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Review and Comparison of Routing Metrics in Cognitive Radio Networks

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Abstract

In this paper, cognitive radio network is briefly introduced as well as routing parameters in cognitive radio networks. Due to lack of Spectrum, using not efficient methods of allocating static spectrum, in cognitive radio networks dynamic accessing spectrum is functional. Utilizing opportunistic a Spectrum requires recognition of routing parameters and metrics in cognition radio networks, which means considering fulfilling the minimum requirements of quality of service (QOS) secondary users need to use the allowed range of primary (main) users. Since primary users are prior to use the spectrum, when primary and secondary users coexist, they need to monitor the bandwidth of the authorized spectrum. One of the most important stages to excess the dynamic spectrum is to explore it. Detection of the presence of the authorized users by unauthorized users is one of the things done in this stage, which is called spectroscopy. In the next stage, we used the analyzed information I was spectroscopy, to decide on accessing the spectrum. cognition radio is defined as a smart wireless communication system, which is aware of the environment and changes its job variables like power forward, type of modulation, carrier frequency etc. using environment learning. For further explaining routing metrics, we try to compare routing metrics in cognitive radio networks and wireless network and analyze its challenges in one-way routing and in multi-route routing.

Keywords:

Cognitive Radio Networks;
Secondary Users;
Primary Uses;
Network Routing;
Wireless Mesh Network.

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1- Introduction

The function of radio spectrum sources and setting up radio waves is characterized by national law enforcement organizations like Federal Communication Commission (FCC). FCC allocates the spectrum to certify holders who are called primary users, in a long-term basis for large geographical areas. However, the main share of the allocated area remains rarely used. The non-efficient function of the limited spectrum makes it necessary to expand the access methods to the dynamic spectrum. In these methods those users we do not have spectrum certificate, secondary users, are temporarily allowed to use the unused authorized spectrum. In the recent years FCC has targeted a more comprehensive part of the spectrum using the cognitive radio networks. Cognitive radio networks are a powerful, critical technology that allows the usage of dynamic spectrum access (DSA) in a more practical way without engaging the primary users. This technology is defined as a radio that can change the parameters of its transmitter in interaction to its environment. Cognitive radio networks are different from general radios in a way that they can allow their users to reconfigure. The cognitive feature is referred to the ability of gathering information from the environment, including information about frequency of transmission, bandwidth, power, and modulation [27].

Using this feature, the second group of users can identify the best spectrum. The reconfiguration feature is referred to ability of changing the parameters according to the gathered information in order to optimize. With using the spectrum in an opportunistic way the cognitive radio network allows the second group of users to know which part of the spectrum is available, what part is best to select, user coordination for spectrum and also to empty the channel when a primary user claims the right usage of spectrum. Considering the more comprehensive usage of sources of the spectrum, especially when the second groups of users are interacting with the first group, the allocation patterns of old spectrum and the accessing protocols of other spectrums cannot be of use. Since the first group of users is in priority to use the spectrum when the second group of users start interacting with the first one then with on-time monitoring of authorized

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bandwidth.

Cognitive radio networks were introduced in [27] and the limitations of its use of spectrum were discussed [5]. In [29, 30] routing and its metrics are discussed. The protocol and their routing metrics were determined [6-9]. Then [10, 11, 12, 15, 16] these two metrics in cognitive radio network and wireless network were compared. [17-25] and [30]. Finally in [26] challenges were discussed, and in [31] the necessity of using "learning automata" samples like multi response learning automata was emphasized.

2-Definition of Cognitive Radio Networks

Wireless communication devices are made from transformation systems of electromagnetic waves in the spectrum of 3 to 300 GHz. Wireless waves with different frequencies have different characteristics that could be more suitable for a certain type of wireless device. For example wireless devices with a narrower wavelength are better for far distance transmissions and devices with a wider wavelength are good for quick communication over a short distance. When waves from different sources get published on the same frequency at the same time there will be collision. So to manage the transmission of radio waves in order to defy collision in a spectrum, the available frequency spectrum is divided into different frequency-blocks and each block is has a specific application and set of rules, defined by the government and assigned to a communication service.

