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Minimal Spanning Tree Technique for Efficient Spectrum Sensing and Optimal Radio Selection Scheme in Cognitive Radio based Wireless Sensor Heterogeneous Area Network (CoRHAN)

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Abstract-
Wireless Sensor Network (WSN) is basically an energy starving network. The key issue in WSN is energy management, as these devices are battery operated devices and most of their powers are utilized in transmission and reception of radio signals. In heterogeneous environment, since each heterogeneous wireless sensor node (HWSN) has its own transmitting and receiving capability, they loss their energy faster than the homogeneous nodes. Behavior of radio conditions makes HWSN to drain their battery power which is the primary concern. Introducing Cognitive Radio Science into a heterogeneous WSN is one way to analyze the radio capability in a given area. We propose a Cognitive Radio based Heterogeneous Wireless Sensor Area Network (CoRHAN), where Cognitive radio enabled device is integrated into a Heterogeneous Wireless Sensor Network. CR device scans the radio capability of HWSNs at a given instant of time, analyze to decide which sensor node with radio capability has the maximum communication capability with reliable transmission so as to send the packet faster rather than forwarding packets to the nodes which have less radio capability. CR device analyzes radio resources collectively in-order to fully utilize the best of different wireless technologies thereby provide reliable radio services effectively and efficiently through optimal radio selection scheme. It observes radio resource utility, verify and update it's local detection statistics for dynamic decision making by thresholding its detection statistics. In such case, the CR becomes more efficient in data gathering and data collection. In addition, based on environmental conditions the CR is able to scan the radio parameters and collect as much as data possible avoiding multi-path congestion within the WSN. CoRHAN shares radio resources fairly and efficiently by integrating multiple networks together. CoRHAN's primary objective is to provide 1) Highly reliable communication whenever and wherever needed 2) Efficient utilization of the radio spectrum. Simulation and experimental analysis proves that CoRHAN improves the reliability of data transmission reducing the bit error rate and delay with optimized sensing time, maximizing spectrum utilization with minimum latency and guaranteed integrity

Keywords: Wireless Sensor Network, Cognitive Radio, Radio Resources, Radio Capability, Spectrum Utilization.

1. Introduction

Wireless Sensor Network (WSN) is basically an energy starving network. Energy Management is the primary concern in WSN, as these devices are battery operated devices and most of its power is utilized for transmission and reception of radio signals. Consider a homogeneous WSN where the dissipation of energy level in communicating with similar devices are more are less uniformly distributed, i. e., near to the sink to the periphery, the energy dissipation [10] of nodes happen uniformly. There are lot of algorithms developed to safe guard energy dissipation which happens in non-uniform manner. But in heterogeneous environment, since each WSN has their own transmitting and receiving capability, processing capability, battery with active or passive capability, they need to form inter-connectivity. Preserving system robustness through management of radio resources among multiple heterogeneous wireless systems becomes the primary focus. Various needs for wide area, metropolitan area, local area, and personal area wireless networks are satisfied through multiple wireless transceivers for different air interface standards. These Heterogeneous wireless systems will cooperate with each other to provide ubiquitous "always best connection" to users [5]. In addition, managing radio resources among multiple heterogeneous wireless systems is important to preserve system robustness. For example, there can be a high-power sensor node (HPSN) or low-power sensor node (LPSN) in a Heterogeneous Wireless Sensor Network environment. The LPSN may forward a packet to HPSN, where the LPSN has to increase its transmission capability power to communicate to HPSN. In a Heterogeneous environment, since there are different energy levels of communications among sensor nodes, they loss energy faster than homogeneous node. When we analyze the complete process in heterogeneous WSN, the energy dissipation is very fast because of the radio conditions. The behavior of the radio condition makes sensor nodes to drain away their battery power which is the main concern. Wireless devices for next generation wireless networks are equipped with multiple

