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Performance Evaluation of Routing Protocols for Cognitive Radio Network

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Abstract: The cognitive radio is able to provide a wide variety of intelligent behaviours. It can monitor the spectrum and select frequencies that minimize interference to existing PU communication activity.When doing so,it will rely on a set of rules that define which frequencies may be considered,what waveforms may be used, what power levels may be used for transmission.This paper deals mainly with manet based routing protocols performance which greatly depends on availability and stability of wireless spectrum and also a crucial parameter that should not be neglected in order to obtain accurate performance measurements of cognitive radio network.The primary goal of any CR network routing protocol is to meet the challenges of the dynamically changing network topology and establish an efficient route between any two nodes with minimum routing load and bandwidth consumption.Here,we evaluate the performance and comparison of AODV, DSR, DSDV and OLSR routing protocols on the basis of various parameters such as packet delivery ratio, throughput and so on. Finally, select the best performing protocol for CRN networks based on different parameters.

Keywords: Routing protocols, Cognitive radio network (CRN), PDR, Throughput.

I. INTRODUCTION

The term "Cognitive Radio" (CR) was coined by Joe Mitola in 1999-2000, in a number of publications and in his PhD thesis. The term was taken to describe intelligent radios that can make decisions using gathered information about the RF environment and can also learn and plan according to their past experience. Clearly, this level of intelligence requires the radio to be self-aware. [13][15]

The term CR is defined in as follows: “Cognitive radio is an intelligent communication tool that is aware of its environment. A cognitive radio network (CRN) allows us to establish communications among CR nodes/users. The network parameters can be adjusted according to the change in the radio environment, topology, operating scenario, or user requirements. Main objectives of the CR network are:- efficient use of frequency spectrum and to achieve the highly reliable and efficient wireless communications. [2][4].

Cognitive radios can change their parameter like frequency, coding techniques, modulation techniques, power etc. according to changing communication environment thus resulting in efficient utilization of available resources [12]. Cognitive radio networks consist of two types of users, primary /licensed and secondary/unlicensed cognitive users. Licensed users have higher priority for the usage of the licensed spectrum [11]. On the other hand unlicensed users can opportunistically communicate in licensed spectrum by changing their parameters in an adaptive way when spectrum holes are available as shown in fig.1 [3] [9][14].

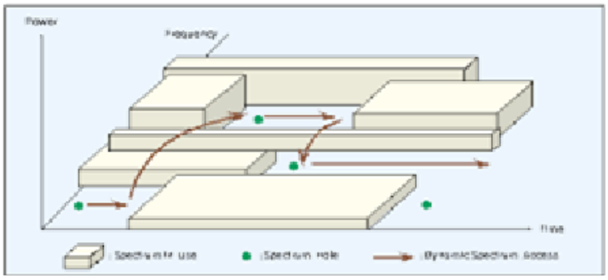

Fig. 1

Cognitive radio-based on sharing has basically two major flavors, that is, horizontal spectrum sharing and vertical spectrum sharing. In the former case, all CR users have equal regulatory status, and in the latter case all CR users do not have equal regulatory status. There are licensed users and unlicensed users in vertical spectrum sharing which dynamically use the spectrum without affecting the primary user’s performances. Horizontal spectrum sharing can be between similar networks (e.g.,IEEE 802.11a operating in Unlicensed National band e.g 5GHz) or between heterogeneous frequencies based networks (e.g., coexistence between IEEE 802.11b and 802.15.1 [Bluetooth] networks). When all the heterogeneous networks having adaptive capabilities then it is referred to as symmetric sharing. While, when there is one or more network without these cognitive/adaptive capabilities, this is referred to as asymmetric spectrum sharing. One example of this is the coexistence of IEEE 802.11 high speed networks with IEEE 802.15.4 low-power networks. This latter scenario is used in this paper work.

