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Channel Allocation in Various Cognitive Radio Networks Phenomena

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Abstract: The spectrum is a precious, scarce limited resource, especially with the tremendous increasing in the wireless services and applications. Cognitive radio is a new technology invented to improve the spectrum utilization by using the white space spectrum, which is licensed but not used in a specific time and space. This study deals the channel allocation implemented in different networks phenomena to improve network performance, in specific scenario, to avoid interference and achieve network throughput.

Key words: Cognitive radio, channel allocation and MAC protocol design

INTRODUCTION

The rapid growth in the everywhere wireless communication services has imposed increasing stress on the fixed and limited radio spectrum. The current frequency allocation policies, which allocate a fixed frequency band to each wireless services is a traditional manner to eliminate interference between different wireless services, achieve spectrum unitization. As extensive measurement studies specified that the Static frequency allocation leads to low utilization in licensed band in most of the time and place (Alex *et al*., 2007) the traditional policies do not allows the use of these under-utilized portion of the licensed band, on the other hand the unlicensed bands have become overcrowded as a result of a heavy propagation of wireless services and devices in this bands. In order to alleviate this sever spectrum scarcity, one explored possibility is to allow unlicensed devices (secondary user) to access the unutilized spectrum when the licensee (primary user) is currently not using it, without hinder the privileges of the primary user and give up the band or channel if its needed by the primary user, this DSA as shown in Fig. 1 is divided into 3 categories the dynamic executive use model, open sharing model and hierarchical model, which incorporate both spectrum underlay and spectrum overlay in underlay the simultaneous access with less interference is allowed, in overlay spectrum either opportunistic access or negotiation access are permissible. In order to obtain, licensed spectrum sharing 2 approaches are been investigated the first is the Opportunistic Spectrum Access (OSA), in which the secondary device senses the spectrum periodically and if it is free (spectrum holes) uses it to transmit, in this scenario spectrum accessibility depends upon the occupancy of high priority primary users as well as other simultaneous secondary users and a static control channel may not be sustained, an alternative approach involves the use of local control channels, which are dynamically assigned within cognitive node clusters. Although, within a node cluster spectrum availability may considered consistent and a control channel may be allocated, node maintenance involve substantial extra network complexity. The second approach is the spectrum sharing by negotiation or marketing, in which secondary user negotiate the use of spectrum with the primary user either on-line or off-line, in this case the primary user usually leased the under-utilized bands to the secondary user for fixed interval and cost. Many works are done using game theory to obtain