wireless transceivers to enable them to access different wireless networks. Wireless transceivers with the Cognitive Radio (CR) [1] capabilities sense and determine vacant bands and make use of the available in an opportunistic manner by dynamically changing its operating parameters. The developments in wireless communication have lead to scarcity in spectrum resources. Statistics shows that these resources are not effectively utilized in terms of temporal and spatial. The novel technology providing dynamic spectrum access is the CR [12]. Surpassing the traditional fixed spectrum assignment approach [9], CR has the capability to sense and determine vacant bands and can make use of the available in an opportunistic manner by dynamically changing its operating parameters. An explosion of interest in CR, that can support multiple protocols and air interfaces facilitating the convergence of Heterogeneous wireless networks, enabling high spectrum utilization, reducing harmful interference and providing more reliable radio services. Sharing radio resources fairly and efficiently among multiple networks is one of the major challenges in integrating multiple networks together [10].
Introducing a CR science into a Heterogeneous WSN is one way of analyzing the radio capability in a given geographical area. In this paper, we propose a Cognitive Radio based Heterogeneous Wireless Sensor Area Network (CoRHAN), where CR is introduced into a Heterogeneous WSN. In a CoRHAN environment huge amount of data is transmitted to Data Acquisition systems via base stations. Objective of CoRHAN is to make an intelligent wireless communication system that is aware of its environment and uses the methodology of understanding-by-building to learn from the environment and adapt to statistical variations in analyzing radio resources collectively in order to fully utilize the best of different wireless technologies to provide more reliable radio services effectively and efficiently through optimal radio selection scheme.
The rest of the paper is organized as follows. Section 2 deals with the system model, phase split-up, flow model and mathematical analysis of CoRHAN. Simulation results are given and discussed in section 3. Finally, conclusion of the work is given in Section 4.

2. Cognitive Radio Based Heterogeneous Wireless Sensor Area Network (CoRHAN)

Cognitive Radio based Heterogeneous wireless Sensor Area Network (CoRHAN) technique can be typically deployed in urban cities for temperature monitoring, population monitoring, logistic management etc. Collecting as much as data from smart cities regarding the number of vehicle movements at a particular location, monitoring the traffic conditions, location where people crowded, monitoring high rainfall and temperatures etc, to perform permutations and combinations for decision making, this could be possible through heterogeneous sensor nodes such as video surveillance sensors, gas leakage sensor, water leakage sensor, forest temperature monitoring sensor, if we consider our home, we can have heterogeneous sensors. Collecting these data for decision making through control applications, for example sensing the smoke data and forward to controller triggers fire extinguisher when fire occurs. Typically collecting data concurrently in a real time manner and triggering control communication becomes a primary focus. Problem relies in reliability of data received by the control network for decision making and communication back to the appropriate controlling or signalling sensor for preventive measures. So, 100% fulfilled data gathering and data collection in needed in a critical environment.
In this paper, we introduce a new architecture called CoRHAN, where CR device in introduced within a small coverage area that has a set of heterogeneous wireless sensor nodes. Considering if the area assumed has densely populated sensor nodes, then we can reduce the number of CR nodes, if the area is sparsely populated then we need to have more number of CR node so that we can collect as much as data for preventive or post maintenance activities. Deploying a CR device within the Heterogeneous WSN was considered as a CoRHAN. Objective of CoRHAN is to reduce false alarms and to make sure that it is a true sensor, true data, and true alarm i. e. having a system where we are able to collect true data with less packet loss as like in wired network.
In this section, an integrated heterogeneous wireless radio access network with varied size and location is considered. Below sections details CoRHAN's System model, Phase split-up, Flow and Mathematical analysis.

A. CoRHAN – System Model

Cognitive Radio based Heterogeneous Wireless Sensor Area Network (CoRHAN) system is a multi-layer infrastructure by incorporating different communication modes over large geographical area. Due to restriction in complexity, bandwidth and energy consumption, cooperative communication is employed such that sensor nodes in a radio access network serve to send data to CR enabled node which performs spectrum sensing and channel switching to improve the communication reliability. CR enabled node collects, stores and transmits data from its neighbor sensor node to Data Acquisition System via Gateways as shown in figure 1. Cognitive radio enabled node senses the surrounding environment to determine spectrum holes to allow secondary users to make use of the available vacant bands in an opportunistic manner by dynamically changing its operating parameters when primary (licensed) users are inactive and vacate instantly to avoid interfering with licensed usage when primary user is in operation. CoRHAN shares radio resources fairly and efficiently by integrating multiple networks together.