II. RELATED WORK

Recent paper work is based on distributed CR routing protocols are as follow:

[1] Rafiza Ruslan, Rizauddin Saian, Nurhamizah Mohd.Teramizi in [1]- As cognitive Radio (CR) has the capability to identify the unused spectrum in order to allow CR users to use it without any interference with the primary users (PUs). Routing is a important task in CR network (CRN) due to diversity in available channels. In this paper, they used Ad-Hoc On-Demand Distance Vector (AODV) and Weight Cumulative Expected Transmission Time (WCETT) routing protocols for the efficient route selection between the source and destination in CRAHN. The performance of AODV and WCETT are evaluated on the basis of average throughput in three different kind of routing structures to satisfy different requirements from users: 1) single radio multi-channels, 2) equal number of radios and channels and 3) multi-radios multi-channels. Their simulation result shows AODV has a efficient average throughput in single radio multi-channels whereas WCETT has a efficient average throughput in equal number of radios and channels as well as in multi-radios multi-channels.

[2] Matteo Cesana, Francesca Cuomo, Eylem Ekici in [8] their working concept is based on CRN network. They mainly focused on the issues related to the design and maintenance of routes in multiple hop CRNs, clearly highlighting their strengths and drawbacks. In a nutshell, the main challenges for routing information throughout multihop CRNs include: spectrum-awareness, setup of quality" routes and route maintenance has been considered.

[3] S. Selvakanmani and M. Sumathi, in [5] - They gave overview of various routing protocols for adhoc networks based on Multiple channel usage, Link Modelling, Geographic routing, Spectrum awareness, and Connectivity. They also showed classification of mobile cognitive radio adhoc network as Infrastructured CR (Primary/licensed) and Infrastructureless CR (secondary/unlicenced) [7].
In infrastructured networks, a central, fixed infrastructure component called base station will be there for the communication among the communicating devices. In infrastructureless networks, the devices communicate without the support of the fixed component. The Unlicensed network does not have a license to operate in a desired band.

[4] Hang Su and Xi Zhang in [10] -They have proposed the cross-layer based opportunistic multi-channel medium access control (MAC) protocols, which includes the sensing of spectrum at physical (PHY) layer with the scheduling of packet at MAC layer. In their proposed protocols, each secondary user is equipped with two transceivers. First transceiver is tuned to the dedicated control channel, while the second is designed specifically as a cognitive radio that can periodically sense and use the identified un-used channels. To obtain the channel state accurately, they proposed two collaborative channel spectrum-sensing policies, namely, the negotiation based sensing policy and random sensing policy, to help the MAC protocols for detecting the availability of leftover channels.

[5] Ms. Shubhangini, R. P. Deshmukh and A. N. Thakare [6] - They evaluate the special features of cognitive radio networks using the AODV & DSDV routing protocol for CRAHNs as in the wireless communication & propose new routing metrics, including transmission delay. Routing protocols for network without infrastructures have been developed. They have capability to determine how messages can be forwarded, from a source node to a destination node in the mobile nodes of the network. They also discuss about the packet transmission over number of nodes and the next hope packet forwarding from source to destination.

III. CLASSIFICATION OF ROUTING PROTOCOLS

Routing protocol is a standard, which controls how nodes decide which way to route packets between computing devices in a CR mobile ad hoc network. In ad hoc networks, nodes are not familiar with the topology of their networks. Instead, nodes have to discover it: typically, any new node announces its presence and listens for announcements broadcast by its neighbors. Each node learns about others nearby and how to reach them, and may announce that it too can reach them. Note that in a wide sense, mobile ad hoc protocols can also be used literally for specific purpose. The following are some ad hoc network routing protocols that are also used for CR network:

3.1 Proactive or Table-driven routing protocols

In this, each node maintains one or more tables containing routing information to every other node in the network. All nodes update these tables so as to maintain a consistent and up-to-date view of the network. When the network topology changes the nodes propagate update messages throughout the network in order to maintain consistent and up-to-date routing information about the whole network. These routing protocols differ in the method by which the topology change information is distributed across the network and the number of necessary routing-related tables. Some of used in this paper are OLSR and DSDV.Their breif description given below:-