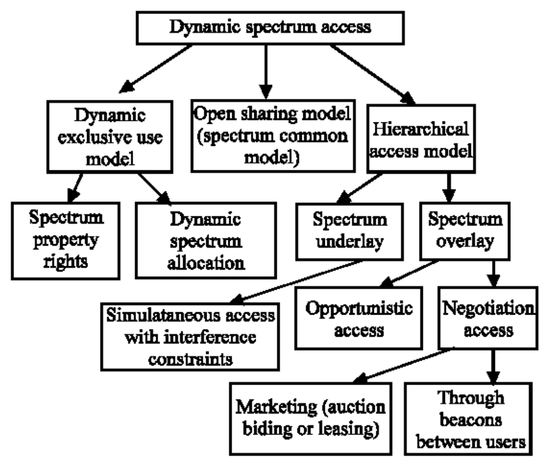

Fig. 1: Classification of dynamic spectrum access

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marketing (Papadimitratos *et al*., 2005). The spectrum sharing between different radio access systems implemented by Cognitive Radio techniques (CR), can be applied in 2 ways. Centralized Cognitive radio, where central control is responsible of collecting sensing information and managing the spectrum holes and assign necessary resources to the CR nodes. Decentralized cognitive radio, where any of the system operators needs to sense the spectrum and exchange this sensing information between the communicating nodes. In each case, the main essential issues is the primary user presence/absence detection (spectrum holes) and the maintenance of the secondary user communication when the primary user reclaim the frequency band. This sensing information is superposition since the network performance is depending upon it. There are 3 types of signal detection, Matched filter, which is the optimal way for any signal detection since, it maximizes received signal to noise ratio, however it requires a priori knowledge of primary user signal at both PHY and MAC layers, such as modulation type and order, packet format, pulse shaping. The advantage of matched filter is that it requires less time to achieve high processing gain due to coherency however, the need of a dedicated receiver for every primary user is a significant drawback. Energy detection is simplifies matched filtering by performing a non coherent detection, however it has the latter drawbacks threshold used is susceptible to unknown or changing noise level and it is not clear how to set the threshold with respect to channel notches in frequency selective fading, it can not differentiate between modulated signal, noise and interference and it dose not research for spread spectrum signals. And cyclostationary signal detection, which takes more time. Although, this detection types is out of this paper scope we didn't mention it in details. My idea in this survey is to compare between what is already done in this field to help improving my new MAC algorithm implemented in cognitive ad-hoc network getting benefits and eliminating drawbacks of what had been done There are several desired features for an efficient cognitive MAC protocol. First, it should be able to predict future spectrum usage based on statistics of local spectrum utilization up to the current time instance. To implement this feature, a CR device should monitor the spectrum usage continually to maintain an accurate view of spectrum utilization. Second, it can bundle several continuous idle channels from a wide spectrum hole to speed up data transmission. Third, it should be a distributed algorithm so as to be employed in ad-hoc network (Alex *et al*., 2007).