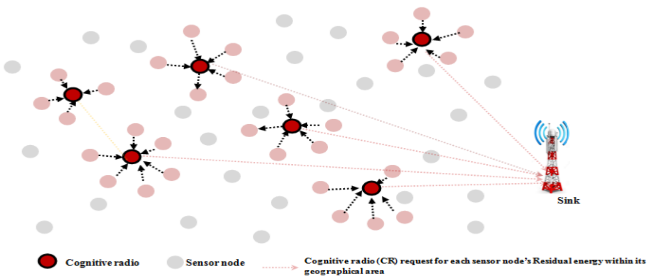

Fig. 1. System Model-CoRHAN

Figure 1 displays the system model of CoRHAN, where CR is introduced within Heterogeneous Area Network environment. Each radio access network consists of group of sensors that have different radio techniques to communicate over noisy channels with a single cognitive radio enabled node deployed randomly within the given geographical area. Geo-location is an important CR enabling technology due to the wide range of applications that may result from a radio being aware of its current location and possibly being aware of its planned path and destination. CoRHAN enables integration of multiple radio access network communication to the sink. For example, in a small geographical area, consider some 5 to 20 heterogeneous wireless sensor nodes, each heterogeneous node has their own radio capability. High transmit node with high energy level may fade faster than a low energy node. So the introduction of CR node into the given geographical area will scan the radio history or radio capability at the given instant of time for these set of sensor nodes, analyze among those set of sensor nodes as which SN with radio capability has the maximum communication capability such that, the radio access network can be selected among that geographical location among the nodes to send the packet faster instead of forwarding packets to the nodes which have the less Radio capability. In such case the CR's radio selection scheme becomes more efficient in data gathering and data collection. In addition, based on environmental conditions the CR is able to scan the radio parameters and collect as much as data possible avoiding multi-path congestion within the WSN.

B. CoRHAN – Phase Split-up

Detailed phase split-up diagrammatic representation of CoRHAN is referred in figure 2. CR enabled node monitors the spectrum and choose frequencies that minimize interference to existing communication activity. When doing so, it will follow a set of rules that define what frequencies may be considered, what waveforms may be used, what power levels may be used for transmission, and so forth.

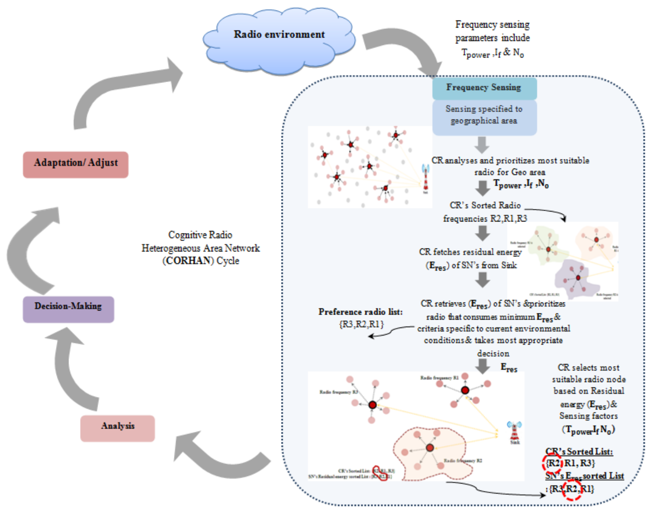

Fig. 2. Phase split-up representation of CoRHAN

It may also be given rules about the access protocols by which spectrum access is negotiated with spectrum license holders, if any, and the etiquettes by which it must check with other users of the spectrum to ensure that no user hidden from the node wishing to transmit is already communicating.

i. Spectrum Sensing

Cognitive radio (CR) scans the given area and begins to sense the radio node that has less interference, better transmission power and less noise for data transmission as shown in figure 3. CR node scans and makes an analysis of each radio node's interference, noise and transmission power and takes a preliminary decision (refer figure 3 where radio frequencies R1, R2 and R3 is selected) to switch over. By this, CR retrieves the interference (I_f), transmission power (T_{power}) and noise (N_0) factors from the surrounding nodes and sorts the most appropriate and suitable radio for particular geographical area based on the above sensing factors