3.1.1 Optimized Link State Routing Protocol (OLSR)

OLSR is a proactive link-state routing protocol, which uses hello and topology control (TC) messages to discover and then disseminate link state information throughout the mobile ad hoc network. Individual nodes use this

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topology information to compute next hop destinations for all nodes in the network using shortest hop forwarding paths. Using Hello messages the OLSR protocol at each node discovers 2-hop neighbor information and performs a distributed election of a set of multipoint relays (MPRs). Nodes select MPRs such that there exists a path to each of its 2-hop neighbors via a node selected as an MPR. These MPR nodes then source and forward TC messages that contain the MPR selectors. This

Being a proactive protocol, routes to all destinations within the network are known and maintained before use. Having the routes available within the standard routing table can be useful for some systems and network applications as there is no route discovery delay associated with finding a new route.

3.1.2 Destination Sequenced Distance Vector (DSDV)

Every node will maintain a table listing all the other nodes it has known either directly or through some neighbors. Every node has a single entry in the routing table. The entry will have information about the node’s IP address, last known sequence number and the hop count to reach that node. Along with these details the table also keeps track of the next hop neighbor to reach the destination node, the timestamp of the last update received for that node.

Immediately when network topology changes are detected, each mobile node advertises routing information using broadcasting or multicasting a routing table update packet. The update packet starts out with a metric of one to direct connected nodes. This indicates that each receiving neighbor is one metric (hop) away from the node. After receiving the update packet, the neighbors update their routing table with incrementing the metric by one and retransmit the update packet to the corresponding neighbors of each of them. The process will be repeated until all the nodes in the ad hoc network have received a copy of the update packet with a corresponding metric [17].

3.2 On-Demand Routing Protocols

These protocols take a lazy approach to routing. In contrast to table-driven routing protocols all up-to-date routes are not maintained at every node, instead the routes are created as and when required. When a source wants to send to a destination, it invokes the route discovery mechanisms to find the path to the destination. The route remains valid till the destination is reachable or until the route is no longer needed.Two of these are discussed here in this research as given below:-

3.2.1 Ad-hoc On-Demand Distance vector (AODV)

AODV is an ‘on demand routing protocol with small delay. That means that routes are only established when needed to reduce traffic overhead. It supports Unicast, Broadcast and Multicast without any further protocols. The Count-To-Infinity and loop problem is solved with sequence numbers and the registration of the costs. In AODV every hop has the constant cost of one. The routes age very quickly in order to accommodate the movement of the mobile nodes. Link breakages can locally be repaired very efficiently. In AODV the routing table is expanded by a sequence number to every destination and by time to live for every entry. [18]

Unicast Routing: For unicast routing three control messages are used: RREQ (Route Reply), RREP (Route Reply), RERR (Route Error). If a node wants to send a packet to a node for which no route is available it broadcasts a RREQ to find one. A RREP includes a unique identifier, the destination IP address and sequence number, the source IP address and sequence number as well as a hop count initialised with zero and some flags. If a node receives a RREQ which it does not have seen before it sets up a reverse route to the sender. If it does not know a route to the destination it rebroadcasts the updated RREQ especially incrementing the hop count. If it knows a route to the destination it creates a RREP.

Multicast Routing: One of the great advantages of AODV is its integrated multicast routing. In a multicast routing table the IP address and the sequence number of the group are stored. To join a multicast group a node has to send an RREQ to the group address with the join flag set. Any node in the multicast tree which receives the RREQ can answer with a RREP.

3.2.2 Dynamic Source Routing (DSR)

It forms a route on-demand when a transmitting node requests one. However, it uses source routing instead of relying on the routing table at each intermediate device. This protocol is truly based on source routing whereby all the routing information is maintained (continually updated) at mobile nodes. It has only two major phases, which are Route Discovery and Route Maintenance. Route Reply would only be generated if the message has reached the intended destination node.