COGNITIVE RADIO CHANNEL ALLOCATION AND MAC PROTOCOLS

One of the most challenging tasks in developing DSA networks is the design of cognitive Medium Access Control (MAC) protocols. There are several research efforts on cognitive MAC protocol design in both manufacturing standardization and academic research projects. From the standardization point of view, the current IEEE 802.22 draft is the first world-wide standard related to cognitive radio. Its MAC employs the superframe structure. Synchronized distributed sensing is used, which further consists of fast energy detection and fine feature detection. At the beginning of every superframe, Base Station (BS) sends special preamble and SCH (superframe control header) through each TV channel (up to 3 contiguous channels) that can be used for communication and is guaranteed to meet the incumbent protection requirements. Because of the limited number of channels IEEE 802.22 adopts, the sensing overhead is not a major issue. In addition, IEEE 802.22 is operated in a point-to-multipoint model, which is comparably easier than the cases without the control of the BS. There are several ad-hoc model MAC protocols for cognitive radio in academic research projects. Most of them do not consider the hardware constraints on spectrum sensing ability and assume full spectrum sensing in a particular portion of spectrum. Several MAC protocols have been developed for more flexible and efficient use of spectrum resource built on the cognitive radio. Meanwhile, some issues in the design of cognitive MAC also arise in general MAC protocols. This is especially true in developing decentralized cognitive MACs. An optimal DC-MAC and a suboptimal greedy DC-MAC along with an analytical framework were studied by Sabharwal *et al*. (2006). The framework includes 3 components: 1st, a channel occupancy model that confines the dynamics of channel availability; 2nd, a performance metric that guides the design of MAC strategies and 3rd, a method that makes decision on picking a channel to sense and access. The optimal DC-MAC was optimized based on the Partially Observable Markov Decision Process (POMDP) and the suboptimal solution of lower complexity was derived based on a greedy algorithm, the sensing decision under hardware constraints of cognitive radio is considered by Ma *et al*. (2005). It is not assumed that each secondary user has full information about the availability of all channels, which involves continuous full-spectrum sensing synchronous among secondary users. With the occupancy of interested channels by primary network assumed to follow a discrete-time Markov process, at the beginning of each slot, a secondary user with data to transmit needs to choose a set of channels to sense and a set of channels to access based on the sensing result. Such spectrum sensing and access decisions are made to maximize the throughput of the secondary user, while limiting the interference to the primary network by fully exploiting the sensing history and the spectrum occupancy statistics. Joint sensing and access decision is formulated under the Partially Observable Markov Decision Process (POMDP). However, the tradeoff between sensing overhead and transmission throughput gain is not considered. Dynamic Open Spectrum Sharing (DOSS) MAC (Ma *et al*., 2005) protocol allows nodes to adaptively select an arbitrary spectrum for the incipient communication subject to spectrum availability. In this protocol, after the operation of detection of primary users' presence, 3 operational channels (a busy tone band, a control band and a data band) are set up. This protocol allows CR devices to negotiate in the control band and then send data through any continuous fraction of the data band. The hidden/exposed node problem can be eliminated by raising the busy-tone signal in the busy-tone band DOSS MAC provides a scalable real-time efficient spectrum allocation solution. However, multiple radio transceivers are needed for the tri-band design (one transceiver for each channel), thus this protocol is not suitable for nodes with only one half-duplex radio and there is also concern on interoperability with existing open band 802-family wireless devices. In Zhao *et al.* (2005b) and Sabharwal *et al.* (2006), AS-MAC protocol is proposed to coexist with a GSM cellular system; one of the control channels in GSM band is used as the secondary common control channel. A common control channel facilitates many spectrum sharing functionalities such as sender and receiver handshake, communication with a central entity, or sensing information exchange. For multichannel MAC protocol Many MAC protocols have been proposed to exploit multiple channels to increase the network capacity by using either multiple radios or just single radio. The multi-radio multichannel MAC assigns the radios of each node to different channel and enables more simultaneous transmissions so that multiple channels can be used simultaneously for each user. For single-radio multi-channel MAC, the focus is to let different users transmit in parallel on distinct channels, which also increases the throughput and reduces the delay. For Dynamic Channel Assignment (DCA) algorithm (Zhao *et al*., 2005), control messages (RTS/CTS) are exchanged over a control channel and data transfer takes place over a number of data channels. The dedicated radio at the control channel and the problem of control channel saturation are the main concern. Slotted Seeded Channel Hopping (SSCH) algorithm is proposed by Papadimitratos *et al*. (2005), where a number of channels are available for use and nodes exchange pseudo-random schedules for accessing the medium in a time-slotted manner. No dedicated control channel is needed so that the problem of control channel saturation is avoided. Multi-channel MAC (MMAC) (Fujii and Yasuo, 2006) is proposed for single radio ad hoc networks. Multi-channel hidden terminal problem is addressed within synchronized slotted frames. The assumption of global synchronization may incur great overhead for large systems. These researches give solutions for the problems also appeared in cognitive network, but the presence of primary users makes the fundamental difference for cognitive MAC protocol design. Optimal stopping rules have been used by existing research in MAC layer protocols. MOAR (Sabharwal *et al*., 2006) explores opportunity to skip frequency channels in search for better quality channels. To balance the tradeoff between the time and resource cost of channel measurement/channel skipping and the throughput gain available via transmitting over a better channel, optimal stopping rule is devised to maximize the expected throughput. A cognitive MAC protocol based on Opportunistic Spectrum Access (OSA) (Ma *et al*., 2005) was proposed in Tuan and Liang (2006). A testbed was set up to characterize the relationship between secondary users' loading and interference on primary users. However, important issues such as the impact of secondary user's spectrum utilization upon primary user's carrier sensing, the MAC protocol overhead, secondary on secondary user interference were not addressed.

VARIOUS PLATFORMS IMPLEMENTATION

Several studies have been done in spectrum allocation to achieve utilization by implementing cognitive radio techniques this in both centralized and decentralized systems in the following section I will discuss this 2 types in details.