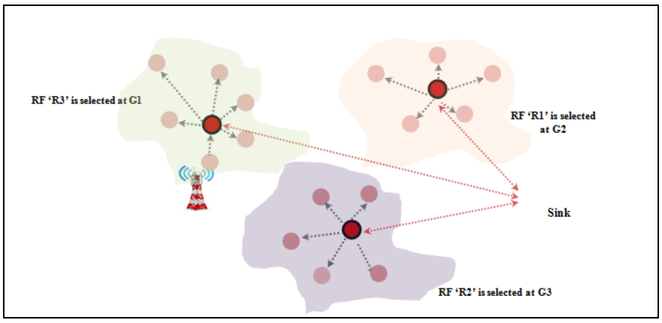

Fig. 3. CR node senses sensor nodes for radio access network within small geographical area

In addition to the spectrum optimization level, the cognitive radio may have the ability to optimize a waveform to one or many criteria. For example, the radio may be able to optimize for data rate, for packet success rate, for service cost, for battery power minimization, or for some mixture of several criteria. The user does not see these levels of sophisticated channel analysis and optimization except as the recipient of excellent service.

ii. Radio access network selection

In addition to this preliminary decision, CR node sends a request to sink to collect residual energy of each sensor node that belongs to particular geographical area. As the CoRHAN network is the combination of a Cognitive radio (CR) enabled node and heterogeneous sensor networks (WSN), sensor node's residual energy (E_{res}) is taken into consideration. CR retrieves the residual energy of sensor nodes from the sink. With this energy value, CR analyses and sorts the most appropriate radio for the given geographical area. With the sensing factors and SN's residual energy consumption into considerations, CR analyses and sorts the most suitable radio from the sorted radio list {R1, R2, R3}{R3, R1, R2} and chooses a best radio (R1) for the deployed area as shown in below figure 4.

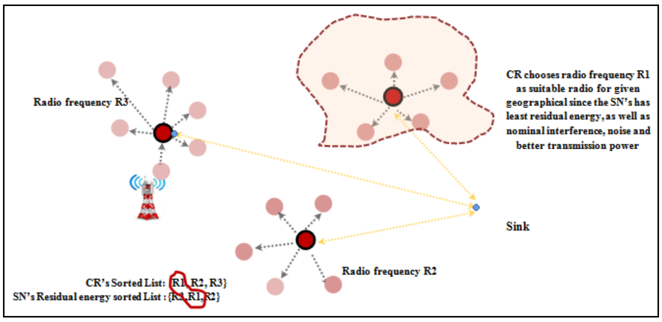

Fig. 4. CR node selects optimal radio access network within geographical area

Thus, radio R1 is selected as the best and most suitable radio for the given geographical area based on CR's frequency sensing factors and the residual energy of each SN's within the sensed area. By taking all these factors into consideration, CR prioritizes and selects the most suitable radio for effective data collection where, the true data collected is assumed to be equivalent to the data collected through wired medium (i. e. false negative is high rather than false positive). Therefore, spectrum sensing and probability of switching between radios is achieved.

TABLE. 1. Notations used in CoRHAN

T_{power}	Transmission power of radio
I_f	Interference caused by other radio nodes
N_0	Noise level of a radio
E_{res}	Residual energy (or) also called as remaining energy
CR	Cognitive radio
SN	Sensor node
R1 R2 R3	Radio frequencies indicating Radio 1, Radio 2, Radio 3

C. *CoRHAN – Flow and Mathematical Analysis*

i. *CoRHAN-Flow Model*

CoRHAN flow model is shown in below figure 5.

