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Abstract—A large number of routing protocols for Cognitive Radio (CR) have been recently proposed to improve the efficiency of spectrum utilization. As an example, we can find the Cognitive Ad hoc On demand Distance Vector (CAODV). This protocol is based on AODV one and uses an on-demand approach for finding routes to which the principals of regions activity avoidance of the Primary User (PU) has been added during the packet transfer. The main drawback of this protocol is that it doesn’t support the Quality of Service (QoS) mechanisms. In this paper, we propose to develop, implement and test a new protocol that integrate the QoS adaption mechanism in cognitive on demand routing protocol. The new protocol, called QoS-CAODV, is a combination of QoS-AODV and CAODV. The performances of QoS-CAODV protocol have been evaluated by numerical simulations (OPNET 14.5). We have observed from results that the QoS-CAODV protocol provides better performance in term of average throughput, end-to-end delay and gives the smallest number of dropped packets.

Keywords—Cognitive Radio (CR), CAODV, QoS-CAODV, routing protocol, OPNET 14.5 simulator.

I. INTRODUCTION

Recent studies on Cognitive Radio (Le-Thanh and Bao, 2011; Long and al., 2011; De-Domenico and al., 2012; Sadeghi and al., 2012) have focused on detecting unused spectrum. Nevertheless, a wireless ad-hoc network is a good architecture to explore routing protocols in CR. Consequently, a number of routing protocols have been proposed and implemented for Cognitive Radio Ad Hoc Networks (CRAHNs) (Cacciapuoti and al. 2010; Peftianakis and al. 2008; Kiam Cheng How and Maode Ma,2010; Kaushik , al. 2010; Ding and al. 2010; Ma, H., Zheng, L. 2008; Weilian Su and Ian F. Akyildiz ; A.Cagatay Talay and D. Turagy Altilar 2009) [5] [9]. It is important that routing protocols include QoS metrics in route finding and maintenance to retain end to end QoS. The ad hoc routing protocols have two routing approaches: proactive (or table-driven) and reactive (or on-demand) routing protocols [11]. Many revisions are done, for example, to the traditional AODV protocol [10] to add QoS challenges. In this case, we can introduce the Cognitive Ad hoc On demand Distance Vector (CAODV). It uses an on-demand approach [8] which assesses the qualities of any available channel, minimizing the route cost by performing a common path and channel selection for each forwarder. The main difficulty of this protocol is it doesn’t maintain the QoS mechanisms. Therefore, we are motivated to propose a new protocol CAODV-QoS which integrates the QoS mechanism in cognitive on demand routing protocol. Our new protocol QoS-CAODV combines QoS-AODV and CAODV protocol. It provides better performance in term of end-to-end delay, average throughput and a small number of dropped packets. All those are evaluated by the simulator (OPNET 14.5). The rest of this article is organized as follows: section 2 introduces a brief description of AODV, QoS-AODV and CAODV protocol. In Section 3, the performance evaluations using OPNET 14.5 is presented in details (the simulation environment, the metrics and the results of simulation). Finally, the conclusion of this article is in section 4.
II. BACKGROUND

In this article, on-demand routing protocols applicable for CRAHNs are classified and reviewed.

A. AODV (Ad hoc On-demand Distance Vector) protocol:

The AODV protocol [1] is a reactive routing protocol based on the distance vector principle, combining unicast and multicast routing. In AODV, the path between two nodes is calculated when it's needed, i.e. when a source node wants to send data packets to a destination, it finds a path (Discovery Phase), uses it during the transfer phase, and it must maintain this path during its utilization (Maintenance Phase). The finding and maintaining process of a path is based on the exchange set of control packets: RREQ (Route REQUEST), RREP (Route REPLY), RERR (Route ERROR) and Hello messages (Hello).

![Figure 1: Example of AODV protocol.](image)

B. CAODV (Cognitive AODV) protocol:

The CAODV protocol [2] (Cacciapuoti et al. 2010) is inspired from the AODV protocol. It has some modifications. These modifications are:

- Whenever a node needs route to a destination, it broadcasts RREQ by amending spectrum related information in it that includes the best available channel.

