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Protocols in Mobile Cognitive Wireless Sensor Networks: A Survey

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Abstract

Introducing mobility and cognitive radio into design of Wireless Sensor Networks (WSNs) puts new challenges particularly in designing of routing and MAC protocols. Mobility can be applied to the sensor nodes and/or the sink node in the network. Many routing and MAC protocols have been developed to support the mobility and cognitive radio in WSNs. Selecting an appropriate protocols for specific applications is an important and difficult task. Therefore, this paper focuses on reviewing some of the recent Mobility based routing and MAC protocols that are developed in the last few years for cognitive sensor networks. Also, we present a detailed classification of the reviewed protocols according to the cognitive approach, routing, MAC, mobility pattern, network architecture, protocol operation, protocol objectives, and applications. Moreover, a comparative analysis between the reviewed protocols is investigated in this survey and drawbacks of each protocol are mentioned.

Keywords: Wireless Sensor Networks, Routing, MAC, Cognitive Radio, Cross layer Design, Energy Efficiency.

INTRODUCTION

With the introduction of concept of transducer/sensor in wired telephone networks, various sensors (e.g temperature, pressure etc) were developed for different application. Also with the invention of radio, the feasibility of wireless telephone/mobile telephone/cell phone has been demonstrated. It also led to the realization of commercially successful wireless sensor networks (WSN) as a natural extension; laboratory prototypes of wireless sensor networks for other applications (such as temperature sensing networks) are successfully demonstrated. These initial efforts led to vision of internet of things (IOT) realizable with various WSNs.

The initial deployments of WSNs assumed that the sensors as well as Base Station/Sink are static, researchers were naturally led to the other paradigms of WSNs where sensors and Base station are mobile such mobile WSNs are expected to find many applications(including realization of vision of IOT). It becomes evident that the design of protocols (MAC, Routing, Transport etc) in mobile WSNs poses interesting new challenges (as sensors and Base station are endowed with mobility). In other words, such structured mobile ADHOC networks (MANETS) are associated with characteristics that can be capitalized to design various protocols.

In this research paper we survey existing efforts on design of protocols in mobile WSNs. This survey paper is staged into VI Sections. In section II, Various paradigms of mobile WSNs and application are discussed. In section III, Design issues in mobile, cognitive wireless sensor networks. In section IV, Protocols in mobile, cognitive, wireless networks. Protocols in mobile, cognitive, wireless sensor networks are discussed in section V. Finally section VI indicates our future work followed by the concluding remark.

VARIOUS PARADIGMS OF MOBILE WIRELESS SENSOR NETWORKS

In wireless sensor networks the following paradigms are possible based upon mobility

i. Mobile Base station and stationary sensors.
ii. Mobile sensors and stationary Base station.
iii. Both Base station and sensors are mobile.

i) Mobile Base station and stationary sensors: over the sensor field, sensors are stationary and BS (base station) is mobile, Mobile BS is used for broadcasting the query and collects the sensed values.

ii) Mobile sensors and stationary base station: stationary dissemination of nodes is placed at uniform intervals on the sensor field and some sensors are made mobile to collect the data from the sensor field. That is such nodes are endowed with planned mobility (path planning). The mobile sensors when travelling over the sensor field can collect required data or collect data from all the sensors which are stationary by using hierarchical or data centric routing protocols such as LEACH, Leveling and sectoring [13].

iii) Both Base station and sensors are mobile: Based on the velocity either of them BS or sensors are considered stationary. If the velocity of BS is smaller compared the sensors then BS deployed over the sensor field could be considered stationary and if the velocity of sensors is smaller compared to the BS then sensor could be considered stationary with respect to BS. If no such condition of velocity exists, then both are consider as mobile then mobile BS start at various locations and move over the sensor field. Since BS is mobile, they collect data from the mobile sensors which are nearer to them or sensor dump the collected data on to the nearest mobile BS. Coordination between the sensors is provided by using TDMA based MAC protocol to dump the data onto the nearest BS during their assigned slot.