The spectrum allocation method has some restrictions, as examples we can mention:

- When the spectrum is assigned to a specific user or wireless service provider this spectrum is used over a large distance but a major part of its spectrum remains unused and other users cannot use this part.
- The allocated spectrum is for the peak of traffic when there are times of very low load. On the other hand with the coming of new technologies and the growing number of wireless devices demand for radio spectrum grows more and more each day. According to the studies done, a wide part of the spectrum remains unused at most times, while other bands are highly used with a heavy traffic. Even so, the unused allocated parts cannot be used by other users except the owners of the same spectrum. Thus, to solve this problem and to make a balance between this and use this spectrum and the shortage of spectrum due to increase in needs, dynamic access method has been presented. In a dynamic access method, unauthorized users can utilize the unused spectrum opportunities. Yet unauthorized users need to be able to adapt themselves to the spectrum opportunities and respect the authorized user's rights. Accessing the spectrum occurs in a dynamic method in two phases of spectrum explore: (measurement and evaluation) and exploiting the spectrum (making decisions and hand-down).

To use this method of allocating the spectrum and, as a result, more efficient use of spectrum opportunities, wireless transceiver must become smarter to access the radio spectrum. These smart transceivers are called cognitive radios. A cognitive radio system which is based on dynamic access is a wireless system that is able to adapt its parameters to the environment and user needs, and can make a reliable communication possible, as a result [5].

3- DSA (Dynamic Spectrum Access) Techniques

It is possible to categorize DSA Techniques in 3 general models:

1. Exclusive Use:

In this technique as done in command and control, a cognitive radio spectrum will be exclusively given to a user with specific service. But in this model, the spectrum owners will give the unused bandwidths to unlicensed users. This model consists of Long Term Exclusive Use and Dynamic Exclusive Use sub models. In Long Term Exclusive Use, a spectrum will be exclusively given to a specific service in a specific time and space. The secondary network can change the wireless services and Spectrum Access Parameters in the allowed period of time. In Dynamic Exclusive Use, spectrum owners will sell or lend their spectrum and earn money this way.

2. Shared Use of Primary Authorized Spectrum:

In this model, the spectrum is not owned by any specific terminal or services and all unlicensed users have an equal right of using the spectrum.

3. Hierarchical access model:

In this model, the secondary user can access the spectrum using two methods. The first method that is called Collaboration Method, the unlicensed users should evaluate the spectrum, detect spectral opportunities and use them for sending. In other words, the unlicensed user can only use the spectrum in the licensed user's absence. In the 2nd method that is called Underlying Method, both licensed and unlicensed users can send a frequency on a specific bandwidth. This way; sending ability of unlicensed users is so limited on the opposite the sending ability of licensed users is similar to noise. Therefore; this method is suitable for short-range usage.

As mentioned, one of the most important levels of dynamically accessing the spectrum is measuring or evaluating the spectrum. Decryption of licensed users using unlicensed users is one of the jobs done in this level that is called Spectrum Evaluation. In next level by analyzing the extracted information from Spectrum Evaluation, the decision about accessing the spectrum will be made and afterwards, the unlicensed users can use the empty frequency bands with a proper sending technique. Cognitive Radio is defined throughout a smart wireless system that is aware of its surroundings and by learning from the environment; it will change its variables such as modulation type, carrying frequency and etc. Two sets of users are defined in cognitive radio networks, 1st the Primary Users, these users have been given a part of a spectrum by the frequency allotment organizations and are allowed to use it. Actually they are the main owners of specific part of the radio spectrum. Since the primary users don't use their spectrum in all times and spaces, some part of the spectrum will be untouched. The untouched part of the allotted frequency band is called spectrum holes or spectrum opportunities. Based on this definition, each of the three dimensions: frequency, time and place can be effective in making spectrum opportunities. Some other dimensions are involved as well. For instance, codes in wide spectrum based systems, or angles in wave shaping systems. But the recognition of spectrum opportunities in each of these dimensions requires its own special method. In cognitive radio networks there are a group of users that are unauthorized to use the spectrum, but should use the spectrum opportunities. We call this group of users "secondary users" or cognitive radio users [29].

4- Routing Metrics in Cognitive Radio Networks

Regulatory authorities started to move used bands by the old system with digital communication transformation technology saying that the need for wireless bandwidth has increased [1]. Yet, even by reusing, the lack of spectrum is still a problem. Recent studies by FCC show that many of the allocated dynamic spectrum bands were used partly and the average percentage use of them was between 15 and 85.

On the other hand, using wireless technologies, which are being operated in authorized bands, especially in ISM band that is empowered by different type of softwares with bases of WLANs, wireless networks, sensor networks, etc. is causing too much swarm in this group. Two important issues in wireless networks are, the erosion of the rare wireless spectrum and the unusability of the authorized spectrum. CRNs (Cognitive Radio Networks) seem to have emerged to solve these problems.