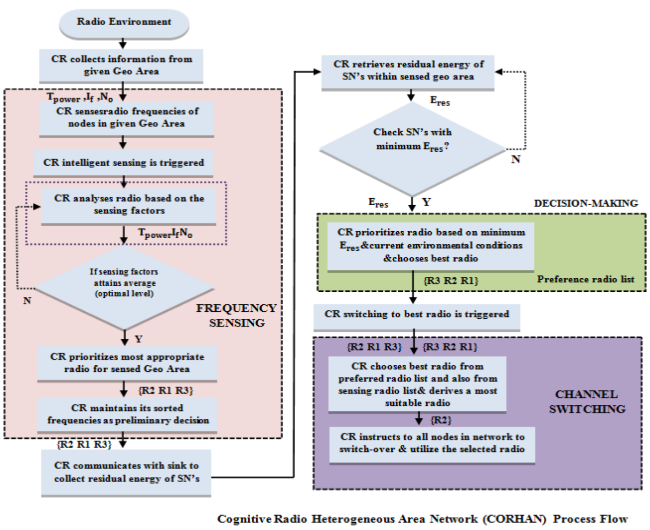

Fig. 5. Flow chart of CoRHAN Process Flow

ii. *CoRHAN-Mathematical Analysis*

Consider a scenario of wireless heterogeneous network where different sensor nodes have different radio techniques. In our scenario, we've randomly deployed cognitive radio (which is a software enabled radio) in the given geographical area which collects data from the sensor nodes. CR node scans and makes an analysis of each radio node's interference, noise and transmission power and takes a preliminary decision to switch over. By this, CR retrieves the interference, transmission power and noise factors from the surrounding nodes and prioritizes the most appropriate and suitable radio for particular geographical area based on the above sensing factors. With this decision alone, CR can't take a decision to switch towards another radio node. So, it sends a request to sink to collect residual energy of each sensor node that belongs to particular geographical area. When CR retrieves the residual energy of sensor nodes in the given geo area, CR prioritizes the radio which consumes minimum residual energy (E_{res}) and also takes the criteria that is specific to current environmental condition and takes decision to select the radio which is maintained under preference radio list. With the sensing factors and SN's residual energy consumption into considerations, CR analyses and sorts the most suitable radio from the sorted radio list as well as from the preferred radio list for the deployed area.

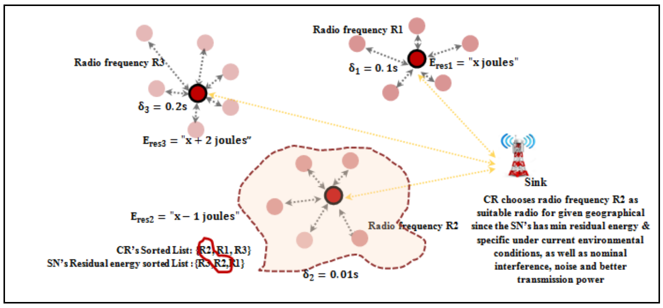

Fig. 6. CR node selects optimal radio access network within small geographical area

CR chooses the radio that consumes minimum amount of residual energy (remaining energy after broadcasting or receiving, etc., and also criteria that are very specific to current environmental conditions are prioritized under preference sorted list. Consider the minimum residual energy consumed by Radio1minimum E_{res1} be 'x' joules, minimum residual energy of radio 2 be Minimum $E_{res2} =$ "$x - 1$"joules and radio 3 remaining energy include minimum$E_{res3} =$ "$x + 2$" joules. CR selection of radio is not only based on minimum residual energy of sensor nodes but also the other current environmental factors like delay taken by the radio to transmit a data. Let us assume the time taken to transmit a data (i. e.) delay caused by radio 1 be $\delta_1 = 0.1s$ and delay of radio 2 be $\delta_2 = 0.01s$ and radio 3 delay include $\delta_3 = 0.2s$. Even though the R3 has minimum residual energy, the delay caused (time taken by the radio to transmit a data)is greater than other two radios (R3>R1&R2), therefore CR prioritizes radio based on minimum residual energy and minimum delay in transmitting a data, and selects the most suitable radio(R2) for the given geographical area. (i. e. Since R2 has minimum residual energy of "$x - 1$ joules" and also minimum delay of $\delta_2 = 0.01s$ for effective data collection by the CR).

Since our scenario is the combination of a Cognitive radio (CR) and heterogeneous sensor networks (WSN), sensor node's residual energy is taken into consideration for monitoring the activity of the sensor nodes. CR communicates with the sink to request for residual energy of sensor nodes within its sensed geographical area. Sink gives the individual residual energy information directly from each node. E_{res} shows the residual energy of sensor nodes of different regions in the network. Using this information, CR can decide whether the SN can be used effectively to collect true data. The reason for collecting individual sensor node's residual energy helps us in giving the constant updates of node's present energy (i. e. after transmitting and receiving) and also enables prolonged network lifetime of the sensor nodes.

Kruskal algorithm constructs Minimum Spanning Tree (MST) where the algorithm finds an edge of least possible weight that connects any two trees in forest.

Steps for constructing MST using Kruskal Algorithm:

Step 1: Sort all the edges in non-decreasing order of their weights

Step 2: Pick the smallest edge, check if it forms a cycle with spanning tree formed so far. If cycle is not formed, include their edge. Else, discard it.

