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Routing on Cognitive Radio Wireless Mesh Networks Survey

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Abstract: The cognitive radio technology, a wireless system can utilize opportunistically the radio spectrum licensed to other systems. Thus, CR is regard as a solution to the troubles resulting from the limited available spectrum and the ineffectiveness in the spectrum usage. The multi-hop CR networks need some novel routing algorithms taking the open spectrum incident into account. [1] The main approach in design the routing algorithm for the CR networks is the joint design of routing and spectrum organization. Works on such issue have just started and are silent in an elementary stage. In this paper, we survey expansively the existing research on the routing protocols for CR networks, particularly with reference to CR networks. We classify the routing protocols, discuss the essential features of the different protocols, and provide the future research directions.

Keywords: Wireless mesh network (WMN), Cognitive radio networks, Infrastructure WMN's, Client WMN's, Hybrid WMN's.

I. INTRODUCTION

Wireless mesh networks are very highly used low cost networks. Now a day's wireless mesh networks are frequently used in local area networks, wide area networks and metropolitan area networks. [2] Due to their high connectivity and improved better performance people have a preference these types of networks everywhere like broadband home networking, community and neighborhood networks, enterprise networks and building automation. Mesh connectivity significantly improve network performance like load balancing, fault tolerance, protocol efficiency and throughput. The WMN maintain cognitive networks and have a capacity of self-healing, self-forming and self-organization. In wireless mesh networks each mesh router act as mesh client but each mesh client will not act as mesh router. The exceptional feature of mesh nodes is they are very high mobile; the nodes keep on change their network topology. Typically, a WMN consists of static wireless mesh routers which are also known as access points, these static mesh routers will form backbone of WMN and provide the mesh and conventional clients. Each AP connects mobile nodes to the wired network through multi hop wireless routing.

II. DIFFERENT TYPES WMN'S

The network nodes are straightforwardly connected to the wired network through AP. The definition of wireless mesh network varies from type to type. The definition is explained based upon the architecture used.
There are 3 different types of architectures in wireless mesh networks:
1. Infrastructure/ backbone WMN's
2. Client WMN's
3. Hybrid WMN's

1. Infrastructure/Backbone WMNs:

This type of WMNs include mesh routers form an infrastructure for clients that correspond to the infrastructure can be build on the various types of radio technology in the wireless mesh networks starting from a mesh router can be connected to the internet. The mesh routers can be placed on the covering of houses in a neighborhood, which can be access points for user inside the home and along the roads. The mesh backbone communication can be traditional establishment using long-range communication technique including directional antennas.

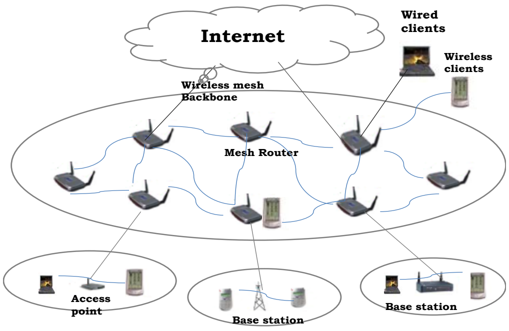

Figure 1: Infrastructure/ backbone wireless mesh networks.

2. Client WMNs:

Wireless mesh network client provide the peer-to-peer networks among the client devices. In the case of the client nodes compose the actual network to perform the routing and arrangement functionalities. Mesh router is not essential for these types of wireless mesh networks. A packet designed to a node in the network hopes from beginning to end multiple nodes to reach the destination. It can be utilize the necessities on end-user devices are greater than before when compare to infrastructure meshing.

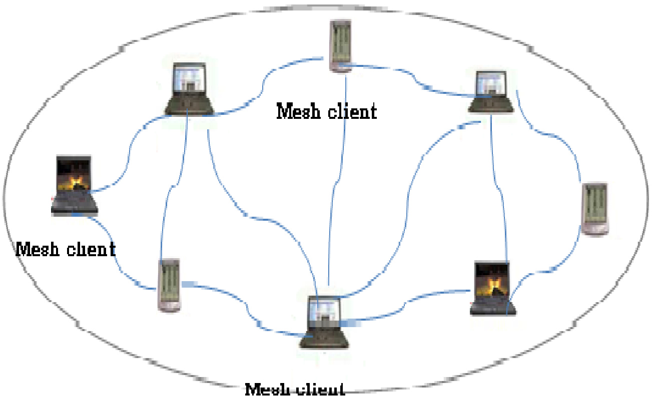

Figure 2: Client wireless mesh networks.