In CRNs, wireless nodes change their parameters to have a better connection and to avoid the interference of the authorized users (primary users) and unauthorized users (secondary users). These changes in parameters are based on the monitoring of the radio environment, like radio spectrum frequency, the behavior of the user and the status of the network. CRNs are made up of the cognition of the sharp spectrum devices, which are able to change their settings while flying. This capacity is free to allow flexible designs and accessing dynamic spectrum strategies to reuse the part that are temporarily abandoned by the authorized users and on the other hand, flexibility in accessing spectrum with increased complexity in designing communication protocols in different layers.

Most of the works in CRNs emphasized on the stack of lower layer protocols, which is physical [3] and [4]. Their purpose was to demonstrate a solution for the problem of lacking channels and effective wireless access, which allows CRNs to discover and use them to decrease channel conflicts and minimize the node interference and increase the average efficiency of the channel.

Routing in multi-purpose CRN is an important issue that affects the efficiency of the whole network. There are different routing protocols for dynamic accessing of the spectrum for accidental behavior of primary and secondary users, source variances like, accessing the channels and radios in one node, and coordination of nodes in different channels. So, expanding traditional routing protocols in Adhoc networks will have a weak throughput, delay and probably lead to missing packages. For instance, using the number of hops without considering the behavior of PU may enable the protocol to lead to an unsustainable route. Even the definition of instability is different in Adhoc and CRN networks. In Adhoc networks instability is when one or more node cannot be accessed by its other neighbors, while in CRN every node is accessible based on Adhoc definition, but one or more of them get to become inaccessible due to PU behavior. One of the most important parts of the routing protocol is its routing metrics, which determines the quality of different routes.

We now have a survey and classification of different CRN routing criteria, as well as other significant aspects of these criteria and routing protocols that use them. We show the challenges of designing CRN routing criteria. Both are taken from traditional networks Wireless and exclusive CRN networks. Next, we classify the CRN criteria into two groups: single-stranded and multispeed. An important aspect for researching CRN routing criteria is the combined criteria of a number of individual measures. Currently, we have several methods for combining local routing criteria with optimal public routing. Figure 1 summarizes the different challenges.

A. Inherited from Traditional Networks

A basic set of challenges derived from traditional networks that the routing metrics of radio-cognitive networks need to solve.

B. Spectrum Availability

Assigning different weights to different channels based on their availability and reliability, and the probability of interruption.

C. Interruption Time

To calculate the channel change time that needs to be paid when the decision is made to change and change the channel.

D. Signaling and Deafness

Problem The Deafness solution affects the selection of updated routing and performance metrics in this section, we present a taxonomy of the different routing metrics that have been used in multi-hop CRNs (Figure 2). We categorize them into two main groups: metrics for single path routing algorithms and metrics for multi-path routing algorithms.