Application

The various application of this paradigms are such as environmental tracking, animal tracking, flood detection, forecasting and weather prediction, industrial process monitoring, automated building climate control, ecosystem and habitat monitoring, civil structural, health monitoring, etc.

Paradigm I sensors are static and BS is mobile, Health applications, such as Tracking and monitoring of patients with static sensors deployed with patient and doctors carry mobile BS.

Paradigm II sensors are mobile and BS is static, forest application, mobile sensors are deployed on animals in forest to track its location and other parameters, static BS is placed at centralized location.

Paradigm III sensors are mobile and BS is mobile, Military applications, such as tracking and environment monitoring surveillance application, the mobile sensor nodes are dropped to the field of interest and are remotely controlled by a BS in vehicle or helicopter. Enemy tracking, security detection can also is done.

DESIGN ISSUES IN MOBILE, COGNITIVE WIRELESS SENSOR NETWORKS

Cognitive radio implementation: In mobile cognitive WSN the sensing units (sensors, cluster heads) are capable of cognitive radio implementation that is spectrum sensing, spectrum sharing, spectrum mobility features. It is typically true that under normal conditions, sensing units (secondary users) require the communication channel (EM wave band) for a short time and hence they can coexist with primary users. Thus the MAC (medium access control) protocols must be designed taking into account such features.

Nature of mobility: The sensing units and BS are mobile in such WSN. Depending on the application of mobile WSN (under consideration) the mobility of sensing units and BS can be

i) Planned

ii) Random

In case of planned mobility the motion can be organized using a suitable path planning algorithm but if the mobility is random their location can only be specified probabilistically.

Structure of mobile cognitive WSN: In many applications, mobile cognitive WSN constitutes an infrastructure less wireless network. Further in such a wireless network, the sensing units are sources and BS (one or more) are sinks. Thus such a wireless network constitutes a structured MANET. Thus design of MAC, routing etc protocols must take into account the features of such a structured MANET.

Identity of Base station: Transfer of data when there is multiple base stations covering the sensor field (for data collection) we consider two cases

1) Identity of BS for transferring data is not important

2) Identify of BS for transferring data is important

Cross layer protocol design: Since sensing nodes opportunistically access the channels (cognitive WSN), the design of MAC protocol and routing protocol is highly inter related (leading to cross layer protocol design)

Traffic type: i) Real time ii) Non real time The sensed data from sensing units belongs to the two types real time data, on real time data for instance in a temperature sensing WSN, most of the time, there are stringent constraints on the delivery of the data to the BS but when an event such as fire is sensed /detected the event must be reported to the BS with strict constraint on the delay. This type of requirement on sensed data transfer to BS holds true in the case of many WSN.

Network topology: since the BS and sensing units (sensors, cluster heads) are mobile; the network topology with respect to BS location and sensing units is changing with time. Since the purpose of mobile WSN is to send the sensed data to the BS mobility must be taken into account when designing routing and MAC protocols.

In network distributed computation: wireless sensor network differ from other wireless networks in the sense that the sensing nodes/cluster heads perform distributed computation (on the sensed data) in a collaborative manner for instance, suppose the temperature sensing nodes are located in a LINE (connected) architecture. Suppose the goal is to compute minimum/maximum temperature on the sensing field the sensed temperature values propagate in a direct manner from last node to the BS with each node computing minimum/maximum of its value and the temperature reading received from a immediate neighbor towards last node this feature of in network distributed computation affects the design of MAC and routing protocols.