3. Hybrid WMN:

This type of architecture is the arrangement of infrastructure and client meshing. Mesh clients which can be access the network through the clients and it forward the other mesh routers. The routing capability of clients provide to improved better connectivity and coverage inside the WMN. The hybrid architecture will be must applicable in the hybrid mesh networks.

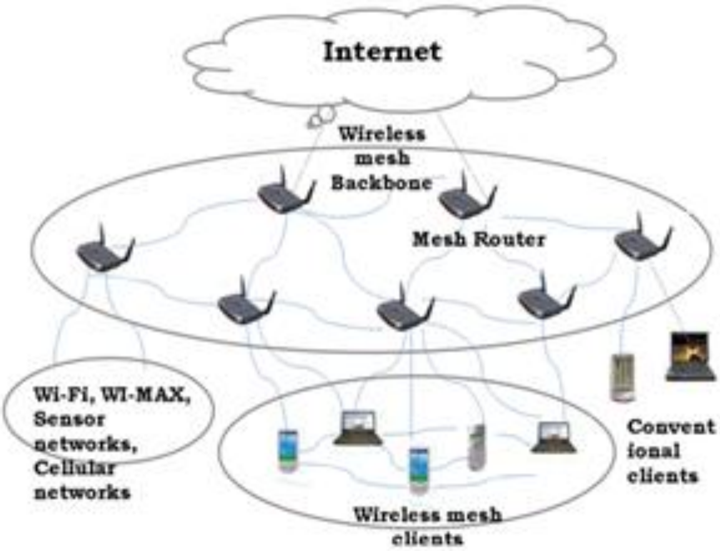

Figure 3: Hybrid wireless mesh networks**.**

Cognitive Radio Networks:

Next Generation communication network, [3] also known as Dynamic Spectrum Access Networks (DSANs) as well as cognitive radio networks will provide high bandwidth to mobile users through homogeneous wireless architectures and dynamic spectrum access technique. Before discussing about the cognitive radio networks let us know about cognitive radio. Cognitive radio means *a* radio system whose parameter is changing dynamically according to the external environmental location. By using the several cognitive radios in the network they built cognitive radio networks. Cognitive radio networks is to improve the developing area for wireless technology the main aim of the cognitive radio networks is rising the spectrum utilization. The network mainly consisting of two types of users they are licensed users and unlicensed users. The Licensed users are also known as primary users and unlicensed users are known as secondary user. [4] Secondary user's access spectrum conditionally that means when primary users are inactive. Cognitive radio has two characteristics they are Cognitive capability, Reconfigurability. Cognitive capability means the ability to sense the unused spectrum at a specific time and location of the radio that can capture or sense the environment. Cognitive capabilities give the knowledge of the spectrum where as reconfigurable arrangement of the radio to that environment. The cognitive capability of a cognitive radio allows real time communication with its environment to find significant communication parameters and adapt to the dynamic radio environment. The steps are in the cognitive radio cycle mainly consisting of spectrum sensing, spectrum analysis and finally spectrum decision.

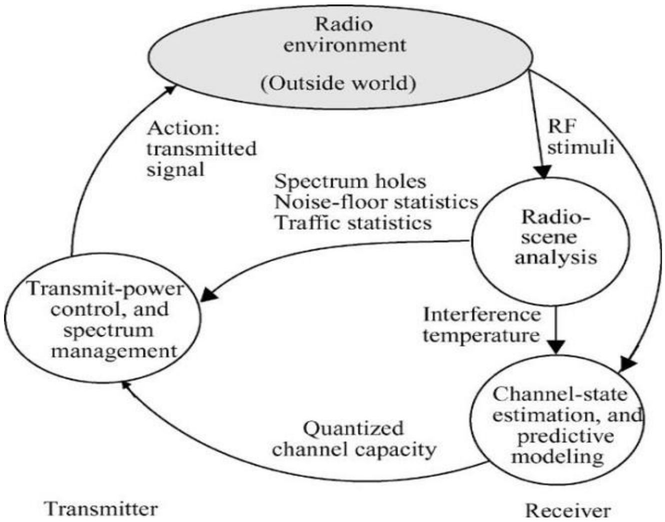

Figure 4: Cognitive radio cycle.