Step 3: Repeat step (2) until there are (V-1) edges in the spanning tree.

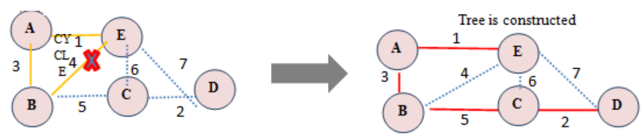

Fig. 7. MST constructed using Kruskal algorithm

Application of Kruskal Algorithm in CoRHAN:

There are different types of Cognitive Radio, like its conventional method such as energy detection method, cooperative sensing method etc. Incorporating intelligence to the CR device for optimal sensing and analysis as the environment in which this CR id deployed initiates communication between a single CR node and set of non-CR based Sensor Nodes where these sensor nodes have different radio parameters by itself. A Minimum Spanning Tree (MST) Protocol gives a tree structure on how these radios are groomed into a particular radio conditions. Instead of scanning in a large scale, we will have what is called a tree structure of high value to a low value tree being constructed between node with top transmit power to node with low transmit power. We add certain parameters in between like for example, node's residual energy, its current coverage area, its storage capacity, interference, noise etc. Based on which we formulate a tree structure, so the scanner, i. e. the CR scanner or CR sensing mechanism will use the tree constructed to find out which are all the nearest values possible instead of scanning from 0 to a continuous pattern of appropriate nearest value. Thereby, educating the CR with high and the low pattern available in a given small geographical area. Within the high and low limits, CR sensing mechanism decides to find out the most appropriate and optimal radio access network with efficient spectrum utilization to be used for data transmission. MST helps to make quicker selection reducing delay in long run as the tree is not constructed in a large, it's a very minimum spanning tree so we can take a least path to find out the best solution possible. A MST technique is used to solve the large complex problem which is broken into a multiple simple problems. Each multiple simple problems are analyzed separately and taken an average and mean value and consider which would be the best path or best method to be utilized currently.

CR prioritizes the radio which consumes minimum residual energy (E_{res}) and also takes the criteria that is specific to current environmental condition and takes decision to select the radio which is maintained under preference radio list. For example, list of radio nodes obtained $\{N_1, N_3, N_6, N_2, N_5, N_4\}$ by the CR and their residual energy is $\{E_{res1} = 4000J, \quad E_{res3} = 10000J, \quad E_{res6} = 2000J, E_{res2} = 8000J, E_{res5} = 7000J, E_{res4} = 6000J$

Consider the below graph,

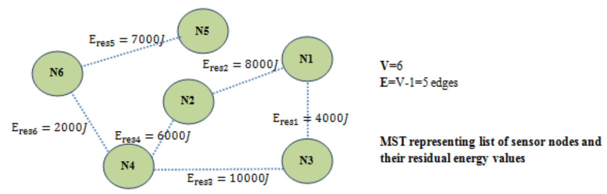

Fig. 8. MST representing list of sensor nodes and their residual energy

This graph contains 6 vertices and 6 edges. So, minimum spanning tree formed will be having (6-1) edges (i. e. 5 edges). Applying Kruskal algorithm to the above scenario,

Step1: Sort all the edges (residual energy) in decreasing order of their weights.

Table 2: List of sensor nodes representing its residual energy in descending order

Nodes (N)	E_{res}(Joules)	Source	Destination
N_6	2000	N6	N4
N_1	4000	N1	N3
N_4	6000	N4	N2
N_5	7000	N5	N6
N_2	8000	N2	N1
N_3	10000	N3	N4

Step2: Pick the smallest edge, check if it forms a cycle with spanning tree formed so far. If cycle is not formed, include their edge. Else, discard it.

Pick edge N3-N4: Including this edge results in a cycle, discard it

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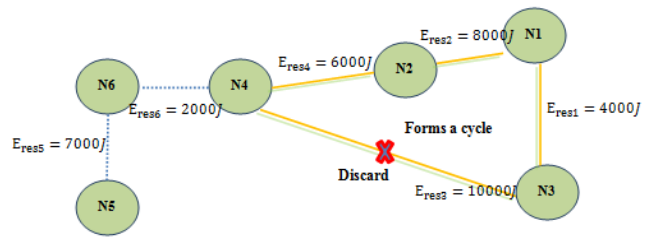