Heterogeneous sensing units: The sensing units (sensors, cluster heads etc) in wireless sensor networks can be heterogeneous in the following aspects/criteria:

i. Heterogeneous with respect to cost/capabilities, but sense the same variable e.g.: temperature
ii. With respect to nature of sensed variables e.g.: temperature, pressure, etc.
iii. With respect to type of deployment: sparse/dense
iv. With respect to type of mobility (random, planned) and scale of mobility (small, medium, etc).
v. Centralized (at BS) and/or distributed (at sensor processing)

PROTOCOLS IN MOBILE, COGNITIVE, WIRELESS NETWORKS

As discussed in previous section mobile cognitive wireless sensor networks are structure MANETS. In this section we summarize important protocols in mobile cognitive wireless networks in that direction we briefly discuss MAC protocols and routing protocols in arbitrary MANETS.

MAC protocols in arbitrary MANETS

[2] In arbitrary MANETS MAC protocols are broadly classified into the following three categories.

i) pure contention based protocols
ii) contention with reservation protocols
iii) contention with scheduling protocols

Pure contention based protocols: These protocols follow a contention-based channel access policy. A node does not make any priori reservation to transmit a packet and it contends with its neighbor nodes for access to the shared channel. Contention-based protocols cannot guarantees Qos to sessions since nodes are not guaranteed regular access to the channel. This protocol can be further divided into two types:

Sender-initiated protocols: Packet transmissions will be initiated by the sender node.

Receiver-initiated protocols: The receiver node will be initiates the contention resolution protocol.

Sender-initiated protocols are further divided into two types:

Single-channel sender-initiated protocols: In these protocols total available bandwidth is used without being divided. A node that wins the contention to the channel can make use of the entire bandwidth.

Multi channel sender-initiated protocols: In multi channel protocols, the available bandwidth is divided into multiple channels. This enables several nodes to simultaneously transmit data, each using a separate channel. Some protocols dedicate a frequency channel exclusively for transmitting control information.

Contention with reservation protocols: Wireless sensor networks sometimes may need to support real-time traffic, which requires QoS guarantees to be provided. In contention-based protocols, nodes are not guaranteed periodic access to the channel. Hence they cannot support real-time traffic. In order to support such traffic, certain protocols have mechanisms for reserving bandwidth a priori. Such protocols can provide QoS support to time-sensitive traffic sessions. These protocols can be further classified into two types:

Synchronous protocols: This protocol requires time synchronization among all nodes in the network, so that reservations made by a node are known to other nodes in its neighborhood. Global time synchronization is generally difficult to achieve.

Asynchronous protocols: It does not require any global synchronization among nodes in the network. These protocols usually use relative time information for effecting reservations.

Various reservation-based random access protocols are such as shown in Figure 1

Contention with scheduling protocols: These protocols focus on packet scheduling at nodes, and also scheduling nodes for access to the channel. Node scheduling is done in a manner so that all nodes are treated fairly and no node is starved of bandwidth. Scheduling-based schemes are also used for enforcing priorities among flows whose packets are queued at nodes. Some scheduling schemes also take into consideration battery characteristics, such as remaining battery power, while scheduling nodes for access to the channel. Some of the existing scheduling-based protocols are such as shown in Figure 1

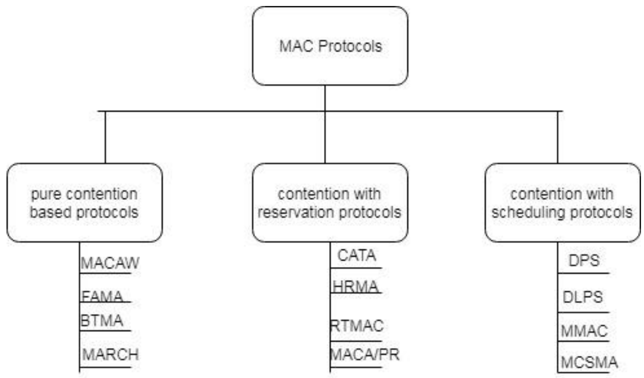

Figure 1: Classification of MAC protocols

Routing protocols in arbitrary MANETS

Routing protocols in arbitrary MANETS are broadly classified into the following three categories

i) Table driven (proactive) protocols
ii) On demand (reactive) protocols
iii) Hybrid protocols

Proactive or table-driven routing protocols: In table-driven routing protocols, every node maintains the network topology information in the form of routing tables by periodically exchanging routing information. Routing information is generally flooded in the whole network. Whenever a node requires a path to a destination, it runs an appropriate path-finding algorithm on the topology information it maintains. Some of the various table-driven routing protocols are as shown in figure 2.