1. Spectrum sensing: Cognitive radios observe the available spectrum bands, capture their data, and then find the white spaces.
2. Spectrum analysis: The capabilities of the spectrum holes that are detected through spectrum sensing are expected.
3. Spectrum decision: A cognitive radio finds the statistics data rate, the communication mode, and the Bandwidth of the communication. Then, the appropriate spectrum band is selected according to the Spectrum properties and user requirements. Re configurability is the capability of arranging parameter for the communication on the fly without any modification on the hardware components. This Capability of cognitive WMN is able to adjust simply to the dynamic radio environment.
Operating frequency: A cognitive radio has the capability of changing the operating frequency. **Modulation:** A cognitive radio should reconfigure the modulation scheme adaptive to the user quality requirements and channel conditions.
Transmission power: Transmission power can be configured within the power constraint.
Communication technology: A cognitive radio can also be use to must provide interoperability among different messages in communication systems.

III. ROUTING PROTOCOLS FOR CRNS

3.1. Dynamic Spectrum-aware Routing: [5] Dynamic spectrum-aware routing protocols enable CR technologies to successfully utilize unallocated wireless spectrum band. In such routing protocols route discovery is incorporated spectrum sensing technology. The main goal of such protocols is to create and maintain route across region of different available spectrum bands. In the rest of the sub section we summarize these protocols and bring to light their advantages and their routing techniques form of table is presented at the end of each protocol.
3.1.1. Spectrum-Aware Routing (SPEAR): A routing protocol that supports high-throughput packet transmission in the presence of the spectrum heterogeneity is being investigate in it achieves persistent end-to-end performance by integrating flow different channels to links on the same flow for minimizing interference and integrates spectrum discovery with route discovery Maintains a list of deserted locally available channels. These channels are neither occupied by primary user nor reserved by nearby neighbours. In SPEAR route discovery is done by broadcasting a Route Request message on common control channel and being recognized by sender and receiver IP addresses. As an intermediate node receives this message, it checks if it has a common channel with the previous node then it appends its own id and available channel set with the received message and then broadcast it. The destination node selects the best path on the basis of maximum throughput, minimizes end and link quality. During the transmission node periodically channel condition reservation message with each message containing timeout and time the end of communication nodes along the path are notified to stop sending reservation messages.
3.2. Spectrum Aware Mesh Routing (SAMER): A routing protocol for mesh CRNs future in handles the diversity in channel accessibility and balance between long-term route stability and short-term route. [6] SAMER uses the available white spaces by transmit the data over the route with higher spectrum availability. This spectrum availability is used for computing routing metric for long-term routes. It achieves the balance between long-term and short-term routes by construct a runtime forwarding route mesh. This mesh is periodically updated and provides a set of candidate routes to the destination. These packets are routed towards the destination across this mesh. The routing decisions are taken with the collaboration of PHY and MAC layer. SAMER builds dynamic candidate, candidate forwarding mesh and opportunistically forwarding.
3.2.1. Dynamic Candidate Mesh: In constructing dynamic candidate mesh a cost to destination is compute by every node in the network. The cost in reality shows the spectrum availability of the highest spectrum route. This route contains smaller number of hops than a specified threshold. This each node constructs a set of forwarding nodes to destination. Opportunistic Forwarding SAMER uses those links for forwarding that contains the highest spectrum availability. It used

Path Spectrum Availability (PSA) metric which is define in term of throughput between a pair of nodes for computing spectrum availability.