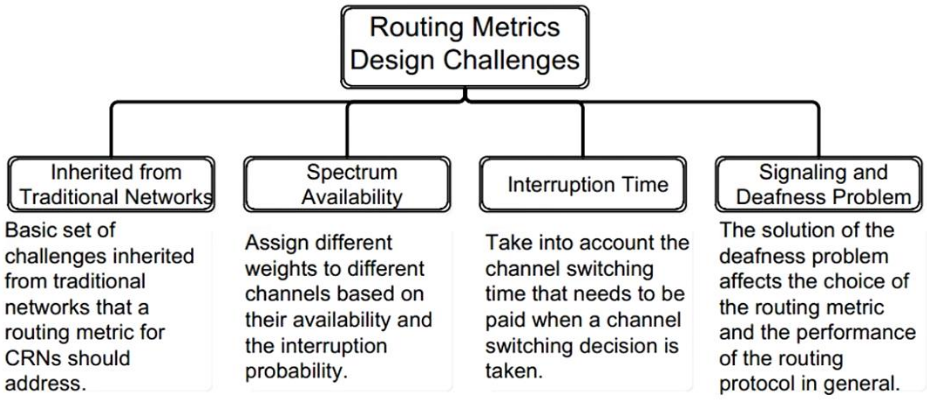

Figure 1. **Routing metric design challenges [30].**

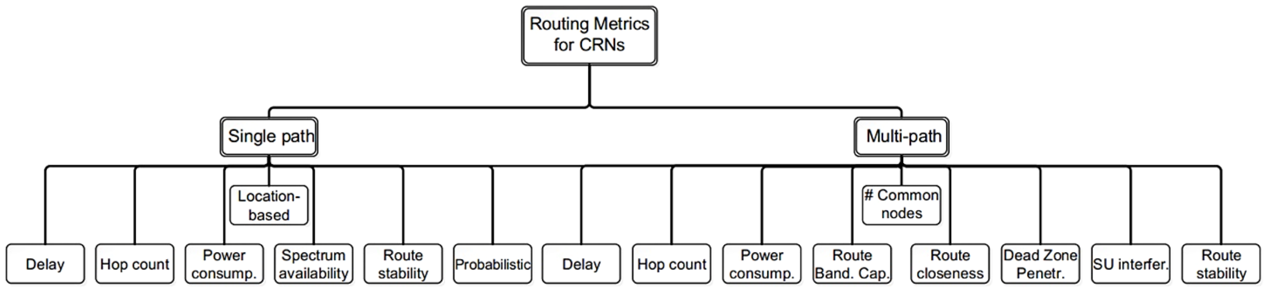

Figure 2. **A taxonomy of routing metrics for CRNs [30].**

A. Single-Path Routing

1) Delay: This classical routing metric captures all factors that contribute to the end-to-end delay. These include the channel switching time, MAC backoff time, queuing delay, transmission delay, among others. It is usually used alone or combined with other metrics.

2) Hop count: Hop count as a metric is usually used as a reflection of other metrics, based on a lower-is-better principle, such as an indication of “faster” transmission routes (delay) or routes that consume less networking resources (as they pass through a lower number of nodes). It has been used as the main routing metric or as a filter to select among the candidate paths.

3) Location-based: Many of today’s wireless devices are location-enabled, e.g. through the GPS system or network based localization, and this is expected to become more ubiquitous in the future. In addition, location information of CRN nodes can be obtained via Previous FCC Geolocation-Databases or estimated via measurements accurately.

4) Power Consumption: A major issue when dealing with protocols for mobile devices is being energy-efficient to conserve the limited battery resource. This applies in CRNs as well as in traditional ad-hoc networks. However, in CRNs each SU has the extra overhead of continuously sensing the presence of PUs. Therefore, it is even more

important to have power consumption as a metric for CRNs [5]. Or carefully measured by measurement, One ETX metric is (Expected transfer number). This criterion is most often used for wireless communications. In wireless Mesh networks, the ETX metric is used to estimate the number of transmissions needed to send a packet through the desired path. This definition includes the number of retransmissions due to the destruction of data resulting from competition over the access environment or environmental collisions. In radio-cognitive networks, there is a similar definition for this criterion, with the difference that the main reason for retransmission in these networks, in addition to the above, is the restoration of the activity of primary users in the frequency range of the licensed [22, 23].

5) Spectrum availability: The spectrum availability metric between two nodes refers to the bandwidth available for the two nodes for communication taking both the PUs’ activity and other SUs’ activity into account.

6) Route Stability: A routing solution that produces stable routes in CRNs is highly desirable as it is one of the main challenges of CRNs due to the PUs’ activities. Unstable routes will lead to frequently firing new re-routing events which consumes the network resources and degrades its performance. Route stability can be captured explicitly in the routing metric. Here, the concept of Expected Transmission Time (ETT) (the time needed to transfer) is also expressed. In wireless networks, this criterion in its calculations, in addition to the Expected Transmission Count (ETX) parameter, also affects the bandwidth of the connection.

7) Probabilistic: When the exact status of the spectrum is not available, or is difficult to reconstruct in a distributed way, routing decisions should be based on probabilistic metrics.

B. Multi-Path Routing

1) Delay: As in single-path routing, delay as a routing metric captures different aspects including channel switching time, end-to-end delay, transmission delay, among others. It can be used as the main metric or as a filtering metric. The Opportunistic Link Transmission (OLT) metric is proposed. This metric captures three aspects of delay: OLT = dtx + dq + daccess, where dtx denotes the link transmission delay, dq denotes the packet queueing delay in a node, and daccess denotes the link access delay.

2) Hop count: This classical routing metric is used to filter out routes or as a tie breaker. A RREQ packet received with an old ID will be forwarded only if its hop count is smaller than the previously received one.

3) Power Consumption: In the NDM AODV protocol [13], secondary routes are selected based on the remaining energy at each node along the route. The protocol calculates the total remaining energy of all nodes in the path and then selects the path with the maximum total remaining energy.