Fig/9. Step 2 in MST to pick the smallest edge in CoRHAN

Step3: Repeat step 2 until there are (V-1) edges found in the tree. Replacing Step (3) the graph obtained is,

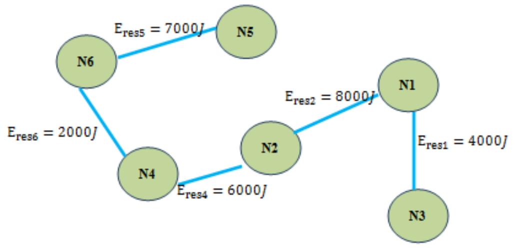

Figure 10: Step 3 with constructed MST in CoRHAN

3. Simulation and Experimental Analysis

In this section, a simple CoRHAN network is simulated using self-written simulator in MATLAB. CoRHAN network consisting of heterogeneous wireless sensor nodes, CR enabled node (node is assumed to have cognitive radio enabled transceivers) and a sink is considered. In our experiments, nodes were randomly deployed in a 500 m X 500 m area. To diversify and analyze the experimental results for various scenarios, we considered dense and scattered deployment of heterogeneous wireless sensor node (HWSN) deployment across the geographical area. We randomly generated 10 different deployments of CoRHAN, by varying the number of HWSN from 100 to 500 with a step of 50 and averaged the simulation results. HWSN were formed as groups, each group having 5% to 10% of HWSNs with a single Cognitive radio device deployed per group. HWSNs in each group communicate to its CR device, which further transmits data to sink.

We used the following metrics to evaluate the performance,

a. ***Sensing Time:*** The time taken by the CR device (sense optimal radio access network among the HWSNs in each group) to choose an optimal radio network for reliable data transmission across a network from source to destination. The simulation results are shown in Figure 11.

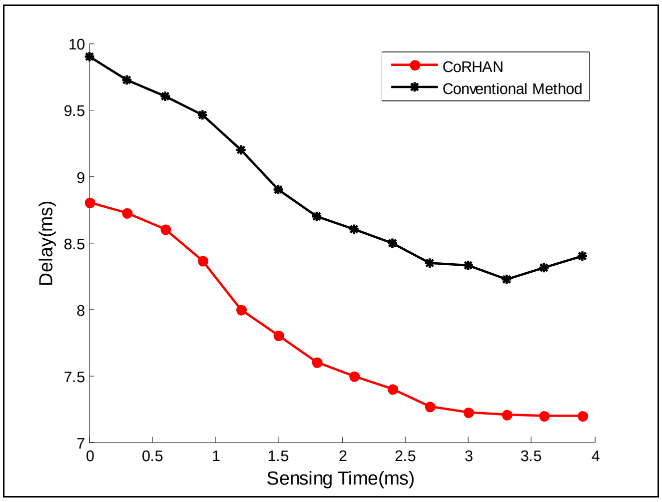

Fig. 11. Delay Vs Sensing Time

From the results, we can see increase in delay during the initial phase of sensing which is caused due to Minimum Spanning Tree (MST) formation for efficient decision making by the CR device for sensing the optimal radio access network. While beyond an optimal sensing the delay degrades and becomes stable, which is due to reusing the MST constraints that were formed during the initial phase rather than reconstructing the tree for decision making, this reduces the delay caused during the sensing phase causing guaranteed reliable data delivery through appropriate selection of optimal radio access network. Results in figure 11 show with optimal sensing, the delay is reduced. This is because during the start-up stage CR device consumes maximum time (delay) for sensing the environmental and HWSNs radio access behavior. As sensing time increases, the Cognitive radio device learns about the HWSN radio access network and becomes capable of deciding with minimal delay as to which radio access network at a particular instant of time is capable and optimal for reliable data transmission. Also CoRHAN can reach the desired delay earlier than conventional methods. After the network becomes dense enough, for example, with more than 250 HWS nodes, CoRHAN's sensing time continues to retain delay that are also close to the ideal results compared to conventional network as shown in figure 11.

b. ***Computational Time:*** Time consumed by the CR device for choosing an reliable radio access network within a group of HWSNs. Experimental analysis was performed to find the computational time consumed by CR device for varied number of HWSNs per group. Results in figure 12(a) shows that computational time becomes stable though the number of HWSN's in each group increases.