It returns the Route Reply; the destination node must have a route to the source node. If the route is in the Destination Node's route cache, the route would be used. Otherwise, the node will reverse the route based on the route record in the Route Request message header. In the event of fatal transmission, the Route Maintenance Phase is initiated whereby the Route Error packets are generated at a node. The erroneous hop will be removed from the node's route cache; all routes containing the hop are truncated at that point. Again, the Route Discovery Phase is initiated to determine the most viable route. [19]. Advantage is that it eliminates the need to periodically flood the network with table update messages which are required in a table-driven approach.

IV. PROPOSED WORK

The proposed work describes the performance of routing protocol with the spectrum selection, route discovery and

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route maintenance in Network layer considering various numbers of nodes for the cognitive ad-hoc networks. The following are considered as our Performance Metrics using which comparison of routing protocols such as AODV, DSDV, DSR and OLSR has been performed:-

4.1 Packet delivery ratio:-

It is defined as the ratio of data packets received by the destinations to those generated by the sources; it can be numerically defined as:

PDR= ∑ (Data packets received by the each destination) / ∑ (Data packets generated by the each source)

4.2 Throughput:-

It is defined as the total number of packets delivered successfully over the total simulation time. The throughput is usually measured in bits per second (bits/sec).

Throughput= (total number of delivered packet * packet size) / Total duration of simulation

4.3 End to end delay:-

The average time it takes a data packet to reach the destination. It includes all possible delays occur while buffering during route discovery latency, queuing at the interface queue. Delay metric is calculated by subtracting time at which first packet was transmitted by source from time at which last data packet arrived to destination

Avg. EED= ∑ time spent to deliver packets for each destination / Number of packets received by all destination nodes

4.4 Average Energy consumption:-

It is the ratio of sum of total energy consumed by each node to the total number of nodes .The energy consumption of the on-demand protocols increases as the maximum motion speed grows.

AEC = ∑ (Initial Energy - Final Energy) / Total number of Nodes

Residual Energy = Initial Energy – AEC

4.5 Normalized Routing Load:-

It is defined as the ratio of number of routing packets transmitted to data packet delivered at the destination. Each hop-wise transmission of a routing packet is considered as one transmission.

NRL = Routing Packet / Received Packets

V. SIMULATION RESULTS

Simulation is performed using Network Simulator-2 (NS-2) version 2.34, since it is open source free software in which various specifications can simply modified and changed. The network consists of

Number of nodes placed randomly in a terrain 1000m*1000m with flat grid topology. For MAC layer protocol we have used the Distributed Coordination Function (DCF) of IEEE 802.11 as it captures link breakages effectively as well as IEEE 802.15.4 used for sensing network. TCP traffic is exchanged among the nodes with transport layer protocol being FTP. All the nodes in the simulation has omni-directional antenna. The simulation results are as follow:-

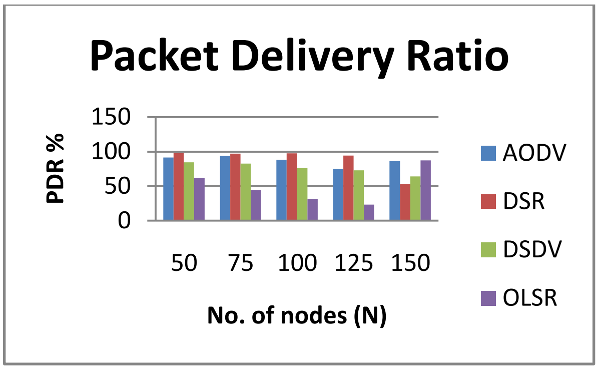

Fig. 2

1. A simulation result shows that PDR for DSR protocol is highest among all protocols which are almost above 90% for all the nodes topology. (Fig. 2)