4) Route bandwidth capacity: This metric takes into account the bandwidth of each link based on the number of nodes sharing it.

5) Route closeness: The routes closeness metric selects routes based on how far away they are from each other. The intuition is that selecting non-close routes makes them less vulnerable to mobile PUs. In other words, if selected routes are far enough, a single active mobile PU would not be able to interrupt all of them at the same time. Closeness of two routes is defined as the sum of the pair wise closeness of their links. The closeness of two links is the area of intersection between the PU’s effective region of the two links. The PUs effective region of a link is defined as the region around the link where a PU is able to interrupt that link, which is a function of the PU’s transmission range. Figure 3 shows an example of the link and route closeness metrics. Figure 3.a shows an example of PUs Effective Region (PuER) of a link L between two SUs: S1 and S2. This region is used to quantify the closeness of two links as shown in Figure 3.b. And finally the more the pair wise closeness of two routes’ links, the more the closeness of the two routes themselves (Figure 3.c).

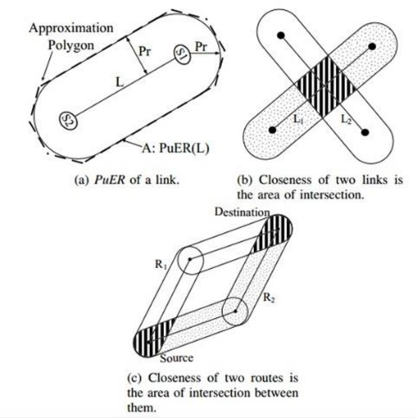

Figure 3. Routes closeness metric definition [30].

6) Dead Zone Penetration: Current routing protocols reconfigure established routing paths to avoid active zones of Pus [14]. Figure 4 shows a motivating scenario for DZP, in which Node 1 maintains the constructed route (1-2-4), even in the presence of a PU, by allowing nodes 2 and3 to cooperatively send data packets to Node 4. This is better than using the alternate route that goes through Node 5.

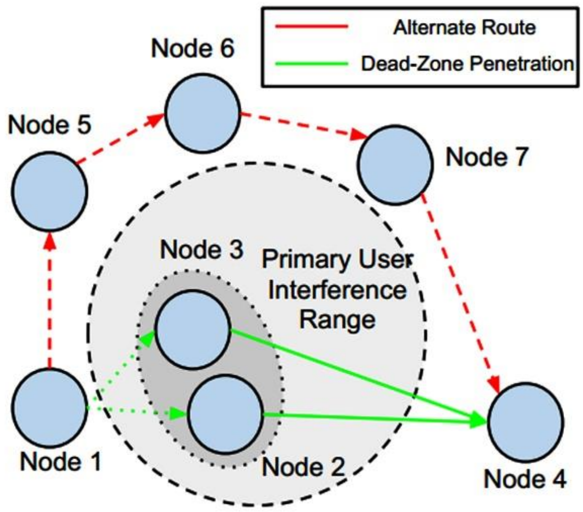

Figure 4. Dead Zone Penetration [30].

7) Metrics that capture SU interference: It is very important in CRNs to pay attention to PU's activity and handle its interference with ongoing SUs' traffic sessions. Most of the routing metrics tend to select routes that are expected to be the least affected with future PU activities. Other metrics take into consideration the interference among SUs themselves where the decisions of channel assignments and next hop neighbours are based on SUs' interference.

8) Route stability: The route stability in CRNs is highly influenced by the behavior of the PUs who affects the connectivity of the network.

5- Comparison between Routing Metrics in Cognitive Radio Networks and Wireless Networks

In source [30] the basic difference between wireless network and cognitive radio network, which is the dynamic accessing to the spectrum, is discussed. Choosing a route between the sender and receiver in a static and dynamic environment may cause instability in the route. Because losing the frequency spectrum in a static environment may cause malfunction in routing. Thus, to select the route it necessary to consider the proper metrics. In this part, we try to discuss some of these metrics and compare them to wireless network routing networks. It must be considered that some of these metrics are more important in cognitive radio networks.

1. Expected transmission count: This metric is discussed in wireless communications. In wireless networks, the ETX metric is the estimation of the required transmission count for sending a package through the intended route. This definition includes the number of resends that are caused by data damaging. Competition on the access environment or environment collision can cause data damaging. In cognitive radio networks we have the same definition for this metric, but the main cause of resend in these networks is considered to be the primary users resuming activities in authorized frequency spectrum [10, 11] as well as the abovementioned reason.

