategy to maximize throughput.

2.3 Research Issues and Limitations of Cognitive Networks

With all of the discussions about cognitive networks, the technology is still in the
infancy stage. There are a large amount of issues and research that focus on the topic

2.3 *.a. Detection of Primary Users*

The discovery or detection of primary users remains a heavily researched topic. A fundamental goal of the cognitive network is to not interfere with existing legacy networks, representing primary users. When a primary user starts to use a particular frequency, secondary users must vacate that frequency. This requires secondary users to continually sense and detect primary user existence. Every primary user does not have the same characteristics, requiring different sensitivity and rate of sensing for detection. As an example, a GPS (global positioning system) receiver typical receive power is −127.5 dBm, while a Bluetooth receiver is at 20 dBm. Another issue is that the primary user typically will not cooperate with the secondary users. Therefore, the secondary user must rely on local sensing information which can be affected by environmental factors including the hidden terminal problem, shadowing, and path loss [5]. The detection of a primary user demands a continuous period of sensing. Primary users may go into and out of the environment, leading to a change in the availability of spectrum. This may require having alternate choices depending on the current situation.

2.3 .b .Channel Assignment Issues

The cognitive radio purpose is to discover available spectrum, more specifically channels, for use in communications. Once these usable channels are found they must be assigned to the radio interfaces of hardware devices. Hardware devices can be equipped with single or multiple interfaces. In the single interface case different channels will have to be assigned over the time. In the multiple interface case channels must be assigned to each interface. Effective channel assignment should aid in attaining the best performance of the network.

2.3 .c. Cognitive Network Routing

In a cognitive network, the dynamic nature can create numerous problems with routing data through the network. There is no guarantee that a channel will be available for use for the entire communication duration between two nodes. There are many reasons why a path between two nodes can be affected. Along with the traditional path breakage problems, channels can become unavailable due to the return of primary user or increased congestion from other secondary users. Traditional routing protocols may not be sufficient. For example, if a channel becomes unavailable on a path, that link will be considered broken and all the packets for that link will be dropped. There are even cases where the network can become disjoint as a result of a primary user entrance. Therefore, it is important to consider how frequently a channel becomes unavailable on a link while
computing the path between source and destination nodes. Cognitive networks have the notion of being a smart, dynamic, evolving technology. This requires an idea of intelligence in the machines that are to implement cognitive networks. New languages that can capture the necessary logic may need to be developed. The Web Ontology Language (OWL) [9], for example, allows both first-order logic, and higher-order, class-based reasoning. The cognitive network may be vulnerable to malicious users because of the inherent flexibility of the design. This issue must also be addressed in the design of the cognitive network.

III CHANNEL ASSIGNMENT PROTOCOLS

There are many design decisions that must be made as to the type of protocol that would be best served for cognitive networks.

3.1 Centralized vs. Distributed Protocols

Wireless network protocols generally are considered centralized or distributed. A centralized protocol commonly requires a central node or a few nodes that will performsome or most of the calculations and decisions for all nodes in the network. The central node or nodes has visibility to the entire network, which allows for performing calculations with the most information. This can lead to a heterogeneous deployment of the nodes (hardware) in the network, because nodes would run different protocols. On the other hand a distributed protocol has homogeneous nodes, where nodes perform the same tasks. As a result the nodes in the distributed case may not have all of the information about the network.

3.2 Coupled or Decoupled Design

Traditionally, the MAC layer uses spectrum management to connect individual nodes while the routing layer establishes paths between nodes in the network. The routing protocol will rely on the lower layers (MAC and PHY) to provide the links that are connecting the nodes in the network. Contrasting a single channel network where usually there is only one link between two nodes, multi-channel multi-interface networks can have many links to the same node or even none at all, as a result of channel assignment. These issues leads to the discussion of coupled or decoupled designs. A decoupled design is where the MAC layer or a layer between routing and MAC performs the channel assignments, while the routing layer continues with its normal operations. On the other hand, a coupled or cross-layer design integrates routing and channel assignment. Figure 2-1 shows the representation of this design in the network stack.

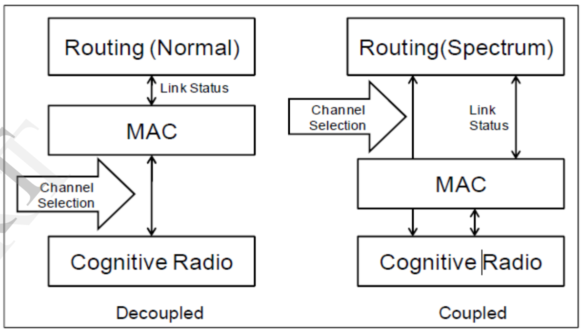

Figure 3-1: Coupled and Decoupled Design

III RESULTS AND DISCUSSION

The cognitive networks is reconfigurability and adaptability to environment stimuli. As a result there are many applications that this
technology has already infiltrated and will penetrate in the future. Cognitive networks have garnered heavy interest for use in military applications. There may be unavoidable interference to military networks because of the sharing of the local spectrum. Cognitive networks would be able
to detect and select the best channels for communications in an unknown environment. Cognitive networks can provide large improvements in the capabilities of emergency network applications. For example, if there is an emergency in a chemical factory, each worker must be advised immediately about leakages through a network capable of multicasting information reliably. The cognitive network would be able to self organize in these emergency situations to setup the necessary communications systems. a cognitive network is that it is typically an ad-hoc network. This leads to its possible use in extreme applications. One such application is underground communications. The network would be able to self configure itself even in environments without any predetermined infrastructure.

V CONCLUSION

The operation of the cognitive network involves the detection of available channels that are not being used for communication byprimary users. Once these channels are known the decision of how to utilize these channels to maximize network throughput, arises. we can achieve significant interference reductions, and subsequent capacity enhancements, for both local UDP traffic and global TCP traffic. We can effectively perform channel assignments in networks with differentprimary user deployments.

V FUTURE SCOPE

Future work on this topic will include the framework uses a novel interference estimation method by utilizing distributed conflict graphs at each network interface to model the interference. Extensive simulation studies in 802.11 based multi-radio mesh networks have been performed. The results indicate that for both local and multi-hop traffic, the proposed protocol can facilitate a large increase in network throughput in comparison with a Common and Centralized Channel

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