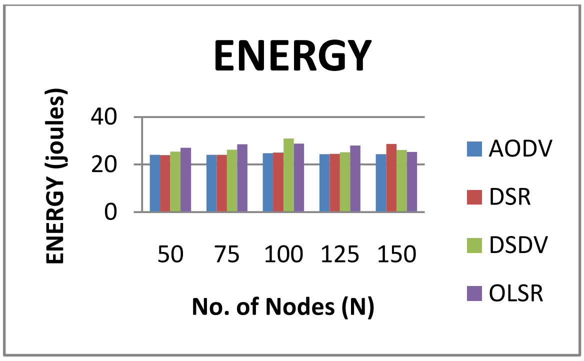

Fig. 3

2. Other important parameter in any network is energy consumption which shows that how much energy is used during whole transmission process. This paper calculates the residual energy of nodes which is more in both DSDV and OLSR protocols for different traffic conditions. (Fig. 3)

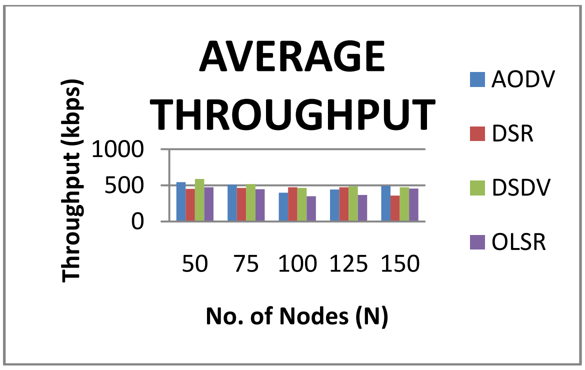

Fig. 4

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3. Performance in case of average throughput, DSDV protocol is more efficient when less traffic is there but with increasing number of nodes it becomes equal to DSR protocol. (Fig. 4)

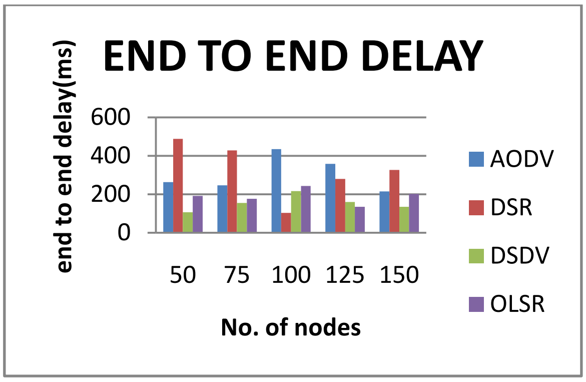

Fig. 5

4. Results in case of end to end delay, DSDV is having minimum value and it is best suited when heavy traffic is present in CR network. (Fig 5)

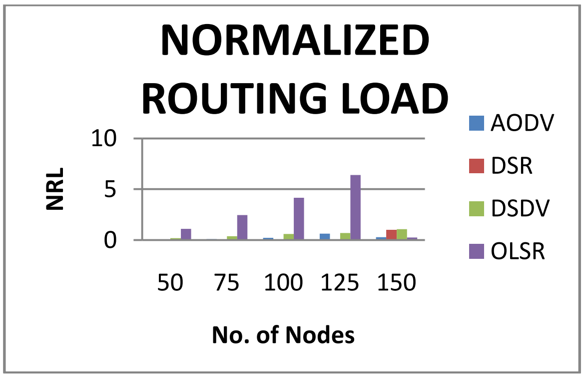

Fig. 6

5. Another parameter used is normalized routing load which is lowest for DSR protocol and slightly more than DSR in case of AODV protocol. Both can be used for efficient CR transmission while required less routing overhead. (Fig. 6)

VI. CONCLUSION

The proposed research work presents extensive simulation analysis for four routing protocols under various traffic scenarios for CRN. Routing protocols will be evaluated for the optimum performance on all chosen metrics i.e. PDR, End-to-End Delay, energy, throughput and NRL. Performance is different for different protocols with respect to various metrics parameter. A future work can be considered by carrying out simulation to analyze and compare the performance of hybrid routing protocol with the routing protocols analyzed in this work where different scenarios could be inspected while introducing randomness to the packet size and rate.

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