Generally, in either network, ETX is a connection through calculation of two delivery rate package parameters in sending direction, df (the possibility of successful delivery of the package to the receiver) and the delivery rate in retuning direction, dr (possibility of successful receiving of the emphasis package ACK in the sender) and be calculated as:

$$ETX = \frac{1}{d_f \times d_r} \tag{1}$$

$d_f \times d_r$ shows successful receiving of the package ACK in return. The total ETX in a route is the sum of ETXs of all involving connection in that route. As an example for the function of this metric, in Cognitive Routing with ETX (CRE) protocol [11] MEDHOC-NET, after receiving the routing request and exploring the route, it goes opposite of all nodes to the source node. On this stage, each group dynamically selects a channel that the amount of calculated ETX of the surrounded connections is efficient. And eventually, the package is sent through the achieved route.

2. Expected transmission time (ETT): In wireless networks metric the connection bandwidth is considered as well as the ETX parameter. If S is the sides of a package and B is the bandwidth, ETT in wireless networks is defined as

follows:

$$ETT = ETX \times \frac{S}{B} \tag{2}$$

ETT of a connection calculates the required time of a successful transmission. But this metric is defined differently in cognitive radio networks and is very much depended on the dual layer physical performance and MAC in frequency spectrum evaluation and estimation of the accessible channel.

In cognitive radio networks, ETT is calculated based on the needs of secondary users for transmission. Considering the heterogeneity of channel access among secondary users of cognitive radio networks, it is required for ETT to be calculated for each accessible channel using relation 3.Because each secondary user may access multiple channels simultaneously.

$$ETT_i = \gamma \times ETX_i \times \frac{M_i}{B_i \times \log(1 + SINR_i)} \tag{3}$$

ETT_i is the expected transmission time in the ith channel, ETX_i is the expected transmission count in the ith channel, and M_i the amount of allocated traffic to the ith channel, B_i the bandwidth of the ith channel, $SINR_i$ is the signal strength ratio to total noise and interference power in the ith channel. Because the capacity of the accessible cannot be calculated by Shannon Capacity Relationship, (y>10) y is used for modeling the real channel capacity [10, 12].

Reference [15] proposes a routing protocol for Cognitive Vehicle Networks using channel information and locations. In this reference, first each node forms the activities of the primary users and the distance of the sender and receiver to minimize the ETT metric of the sums of neighboring nodes, considering the nearer locations to the destination node. Then, based on the gathered information, routing takes place.

3. The number of steps: In counting the steps of routing, routing protocols like AODV [9] and SEARCH [15] are mostly used. This metric reflects the effect of path length on the performance of data streams. Because of tge fact that this metric does not consider transfer rate and packet degradation between different wireless connections, it cannot result in the proper performance of the network. Yet, using this metric in effective algorithms can lead to finding routes with the minimum number of jumps [16]. In cognitive radio network this metric is different from wireless networks due to low activities of the primary users. To further explain this difference take Figure 5 as an example for the effect of presence of primary users in frequency spectrum on cognitive radio networks.

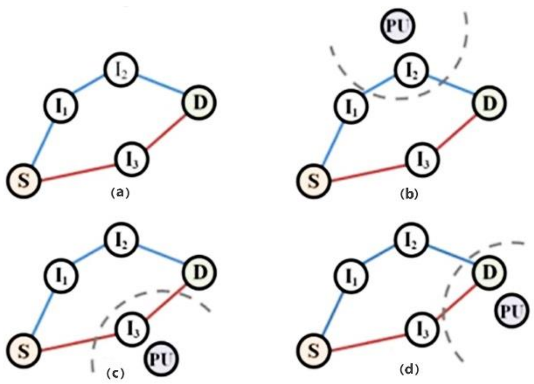

Figure 5. The use of number of steps metric in routing cognitive radio networks [17]

As you can see in Figure 5, when no primary users utilize the (frequency spectrum) used channels, or when the activity of the primary user is in channels other than the used channels, $S \rightarrow I_3 \rightarrow D$ is still the shortest route that connects the two destinations with only two closed steps. (Figure 5.a , 5.b), but when even one primary user return to its frequency spectrum or start an activity near the intended route, the shortest route is going to be $I_1 \rightarrow I_2 \rightarrow D$ because of the establishing of non-interference condition in the performance of primary users (Figure 5.c and 5.d). Not only is this metric affected by the activity of primary users, but also by the number of the active primary users and interference radius of primary and secondary users [17]. This metric is used as a route saving metric in some routing algorithms such as SEARCH. In this route preserving method, the number of steps in each route is compared to the number of determined steps as initial value. If the resulted amount is higher than the threshold value, the current route will be deleted and routing will be run again. The important point in this method is the dynamic changes of routes based on the node's ability to move and the activity of primary users when we have the minimum number of steps.