3.2.2 Building a candidate forwarding mesh: In the presence of Forwarding mesh only contains long-term paths. These paths are the shortest paths in term of hope count. Thus for forwarding packet to the destination node computes a cost for all of its neigh boring nodes and it adds only those nodes in its forwarding set that contain minimum cost. Therefore a cost to destination is prior computed by each network node.

3.3. Spectrum-aware On-Demand routing protocol (SORP): SORP is an on demand routing protocol that is neither based on centralized spectrum band allocation nor multi-channel. The nature of this protocol is due to the lack of shared information. [7] The routing technique future is to select best suitable for RF bands for each node along with the route. The RF band selection is based on the minimum increasing cumulative delay. The switching and back-off delay caused by both the path itself and the interconnect flow are the moderator parameters for calculate the increasing cumulative delay of the path. The future planned a spectrum aware on demand framework for routing and multi-flow multi-frequency arrangement for RF bands.

To form a common control channel (CCC) each node contains a conventional wireless interface in addition to the CR transceiver. Each node is able to provide spectrum sensing the information to the routing protocol through the cross layer design. For route discovery SORP inherits the basic procedures of with modified Route Request (RREQ). In SORP Spectrum Opportunity (SOP) information is piggybacked by communication RREQ messages. SOP information is piggybacked only when the node finds the intersection between the RREQ and its own. Accordingly destination node receives the SOP distribution of all the nodes along with the path and it assigns RF band to its CR transceiver accordingly. This RF band information is sent back to the source node as well as intermediate nodes through the Route Reply (RREP) message. All the nodes along with the path assign the RF band according to the received RREP.

3.4. Multi-hop Single-transceiver Cognitive Radio Networks Routing Protocol (MSCRP): MSCRP future planned is doesn't base on control channel. Therefore routing protocol messages are being exchanged without common control channel. MSCRP is an on demand protocol based on demand distance vector. [8] Modifies to handle the existing channel set problem that each node in the network doesn't recognize the available channel set of other nodes in the network. In the first time introduced the new problem called "deafness", that is due to channel switching of the nodes. To avoid the deafness problem, they future planned that two consecutive nodes in a flow cannot be in the switching state simultaneously. Communicating with a switching node is complicated, therefore MSCRP switching node uses LEAVE/JOIN communication messages to inform its neighbours about its working channel. MSCRP assumes that CR transceiver can tune in a wide range of RF spectrum but it only operates on limited and smaller range of RF and CR transceiver can only operate on single channel at any time. MSCRP is a cross layer protocol so it identifies six system functions that implement the core functionality of spectrum aware routing. These functions are as follows:

The physical layer includes three of them that are spectrum sensing, detecting active primary user and estimating the quality of available channels. The network layer includes two of them that are routing and scheduling in the multi-flow and Multi-channel environment. Link layer has last one that is IEEE 802.11DCF is used as the MAC protocol.

3.5. Reactive Source-Based Routing: In reactive source based routing technique the source specifies how the data travels across the network. Path to destination node is to compute by the source node. In the rest of the sub section we summarize a reactive source-based routing protocol and highlight the communication nodes and routing technique and its advantages.

3.5.1. Routing in Opportunistic Cognitive Radio Networks: Reactive source-based routing protocol for CRNs is future planned by it uses a novel routing metric that is based on a probabilistic definition of the available capacity over a channel. This routing metric mechanism determine the most probable path (MPP) to satisfy a given bandwidth request although it doesn't guarantee to satisfy the demand. So in this case an augmentation phase is used in which bottleneck links are augmented with additional channels so the resulting path meets the bandwidth demand with a given probability. The available capacity is measured as the probability distribution of the PR to CR user interference at any node over a channel. When an application requests a route of capacity demand the source will initiate it and control channel is used for node coordination. Based on the demand all links probabilities are calculated. Once all link weights are calculated.

3.6. Local Coordination-Based Routing: The local coordination is a sort of development scheme that is applied on intersects node on a path. The local coordination is taking place started when nodes evaluate the workload of both accommodating the flow and redirecting it. Nodes choose the flow adjustment or flow redirection based on the evaluation results and region locality interaction. In the rest of the sub section we summarize a local coordination-based routing protocol and highlight its routing technique and its advantages.