- An intermediate (SU) node that receives RREQ checks whether it is in contact with a PU. If yes, it simply adds information about the free spectrum and broadcasts the packet further till it reaches its destination or an intermediate node that has information about the destination as well as the spectrum in its routing table. If no channel is available so, it simply drops the RREQ.

- The destination node chooses the best possible path by taking the best and the shortest path from all feasible paths that it receives.

C. QoS AODV:

The majority of routing protocols for Ad Hoc networks, such as AODV, are designed without considering in an explicit way the QoS of the routes that they generate. QoS routing needs not only to find a route from the source to the destination, but also a route that satisfies as a final constraint like bandwidth, delay, throughput, latency, loss of packages, etc.[6]

The qAODV (Quality of service AODV) [6] protocol increases packet delivery ratio, reduces end to end delay and moderates high mobility. The routing load of qAODV is a little bit higher than traditional AODV.

In QoS-AODV (Quality of service AODV) [6], the AODV protocol is extended by adding new domains: maximum delay and minimum bandwidth extension. Special messages, QoS LOST messages, are sent to all sources potentially affected by the variation of QoS parameters. QoS-AODV guarantees packet delivery ratio, normalizes the overhead load and average latency in mobility.

The QAOVD (Quality of service AODV) [6] protocol is an extension of AODV protocol based on bandwidth and delay constraints. It has two efficient route recovery mechanisms for QoS routing. QAOVD reduces control overhead, delay, improves end-to-end delivery ratio and connection setup latency.

The SQ-AODV (Stability-based QoS-capable AODV) [6] protocol is an improvement AODV protocol. It has two norms: how residual node energy is used for route selection and how protocol can be rapidly adapted to network conditions.

These protocols use only local information at each node without adding any considerable overhead in the network. So, we propose a new routing protocol referred to a QoS Cognitive Ad-hoc On demand Distance Vector (QoS-CAODV) protocol. It is based on a combination between QoS-AODV and CAODV. This proposal avoids regions of PU activity during both route formation and packet discovery without demanding any dedicated control channel. It exploits the presence of multiple available channels to improve the overall performances.

III. Proposed work

This modification is done in our code to introduce QoS-CAODV protocol for CRAHNS. The network is anticipated to guarantee a set of pre-specified QoS attributes to the users in terms of available bandwidth and end-to-end performance. In fact, the classic CAODV routing protocol can be modified. It adds the related QoS information to each node in its routing table. When a path discovery process is initiated, calculating the matching QoS conditions values and finally we can find path with the best QoS condition. A key to offer these QoS conditions is to find a route to the preferred destination that can, with high probability, survive for the duration of the session.
IV. Performance evaluation

A. Simulation environment:
In this section, we evaluate the performances of our proposed protocol, QoS-CAODV, by simulations via OPNET 14.5. We carry out a multitude of tests with random topology where 36 SUs and 10 PUs are randomly placed in 500x500 m.

Table I Standard parameter for simulation

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulator</td>
<td>OPNET 14.5</td>
</tr>
<tr>
<td>Protocol studied</td>
<td>CAODV, QoS-CAODV</td>
</tr>
<tr>
<td>Simulation time</td>
<td>4000 sec</td>
</tr>
<tr>
<td>Simulation Area</td>
<td>500 x 500 m</td>
</tr>
<tr>
<td>Mobility Model</td>
<td>random way point</td>
</tr>
<tr>
<td>Modulation</td>
<td>DPSK</td>
</tr>
<tr>
<td>N primary node</td>
<td>10 nodes</td>
</tr>
<tr>
<td>N secondary node</td>
<td>36 nodes</td>
</tr>
<tr>
<td>speed</td>
<td>17 m/s</td>
</tr>
<tr>
<td>throughput</td>
<td>5.5 mb/s</td>
</tr>
<tr>
<td>Buffer size</td>
<td>256 000 bits</td>
</tr>
<tr>
<td>Transmit power</td>
<td>0.005 w</td>
</tr>
<tr>
<td>Channel type</td>
<td>Wireless channel</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>22.000 khz</td>
</tr>
<tr>
<td>Data rate</td>
<td>1000 kb/s</td>
</tr>
<tr>
<td>Packet size</td>
<td>1024 bits</td>
</tr>
</tbody>
</table>

After a defined time interval, the nodes start their movement according to a mobility model random way point and a moving speed varying between 0 and 17 m/s maximum speed. Each simulation is run for 4000 sec. Simulation’s parameters are summarized in the table I.