4. Delay: as a routing metric, delay consists of different aspects including delay in changing the channel, expected end-to-end delay (EED), and delay in package transmission etc. For example, in reference [18] considering only

two delays for each i connection, delay of transfer and queue delay, EED is calculated as the sum of all delays in each connection as follows:

$$EDD = \sum_{i=1}^{M} EDD_i \tag{4}$$

But, in cognitive radio networks delay metric consists of two other delays which are specific to cognitive radio networks: delay in changing channels, delay in competition to exploit the frequency hole. When the received package from a channel encounters the return of the primary users to the channel, it should wait for a while to re-evaluate the frequency spectrums and connecting to the channel, considering the heterogeneity in access of channel among secondary users. On the other hand, the more frequency difference between the two channels, the more delay of this kind. The second type of delay occurs when the secondary users try to use one frequency channel simultaneously; therefore, the competition issue rises in exploiting the frequency spectrum. This competition usually results in resending the data package and eventually a delay called the returning delay [18]. Reference [19] proposes opportunistic link transmission (OLT) using three aspects of delay in the following relation:

$$OLT = d_{ti} + d_q + d_{access} \tag{5}$$

d_{ti} is the delay in each connection transmission, dq delay in queue, d_{access} is the delay in accessing the frequency spectrum.

5. Route stability: This metric in routing wireless networks tries to select a node for the route, a node which is less movable than others. In wireless networks, grid routers are usually immovable and some of the nodes in the network are connected to wired networks; thus, the stability metric is not considered to be a proper metric for these networks [20], but in cognitive radio networks, the stability of the route is one of the most important metrics. In this metric, a route that is less probable to lose the existing channels is the most proper to send the data. Losing channels can be due to the reclamation of the spectrum by the primary users or changes in environmental situations. To calculate probability of reclamation of the spectrum, the previous information in the MAC layer can be used. And to reflect the physical status of the channel, the rate of unsuccessful sent packages can be used. One of the important methods of increasing the stability of the route is to use many routes in a parallel way. As an example of using this metric, in reference [21] a routing method is proposed for cognitive contingency networks named Gymkhana. In this method, the number of connections in each route toward its destination is set. This design uses a distribution protocol to collect some dependent parameters to nominated routes by avoiding the areas in the network that does not guarantee the stability metric. Reference [22] also selects more stable routes and less delay in changing the channel by defining the stability time of channel. The time of route stability, is when the channel is available for the secondary users. In addition to that, among the nominated routes, that one route which enjoys the parameters of stability, route preserving, and more proper number of steps will be chosen as the supporting route.

6. Interference: In wireless networks this metric is discussed by considering two types of interference called Intra-flow interference and inter-flow interference with Interference aware Resource Usage (IRU) parameters. IRU is an ij connection in c channel which serves ETT metric is calculated as follows [23]:

$$IRU_{ij}(c) = ETT_{ij}(c) \times \left| N_i(c) \cup N_j(c) \right| \tag{6}$$

$\left| N_i(c) \cup N_j(c) \right|$ is the number of neighboring nodes which are affected by the interference due to the activity of ij data connection in c channel. Intra-flow interference is the interference between intermediate router connections of a data flow and inter-flow interference is the interference between neighbor routers belonging to data flows in competition to reach a channel. This metric is important in cognitive radio networks as well as the stability metric. In these networks, paying attention to the activities of primary users, considering the interferences due to primary user networks on secondary user traffic, interference of secondary users to access the channel and choosing the next step are of great significance. In this respect, MRSA3 [24] protocol allocates similar frequency spectrum to the route connection with a two-step distance to avoid to avoid inter-channel interference and establishing the interference metric. In addition, in reference [25] a routing plan is presented to minimize the effect of secondary user interference on primary users with a timing algorithm for cognitive wireless networks. And, data flow controlling methods, data sending schedule, choice of channel and shared routing has been presented to decrease the interference effect due to primary users network function. In chart1 routing metrics for presented protocols are summarized. The worth mentioning point is that considering all of these metrics is a hard task as it requires calculation sources. On the other hand, all of these metrics do not have the same value and need to be balanced. For example, in cognitive radio networks route stability and interference metrics are of more importance than others.