Reactive or on-demand routing protocols: Protocols that fall under this category do not maintain the network topology information. They obtain the necessary path when it is required, by using a connection establishment process. Hence these protocols do not exchange routing information periodically. Some of the existing reactive routing protocols are as shown in figure 2.

Hybrid routing protocols: Protocols belonging to this category combine the best features of the above two categories. Nodes within a certain distance from the node concerned, or within a particular geographical region, are said to be within the routing zone of the given node. For routing within this zone, a table-driven approach is used. For nodes that are located beyond this zone, an on-demand approach is used. Some of the various routing protocols belong to this category is as shown in figure 2.

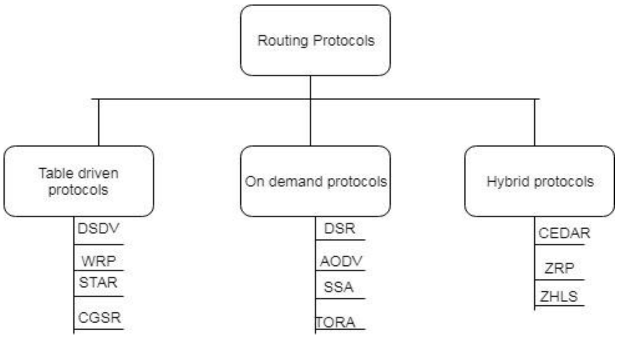

Figure 2: Classification of Routing protocols

Existing cognitive based routing protocols

In literature, various routing algorithms were proposed for cognitive networks. In this section we discuss some of the existing solutions and their issues. Cognitive Ad-hoc On-demand Distance Vector (CAODV) [3][4]routing modifies the existing Ad-hoc On demand Distance Vector (AODV) protocol such that it avoids PU activity areas and applies joint path and channel Selection. This protocol broadcasts the route request to neighbors on each channel and for each available channel it stores multiple paths for a destination. Drawbacks of the protocol are: (1) Applying the shortest path solution without considering channel characteristics in cognitive networks does not give the optimal solution.(2) Flooding the route request packet on all the channels leads to overhead and reduce network life time.

Ant-based Spectrum Aware Routing (ASAR) [9] provides the feature of self adaptation to path and spectrum availability. In this protocol, a forward ant is broadcast on control channels and stores the node address in the forward ant if spectrum opportunity is found. Thus, forward ant travels and records a spectrum feasible path for data transmission between source and destination. The backward ants update the statistic history and path quality in routing table. A deterministic policy for path selection is used in place of probabilistic forwarding to minimize channel hand-off time. Drawbacks of the protocol are: (1) Each ant contains a list of all nodes in the path which results in high overhead on control channel, (2) Mobility of cognitive users are not taken into the consideration.

Spectrum Aware routing protocol for Cognitive AdHoc networks (SEARCH) [6] presents the shortest path based greedy approach for path selection. The objective of the protocol is to minimize hop-count and switching delay which intern minimizes end-to-end delay. Every intermediate hop add its ID, current location, time stamp and flag status indicating the current propagation mode of the algorithm into the route request packet. The drawbacks of the protocol are: (1) The increased size of route request causes high overhead, (2) Route request is forwarded on each channel which also increase the overhead and reduce network's life time, and (3) SEARCH requires location awareness. Considering location awareness is not favorable as GPS service availability to all nodes in network might not be feasible, because in the presence of dense forests, mountains or other obstacles that block the line-of-sight from GPS satellites, GPS cannot be implemented. The power consumption of GPS will reduce the battery life of the nodes and also reduce the effective lifetime of the entire network. In a network with large number of nodes, the production cost factor of GPS is an important issue.