3.6.1. Local Coordination Based Routing and Spectrum Assignment in Multi-hop Cognitive Radio Networks:

An on demand routing and spectrum assignment protocol to exchange the local spectrum information and interact with the multi-frequency scheduling in each node is proposed in modified to form a mechanism on common control channel for exchange the spectrum opportunity (SOP) among the nodes to overcome the inconsistency of SOP. It also identifies traverse flows at every node and calculates RF band used by any node and this is used for multi-flow multi-frequency arrangement. Path delay and node delay show the switching and back off delays along the path and used to calculate the cumulative delay of the path. A local coordination of the routing scheme is used for load balancing on intersecting nodes for multi-frequency traffic. Each network node is equipped with traditional wireless interface in addition to CR transceiver to ensure the successful delivery of routing messages at each node in spite of the inconsistency of the frequency bands as well as every node provides the SOP information to its network layer. The local coordination is applied on every network node of multi-hop CRNs.

3.7. Multi-path Routing: In multi-path routing multiple routes are exposed for any destination node and then some best available routes among discovered route are selected based on different parameters. Multi-path routing has many benefits such as fault tolerance, increased bandwidth and reduction of primary to secondary user interference. In the rest of the sub section we can summarize the multi-path routing protocol and bring to light its routing technique and its advantages.

3.7.1. Multipath Routing and Spectrum Access (MRSA): Existing multi-path routing protocols for conventional wireless networks cannot be adapted in CRNs since they neither consider the diversity in spectrum availability nor coexistence of primary and secondary users. MRSA is the first multi-path protocol for CRNs that minimizes the inter path argument and interference. [9] It overcomes the disruption of primary users with minimum deprivation by distributing the traffic of each flow over multiple paths. For traffic distribution it uses round robin fashion that is not an effective technique. In MRSA "spectrum wise disjointness" concept is revised as if multiple paths do not have any interfacing spectrum bands between them then these paths are spectrum wise disjointed.

3.8. Tree Based Routing: In tree based routing protocol a tree structured network is enabled by configuring a root. [10] Tree based routing is central routing scheme which is controlled by a single network entity called Base Station. Thus network topology can be quickly constructed among CR station by configuring cognitive base station as root. In the rest of the sub section we summarize the tree based routing protocol and underline its routing technique and its advantages.

3.8.1 Cognitive Tree-based Routing (CTBR): Cognitive tree based routing is an expansion of tree based routing protocol future planned for wireless mesh networks. It uses global and local decision schemes for adjustment route calculation. Global decision scheme path selects route with the best global end-to-end metric whereas local decision scheme path selects the best interface with the least load. Multiple paths with the same global end-to-end metric can exist for the same destination. In this case the end-to-end path is selected based on the local decision scheme, which uses load measuring. CTBR uses the routing procedure of TBR in which root periodically sends Root Announcement message for tree formulation. Any node receives the RANN, cache the node whom it receives the RANN as its potential parent and then rebroadcast RANN with updated cumulative metric. The node will select a parent node from all potential parent node based on the best metric for the path to root node. For registering with root every node that contains known path to root sends route reply. Any intermediate node that receives RREP forwards the message to its parent node as well updates its routing table by selecting source node of RREP as its destination. Thus at the end root constructs a tree as it has learnt all network nodes. To make TBR adaptable for CRNs a link quality metric has been introduced.

IV. CONCLUSION

In this paper we present the routing on cognitive radio wireless mesh networks. WMN consists of the different mesh network architectures on the cognitive radio networks. Such as Infrastructure/ backbone WMN's, Client WMN's, Hybrid WMN's. Firstly we discussed the architecture and main routing differences and challenges for CRNs .We should studied the different routing protocols on cognitive radio networks. Although many routing techniques look promising but mostly presented techniques uses the same routing metrics as conventional wireless mesh networks. There is needed to be design of new routing metrics those exploits all the dynamic characteristics of Cognitive Radio Wireless Mesh Networks and based on the such metrics novel routing proposals should be presented.

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