B. Simulation results
From simulation results in figures, it is observed that the performance of our protocol QoS-CAODV is better than other cognitive on-demand routing protocols (such as CAODV), because of the proper receiving of packets and less packet dropped. The QoS-CAODV gives the best performance regarding to the packet transmission over the different channel.

1) Average throughput analysis:
In Fig 3, we observed that QoS-CAODV provides higher average throughput than CAODV. The QoS-CAODV always creates more robust path for data delivery and, as a result, it reduces the number of dropped packets caused by the interference of PU activity. The CAODV has a lower throughput than the QoS-CAODV due to higher drop rates (the throughput difference between both protocol is 0.69 bit/sec).

2) Average end-to-end delay analysis:
In Fig 4, we observed that the delay in QoS-CAODV is minor, which indicates that this protocol presents better quality of service than CAODV protocol. It shows that the average value of delay is almost 0.018 seconds for CAODV, 0.006 seconds for CAODV-QoS. After 3 minutes, it drops and attains a constant value of 0.005 seconds for CAODV, 0.002 seconds for CAODV-QoS.
The CAODV protocol has a long delay because their route discovery takes more time as the optimal path is selected.

3) The Route Discovery Time analysis:

Having considered the achieved results in Fig.5, we see that the Route Discovery Time in QoS-CAODV has been decreased compared to similar conditions in CAODV routing.

4) The Data Dropped analysis:

In Fig 6, we see that the number of deleted packets in QoS-CAODV routing has been decreased compared to the CAODV protocol. Some packets have been buffered in nodes because their needed resources and will be deleted after their life cycle.

Fig 6 shows that the average value of Data Dropped is 2000 bit/seconds for CAODV and 800 bit/seconds for CAODV-QoS. After 3 minutes, it drops to 200 bit/seconds for CAODV and approximately 50 bit/seconds for CAODV-QoS.

5) The Total Route Errors Sent analysis:

The route errors sent is caused by the repeated packet of route request for a particular route in which the route may be broken or will be moved out of active route because the needed resources have not been supplied.

In Fig.7, the simulation results achieved less total route errors sent request for CAODV-QoS, 1.8 routes compared to 1.6 routes for CAODV routing.
6) The Total Route Replies Sent analysis:

Total Route Replies Sent represents total number of route reply packets sent from all nodes in the network if they are destinations of route requests.

![Fig 8. Total Route Replies Sent vs time](image)

From Fig 8, it is clear that CAODV consistently have more route replies sent from destination than CAODV-QoS which is due to less probability of route errors and packets dropped in CAODV-QoS.

7) The Media Access Delay analysis:

This delay is calculated as the duration from the time it is inserted into the transmission queue until the time when the frame is sent to the physical layer for the first time.

![Fig 9. Media Access Delay (Sec) vs time](image)

In Fig 9, it shows that the average value of Media Access Delay is almost 0.022 seconds for CAODV, 0.010 seconds for CAODV QoS. After 3 minutes, it gradually drops and attains a constant value of approximately 0.002 seconds for CAODV QoS, 0.004 seconds for CAODV.

V. CONCLUSION

In this article, we present the implementation and the test of a new protocol, QoS-CAODV, that illustrates the adaptation of QoS concept in cognitive on demand routing protocol. It is a mixing between QoS-AODV and CAODV (is based on AODV and uses an on-demand approach). Our simulation work illustrates the performance of the QoS-CAODV routing protocols in term of some metrics such as throughput, end-to-end delay, less route replies sent, less route discovery time and small number of dropped packets and route error sent. As perspective, we can test our protocol according to different technologies like WIMAX, LTE 5G...

REFERENCES