Optimal Primary-aware Route quality (OPERA) [5] presents the metric which calculates the link delay and end to end delay for any pair of source and destination nodes. Link delays are calculated considering the probability of link availability, expected throughput, and sensing process characteristics. This metric gives the theoretical bound to end-to-end delay. OPERA combined with Dijkstra and Bellman-Ford algorithm for searching shortest path in weighted graph gives optimal results. The drawbacks of OPERA are: (1) it lacks in route recovery process, (2) the overhead for calculating the efficient route is very high as the weighted metric of OPERA should be calculated multiple times and hence the Dijkstra or Bellman-Ford algorithm should also search for the shortest path multiple times, (3) the OPERA routing metric uses probability of PU availability and not the actual sensing output, hence can interfere to PUs

A Spectrum Aggregation-Based Cooperative Routing Protocol for Cognitive Radio Ad-Hoc Networks: [14] present a spectrum aggregation- based cooperative routing protocol, termed as SACRP, for CRAHNs. It proposes two different classes of routing protocols; Class A for achieving higher energy efficiency and throughput, and Class B for reducing end-to-end latency. Based on stochastic geometry approach, we build a comprehensive analytical model for the proposed protocol. The Objective is to provide higher energy efficiency, improve throughput, and reduce network delay for CRAHNs. In this regard, we design the MAC and Physical (PHY) layer, and proposed different spectrum aggregation algorithms for cognitive radio (CR) users. The Drawback is network reliability and PU receiver protection not consider.

Throughput-Optimal Cross-Layer Design for Cognitive Radio Ad Hoc Networks: [1] present a distributed, integrated medium access control, scheduling, routing and congestion/rate control protocol stack for cognitive radio ad hoc networks (CRAHNs). These protocols combine back-pressure scheduling with a CSMA-based random access with exponential back offs. The objective is to maximizing the throughput using a network utility maximization (NUM) formulation; we evaluate our solutions through ns-2 MIRACLE-based simulations. The Drawback is Mobility of cognitive user is not considered and overhead is high.

Cognitive Routing Protocol (CRP) [10] presents solution for joint spectrum and node selection for cognitive networks. This protocol defines two classes of cognitive users. The first class tries to minimize the end-to-end CR route latency, while the second class gives greater importance to the PU protection. Second class of flows is of interest in cognitive networks as cognitive user should not interfere with the PUs while using the licensed spectrum. In CRP, each user first identifies the best locally available spectrum band. Selection of spectrum band is defined as an optimization problem where the constraints are: Probability of spectrum band availability is greater than the user defined limit. Bit arrival variance of the spectrum band must meet the minimum user defined threshold. Spectrum selection should not cause the severe multi path fading, i.e. coherence bandwidth of the spectrum band is less than the signal bandwidth. Switching latency must be contained within the predefined threshold. After spectrum band selection, next hops are selected based on minimum forwarding delay. Drawbacks of the protocol are: (1) the channel characteristics such as bandwidth are not considered while selecting spectrum band, (2) CRP also assumes location awareness, (3) results of the paper also show that the performance of CRP is average for flows of second class, (4) the spectrum selection rule of CRP uses probability of PU availability and not the actual sensing output, hence can interfere to PUs.

Dynamic Channel Access to Improve Energy Efficiency in Cognitive Radio Sensor Networks[8] The two sequential channel sensing and accessing schemes have been proposed for intra- and inter-cluster data transmission, respectively, which form a comprehensive solution to control the dynamic channel access in clustered CRSNs for achieving optimal energy efficiency. The Objective is to investigate the dynamic channel accessing problem to improve the energy efficiency for a clustered CRSN. The Drawback is Mobility of cognitive user is not considered.