Centralized CR channel allocation scenarios: In cellular network, which is called centralized CR system, in this scenario the base station collects the sensing reports from CR terminals, analyzes the spectrum holes and assigns necessary resources to CR terminals. The procedure that establishes the control channel and sets up the common parameters for data Communication between CR terminals and BS discussed by Jung and Yoo (2007). The rendezvous approach in IEEE 802.22 WRAN select the control channel among the CR spectrum holes, the BS establishes the down broadcasting to send control information to CR terminal, while each CR terminal does the up uni-cast control channel to BS. When selecting the spectrum holes for setting up the control channel, all occupied spectrum is excluded. This leads to frequent failure when either up or down control channel cannot find available spectrum holes. In other way, the spectrum allocation problem was formulated as a potential game and then converged to a deterministic Nash equilibrium point. the game theory is characterizes as a set of mathematical tools extended for the aim of analyzing players interactions in decision processes, it can be used to expect the outcome of these interactions and to classify optimal strategies for the players so channel allocation can be modeled as the result of a game, in which cognitive radio are the players, their acts are the selection of a transmitting channel and their favorites are associated with the quality of the channel, which is determined by the CR measurements in different radio frequencies by Nie and Cristian (2005) a protocol using Bernoulli trial proposed with random access for decision making, in which each user is winning with a known probability according to the number of the nodes, if this probability is 0 transmitter monitors the common control channel if 1 sends START packet including the interference estimation, which had been calculated based on the channel status table's information, when receiving the packet the receiver computes the current interference for all channels and choose the channel with the highest utility function, comprise the selected channel's information on signaling packet, which will be transmitted in the common control channel. When chooses the newly selected frequency, the transmitter acknowledges and starts transmitting, while all the other users updating their channel status tables. This study defines the function utility for accommodating users as a potential game and thus congregates to a deterministic channel allocation Nash equilibrium point. The study by Zhao *et al*. (2005a) uses the game theory approach to realize a good strategy to perform channel allocation either by auctioning or bargaining manner to bring revenue to the primary user (licensed user), the study formulates the spectrum sharing in CRN as an oligopoly market competition and uses Cournot game to obtain the spectrum allocation for secondary users. In an analogous way Jiang and Tan (2006) proposes the adaptive election algorithm to carry out mobility requirements of CR users and avoid multiple access interference from other users by using forward election strategy associated with smart antenna communication system, to mitigate the undiscovered weak signals the author suppose that each user has smart antenna with good performance in both orientation and transmission gain, the model identify a fixed pairs of nodes distributed uniformly in a square region of dimension with a number of available frequency channels, there are several metrics for the adaptive election algorithm as it encourages the agility of detecting and accuracy of decoding and evading fixed partner. The spectrum allocation power control schemes that maximize the spectrum utilization by dividing the spectrum of interest into a set of non-overlapping channels in a number of cell, each with base station to serve the CR users, this study consider the interference effects based on SINR, counting the aggregate interference caused by the transmission and maximize the number of the CR user served, while guaranteeing protection to primary user (Tuan and Liang, 2006). Directional antenna technology has been identified as a promising technology in wireless network to enhance network performance. Its use not only increases the spatial reuse and extends the transmission ranges but also results in better signal quality than omni-directional antennas, which in turn achieves higher data transmission rates. The directional deafness problem occurs because a node using a directional antenna is deaf in all the directions except for the direction in its main beam. Similarly, the directional hidden terminal problem occurs when a node is unaware of the state of a channel, when it orients its antenna to a new direction. The physical carrier sensing is also affected by directional antennas, since typical signal strength values are usually different from the values used in omni-directional antennas.