6- Routing Challenges

1. Select an empty channel: In a dynamic multiplier cognitive radio network, selecting a channel is significant. The simplest way to select a channel is accidental. But, selecting bands on the background information of the channel is a smarter method. For example, a channel that has been uncertain for a long time should not be used. Each node should save the information about successful sends and its rates in each channel.

2. Resuming the route: Each dynamic route must include a mechanism to resume the lost route to present an alternative one.

3. Using the location information: one of the issues that can help identify the topology of the network is the information about the location of the nodes in the network. So in these networks the messages will be sent to nodes that we are sure are toward the destination. Then we can expect a decrease in power consumption, delivery time and related interference. But this required the nodes to be equipped with GPSs.

4. Inter-layer routing: in usual networks the MAC layer and the network layer work separately. MAC layer monitors the proper delivery of data packages. While the network layer designs the route and delivers it to MAC layer. This task is done independently. But cognitive radio networks require the analysis of the spectrum and the identification of the existing channels before routing. This task is up to the MAC layer and the physical layer. Therefore, we need a collaboration of layers in cognitive radio networks so that MAC layer information be available in network layer. This method which is used in cognitive radio networks is an inter-layer method.

5. Controlling information: we need a newer method to operate in a multi-frequency environment and exchange of controlling messages in cognitive radio networks. Controlling information can be related to the backgrounds of adjacent nodes or existing channels or information about the network topology, which can be used to find the destination of the package. On the other hand, when the accessing time is short, the synchronization the sender and receiver becomes more complicated. So an opportunistic environment leaves two basic questions unanswered for making a multiple cognitive radio network; one, the need for a smart method to broadcast controlling information with minimum amount of consumption and two, the need to synchronize the sender and receiver [26].

The solution is to use LA or Learning Automata in channel allocation. LA makes find routes in a foreboding way. LA is a method in which users compete to access channels through a series of games and the environment reaction (sum of interferences) is a reward or punishment. The result of the game is calculated by a special formula.

7- Conclusion

Cognitive radio technology is proposed as a revolutionary method to use the low spectrum sources in a more efficient way. With synchronizing the frequency and the authorized band which are temporarily unused and matching performance parameters with the environmental changes, cognitive radio technology provides more bandwidth and a reliable and variable bandwidth communication to increase the functions of data for wireless devices. Expanding the traditional routing protocols of Adhoc directly in CRNs will have a weak throughput, delay and probably lead to losing the packages. There are a number of challenges to design metrics for routing cognitive radio networks, including traditional network interferences, spectrum reliability, pausing time, signaling and spectrum listening issues. In this paper, we presented and classified the routing metrics in cognitive radio networks based on two main groups of one-way routes and multiple routes. The metrics of both groups are different from the traditional Adhoc network and are of more importance. The quality of increasing utility is also discussed. In addition, we tried to calculate the comparison of routing metrics in cognitive radio networks and wireless networks, and demonstrated that not only the definition of some metrics but also the priority of routing metrics are different in cognitive radio networks and traditional networks. It is required that routing in cognitive radio network takes place with the consideration of MAC layer and physical layer parameters, because the environment is dynamic. In other words, we need inter-layer designs. Future considerations in routing cognitive radio networks can be the lack of routing designs for nodes with high ability to move, route preserving mechanisms, clustering mechanisms with interference (due to primary user activity) awareness, and lack of researches on inter and intra system routing.

The natural characteristics of modern communication technology impose new challenges on designing patterns of division and management of the effective spectrum. It is expected that the researchers find new solutions to improve the performance of the higher spectrum so that secondary users can find their routes and primary users preserve the same quality of service. One of the methods to tackle routing challenges is to use LA algorithm. LA functions in a foreboding and active way. Secondary users utilize the channels that are free at the moment considering the QOS of primary users and routing metrics. Therefore, they help the efficiency of the spectrum by selecting channels that are free for a period of time. The degree of routing metrics significance (the number of required transmissions, the time of required transmission etc.) in cognitive radio networks are different than that of wireless networks and are mostly of more importance. The challenges of routing are: selecting a vacant channel, resuming the route using the location information, inter-layer routing and controlling information. In order to cope with these challenges, routing algorithms must be used with new smart methods.

8- References

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