Spectrum-Aware any path Routing in Multi-Hop Cognitive Radio Networks:[7] A new cognitive any path routing metric is designed based on channel and link statistics to accurately estimate and evaluate the quality of an any path under uncertain spectrum availability. A polynomial-time routing algorithm is also developed to find the best channel and the associated optimal forwarding set and compute the least cost any path. The Objective is to improve the performance of multi-hop CRNs and make it a robust spectrum cloud. We demonstrate that SAAR significantly outperforms other routing algorithms in terms of packet dropping ratio, end-to-end delay, and throughput. The Drawback is Mobility of cognitive user is not considered and overhead is high.

A distributed scheduling approach for QoS improvement in cognitive radio networks: [12] proposed QIPS scheme offers increased network performance by dividing the network into regions and allocating a base station for each region. This base station allocates the proper scheduling for each node in the cognitive radio network. The objective is to improve the quality of service, increases the throughput and network efficiency and reduces the computational complexity of cognitive radio networks. The Drawback is mobility not considered, PU interference not considered.

Spectrum-Availability Based Routing for Cognitive Sensor Networks: [11] proposes two CSN routing metrics. In the first routing metric, the delivery success probability through all possible channels is defined in the constraint that only one re transmission is permitted to reduce rerouting. Similarly, the second routing metric considers the average transmission delay over all possible channels is presented. The Objective is to estimate the spectrum availability and spectrum quality from the view of both the global statistical spectrum usage and the local instant spectrum status, and then introduce novel routing metrics to consider the estimation. It uses CAODV protocol for routing. The Drawback is Mobility of cognitive user is not considered, throughput decreases with increase in packet size.

Table 1: Survey of various routing protocols in cognitive networks

Reference	Year	Protocol	Drawback
Ant based spectrum aware routing	2009	ASAR	High Overhead. Mobility of user is not considered
A routing protocol for mobile CRANs	2009	SEARCH	Requires location awareness. Overhead is high.
Optimal routing metric for CRANs	2012	OPERA	High complexity and overhead. Can interfere to PU.
A spectrum aggregation based cooperative routing protocol for CRANs	2015	SACRP	Network reliability and PU receiver protection not consider.
Throughput optimal cross layer design for CRANs	2015	CAODV	Mobility of user is not considered and over head is high.
Performance Comparison of Routing Protocols For CRNs	2015	CRP	Spectrum characteristics Were not considered. Can interfere to primary users
Performance Comparison of Routing Protocols For CRNs	2015	Coolest Path	Spectrum characteristics were not considered. Can interfere to primary users.
Performance Comparison of Routing Protocols for CRNs	2015	SAMER	Mobility of cognitive user is not considered. Lacks in route recovery process.
Dynamic Channel Access to Improve Energy Efficiency in CRNs	2016	CAODV	Mobility of cognitive user is not considered.
Spectrum-Aware any path Routing in Multi-Hop CRNs	2017	SAAR	Mobility of cognitive user is not considered and overhead is high.
A distributed scheduling approach for QoS improvement in CRNs	2017	CAODV	mobility not considered, PU interference not considered.
Spectrum-Availability Based Routing for CSN	2017	CAODV	Mobility of user is not considered, Throughput decreases.