Decentralized CR networks: Research has begun on distributed techniques for dynamic spectrum allocation, where no central spectrum authority is required. Decentralized approaches may be less efficient, but require much cooperation. Game theoretic aspects of this are studied later by Zhao *et al*. (2005b) to deal with this new approach. The decentralized approaches, requires control channel to communicate between devices. They make local, independent decisions about how to best communicate and use these low-bandwidth side channels to negotiate communications parameters. It is obvious that detecting the primary user presence is a main challenge especially when the signals are comparative weak, while the feasible weak signal detection method as cyclostationary feature detection takes much time and corrupted the weaker signals dependability. Noun *et al*. (2006) proposes a multi-channel MAC protocol using CSMA/CA schemes of IEEE 802.11 DCF with and without common control channel, it requires at least two transceivers at each node, a node chooses an available unshared channel with 2 hops neighbor as home channel and tuned its receiver to the HCh, this situation changed if HCh becomes unavailable or when neighbors disagree with it or when it cause high collision rate. The network information (the channel, in which primary user recently detected and the elapse time since the node last watched signals from primary users) distributed by adding ch-info field to the MAC layer header, which consist of HCh of the sender, retry count for transmitting the packet and disagreement flag (Noun *et al.*, 2006) the throughput of this research depends on the number of available channels, which is implausible condition. Other criteria for concurrent transmission proposed bu Wang *et al.* (2007) where each node checks for concurrent transmission before executing the CT neighboring discovery algorithm, adding the data packet sending time information to the header to overcome the exposed and physical/virtual hidden problems, the work topology is so simple and not considering the nodes location. A good idea to provides the detection and protection to the primary system and to avoid the incumbent hidden problem in multi channel CR environment through collecting information from the neighbor nodes is proposed by Hao *et al.* (2007) where the available channel list is added into the RTS and CTS packets so the communicating pair can know, which data sub channels are available then both the sender and the receiver switch to reserved channel and start communication the protocol encounter access delay degradation and regards the avoidance of interference to primary user near the destination, but there are other potentials to interference with secondary users them self that is what a slot level opportunities exploitation approach discussed by Zhao *et al.* (2007). The studies focuses on decentralize CR based ad-hoc network and a cluster based protocol was proposed to solve the common control channel problem by implementing neighbor discovery algorithm, in which a node first detect the existing channels when it wants to join the network, then it scans one of its channel for a given period of time, waiting for beacons on the channel and formatting a cluster by exchanging neighbor's information, provide network topology management by using 1 and 2-hope gateway node to interconnect to different clusters. deciding the channel selection by using POMDP and employing only one transceiver without control channel the algorithm can alleviates CR-CR, CR-PU and PU-PU interference, the simulation gives a good result especially when the number of the CR is large. the similar protocol is proposed by Su and Zhang (2007) the only difference is that each node containing 2 transceivers one to monitor the control channel and the other can tune to sense, receive, transmit signals/packets, then executing a random sensing policy or a negotiation sensing policy to detect the channels status (idle, sensed or not sensed) add the channels status information in RTS, CTS. The research compares the number of the sensed and available channels to achieve optimum utilization by using probability, binomial and Markov matrix, however the time required to the SU and the probability of the PU return is not taken in consideration. A cognitive mesh network is discussed under interference temperature model where each node in the mesh network calculate the appropriate (either fixed or dynamic transmission power), based on the collected statistics interference temperature derived for each channel at various locations in that area to keep the primary power threshold constraints (Fujii and Yasuo, 2006). A Cognitive Mesh Network (COMNET) algorithmic framework proposed by using cognitive spectrum sensing and management techniques, that allows radios to intelligently locate and use frequencies other than those in the 2.4 GHz ISM band to solve traffic congestion in the limited bandwidth available for large number of nodes in closeness, which improves the network performance. This almost done by allowing the cognitive mesh client MC to be equipped with a single tunable transceiver, to watch the primary channel, while continuing operation in the secondary band, using the received signal strength values on any given channel to formulate the sensing task as a linear programming problem, estimate the interference caued at any random location and frequency due to the mesh traffic and using the sensed idle channel information to solve channel assignment problem in each mesh router MR. This scenario is operates as follows, each node is tuned to a already known primary band periodically and sense the total received power for a short duration, this sensed information with primaries to nodes distances and the cluster ID are appended to the data packet directed from MR to the gateway, then each router can calculate the estimated measure of interference introduces by its own cluster, at any geographical site and channel and keep the transmitted power less than the predefined threshold (Kaushik and Chowdhury, 2008).

CONCLUSION

In this research, I studied the implementation of the channel allocation in various wireless networks based on the cognitive radio technology, which equipped each node by the capability of sensing the environment, detecting the white space spectrum and deal with it in a proactive manner without interfering with the licensee. Looking in various applications we notice the importance of messaging to distribute sensing information among all the nodes in the communication vicinity. as we have been seen most of the implementation to allocate the channel is done by modifying IEEE 802.11MAC protocol either by controlling the back-off interval time or by appending additional fields to the packet format, this gives similarity between all the applications, which may led to a reasonable compatibility between all the wireless networks in the next generation network protocol. This study is studying the wireless communication next generation network techniques implemented in variant phenomena to compare the network performance for each of them, looking for the optimum solution for the scarce previous spectrum opening novel approaches and giving opportunities for new wireless services. Our future research, is the optimal channel allocation algorithm in ad_hoc cognitive radio networks.

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