Cognitive cross-layer multipath probabilistic routing for cognitive networks: [15] Mobile Ad-hoc Networks (MANETs) is a set of mobile nodes that can move around arbitrarily, and communicate with others in a multi-hop fashion without any assistance of base stations. With recent advances in Cognitive Radio (CR) technology, it is possible to apply the Dynamic Spectrum Access model in MANETs. This introduces the concept of Cognitive Radio Ad Hoc Networks (CRAHNs). Applying CR techniques provides better throughput, even in congested spectrum along with better propagation characteristics. CRAHN is a kind of intelligent network that is aware of its surrounding environment, and adapts to the transmission or reception parameters to achieve efficient communication without interfering with primary users. Routing in CR environment is a challenging task as the availability of channel is constrained by the presence of primary user. The problem of routing in CRAHNs targets the creation and maintenance of wireless multi-hop paths among cognitive nodes by deciding both the spectrum to be used and the relay nodes of the path. This paper proposes a cognitive cross-layer multipath probabilistic routing for cognitive radio based networks. The proposed solution uses spectrum holes identified by MAC layer, decides the channel to be used and transmit power level for each hop in the path. The proposed solution is implemented in NS2, and performance of the proposed solution is compared with the existing solution from the literature. The paper also shows that the proposed solution outperforms existing solution in terms of packet delivery ratio, average end-to-end delay and energy consumed per data packet.

Existing cognitive based MAC protocols

In any cognitive network, functionality of cognitive cycle is the main challenge of MAC layer. Cognitive cycle builds the spectrum opportunity map and dynamically schedule resources among cognitive users. Furthermore, cognitive cycle allows cognitive users to vacate the selected channel when primary user becomes active. Cormio and Chowdhury provide a survey of MAC protocols overview and general classification in cognitive environment. Below are some of the main issues of MAC layer in cognitive networks.

Selection of transmission channel: In cognitive MAC, the change in transmission channel may cause the change in the rate of transmission and other parameters. The selection of transmission channel from the spectrum holes identified by the spectrum sensing is a challenging task.

Control information sharing: Control signaling is necessary for every communication protocol. It can be done in following manner:

Common Control Channel (CCC): Portion of spectrum from cognitive user band is allocated as CCC.

Time Slot Based: Portion of time slot in all the channels are used for control signaling.

Frequency Hopping Sequence: Sequence of frequencies is used for control signaling. Cognitive users hop between these bands for control signaling.

Channel Synchronization: The process of node moving from one channel to another is called channel switching. Before the actual data transmission, both the transmitter and receiver should synchronize their respective radios to the same channel, this is known as channel synchronization. Channel synchronization will be difficult if neighbors are not informed about channel switching. In cognitive networks, channel switching is more frequent as users must vacate the channel whenever primary user comes back. This requirement makes channel synchronization as one of the important feature of cognitive MAC protocol.

Medium access control: Medium access control among the nodes is needed to avoid collision similar to normal MAC strategies.

Multi-channel Hidden Node Problem: In multi-channel environment with single half-duplex transceiver, node can only hear RTS and CTS transmitted on the tuned channel. In such case node is not able to hear other channel RTS and CTS, which leads to multi-channel hidden node problem.

Channel Scheduling: When a node has packets queued for multiple destination nodes operating on different channels, channel scheduling is needed to schedule the packets on the radio interface based on the operating channel. If we schedule packets using FIFO algorithm, in worst case, channel switching could be needed for every single packet which will lead to higher transmission delays.

Some of the cognitive MAC protocols from literature with respect to the issues discussed above are presented in table II. Busy tone broadcasting based protocols requires multiple radio transceivers and separate frequency bands for busy tone channel and control channel. To avoid interference to primary user in TDMA based protocols (like C-MAC), all secondary users should be synchronized and follow the same time-slot division as of the primary user. Thus, for more than one primary user network, TDMA based approach cannot be used. Most of the contention based protocols lack in providing solutions to multi-channel hidden node problem. Cognitive MAC protocol which solves all the challenges of cognitive networks is still needed. Selection of channel at MAC layer will not always give efficient end-to end solution.

Table 2: Comparative Analysis of MAC Layer Strategies

Protocol	Spectrum Access method	Medium Access	Interface Requirement	Multi channel hidden node	Channel synchronization	Spectrum sensing	Channel scheduling
DOSS	Busy tone broadcasting	REQ_REQ ACK-DATA-ACK	Multiple	Yes	Yes	Yes	NO
C-MAC	TDMA Based	TDMA Based	Single	Yes	Yes	NO	NO
HCMAC	Contention Based	RTS-CTS	Single	NO	Yes	Yes	NO
MMACCR	Contention Based	ATIM Window with RTS-CTS	Single	Yes	Yes	Partial	NO
CREAMMAC	Contention Based	RTS-CTS	Single	NO	Yes	NO	NO
CRCRMA/ CA	Contention Based	RTS-CTS	Single	NO	Yes	Yes	NO
CAD MAC	Channel Aggregation Based	RTS-CTS-RES	Single	NO	Yes	Yes	NO

PROTOCOLS IN MOBILE, COGNITIVE, WIRELESS SENSOR NETWORKS

In section 2, we identified all the 3 possible paradigms of mobile wireless sensor networks, we first consider the paradigm where BS is mobile and sensors are stationary

In such a mobile cognitive WSN, The BS visits the sensor field, collects the data and processes the data immediately or at a later time. We are naturally led to two cases

I)planned mobility of base station: In this case, we are naturally led to problem of planning path of the base station over the sensor field i.e. actual path the BS traverses, velocity/acceleration of BS for instance, the velocity could be decided based on the delay constraints on base station to visit various regions of sensor field. Also in the case of an EVENT (such as FIRE) is detected on the sensor field, the path/route of base station may need to be diverted. In summary, optimal path planning of base station meeting various constraints is a relevant important problem.

II)Random mobility of Base station: In this case, the base station visits various regions of sensor field at random times thus, real time constraints on data transfer to Base station (and control action) from various regions of sensor field may be met or may not be met.

Note: In this paradigm, the MAC protocol as well as routing protocol design is very closely related to the static WSN paradigm i.e. Base station and sensors are static further cross layer protocol design (i.e. MAC protocol takes into account routing protocol design and the other way) in this paradigm is also very much related to those in static, cognitive wireless networks we briefly discuss routing, MAC protocol design for networks in this paradigm.

In this paradigm of WSN, the sensed data from sensor need to be communicated to the associated cluster head (CH), from such CH to other cluster heads and eventually to the base station. We propose the following protocols. By exercising power control, the data transfer from sensors to CH's can take place using TDMA scheme i.e. sensor nodes (in a local cluster) use a TDMA schedule to transfer data to CH, during their allocated slot alternatively the sensor nodes can employ slotted ALOHA protocol to locally access the channel. In such MAC protocol employed by sensors, there is no cognition with respect to channel utilization. Hence if carrier sensing is done the nodes utilize CSMA/CA protocol(on any particular channel) equivalently in the case of such mobile cognitive wireless sensor network, the sensing nodes constitute secondary users and perform spectrum sensing (to detect primary users) to opportunistically access the primary user channels. The sensing nodes share the unused PU channels.

Our main findings are summarized as follows

Based on literature survey conducted in this work, the below mentioned gaps are found.

1. Wireless sensor network disconnects into parts frequently due to link failure between the nodes.
2. The single hop communication is very energy exhaustive where as multi hop makes the nodes nearer to the sink. But nodes nearer to base station will die soon since it participates in routing of every packet.
3. Equal sized Clustering of nodes is important to prevent pre mature deaths of cluster heads.
4. Mobility of nodes is not considered in most of the existing cognitive based routing protocols.
5. Most of the contention based protocols lack in providing solutions to multi-channel hidden node problem.

CONCLUSION

Recently, many routing and MAC protocols are developed especially to support Spectrum scarcity of cognitive Networks. This paper reviews the recently cognitive based routing and MAC protocols that are developed in the last few years for the Cognitive Networks (CNs). In this survey, we consider various paradigms of mobile cognitive wireless sensor networks and briefly summarize some typical applications various design issues in such networks are identified. Moreover highlighting the features and drawbacks of each protocol. The effort in this area should be continued in the area of the hierarchical routing to improve the performance of MWSNs.

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