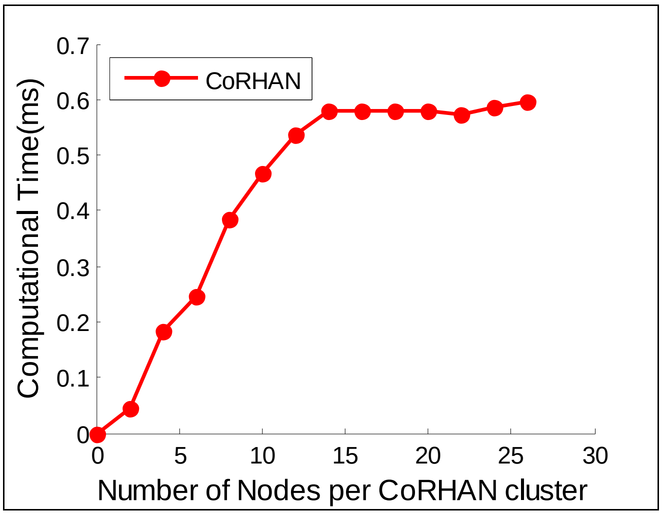

Fig. 12. (a) Group's computational time in CoRHAN

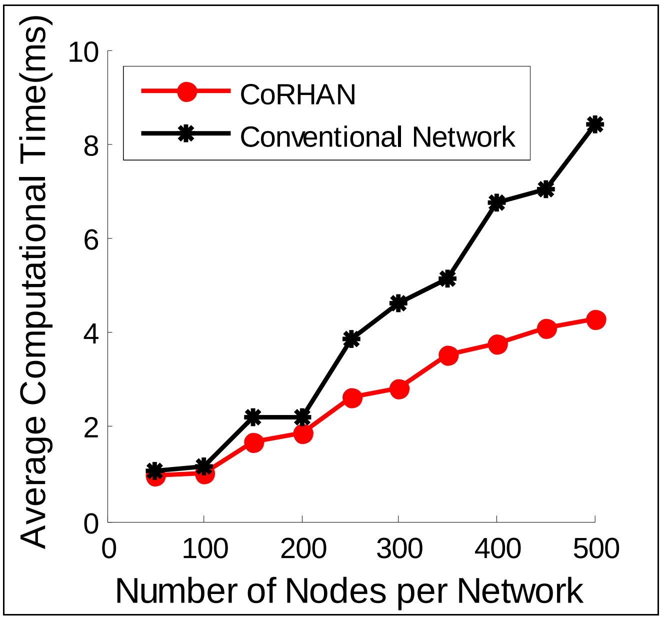

Fig. 12 (b). Overall Networks computational time

Stability in computing even with increase in number of nodes in a group is achieved was due to the intelligence of the CR device in dynamically analyzing the sensed constraints across various nodes and thereby deciding the optimal radio access network for data transmission. Results in figure 12(b) shows the average computational time consumed by the CR devices in selecting the optimal radio access network for data transmission in CoRHAN against the computational time consumed for radio access network selection in an conventional network for data transmission. From the results, we could see that computational time in CoRHAN is 10% to 14% faster in decision making when compared to the conventional network.

c. ***Spectrum Utilization:*** In this section, we conduct experimental simulations to quantify and validate the performance of CoRHAN in spectrum utilization. We start by examining the appropriateness of CR device's sensing capability in CoRHAN. We randomly place a number of primary and secondary users in a given area (10x10), consider a group in CoRHAN. Each primary user randomly selects one channel to utilize from a pool of channels (e. g. 10 channels). Given the location and channel selection of primary users, each secondary user n adjusts it's transmit power (and hence interference range) on each channel m to avoid interference with primary users. Channel availability, reward and interference constraints are derived. By default, we assume that there are 10 channels, 20 primary users and 10 secondary users. We study the statistical performance of spectrum utilization in terms of the average system utility over 500 deployments.

Impact of the Number of Primary Users:
We start by quantifying the performance of sensing mechanism of CR device under different configurations of primary user deployment. Note that the configuration of primary users determines channel availability, reward and interference constraints seen by secondary users. In the simulated system, increasing the number of primary users would expand the primary protection area, and force affected secondary users to reduce their power. The impact is two-fold. First, the number of available channels, and channel reward at secondary users are reduced, degrading spectrum utilization. Second, the interference among secondary users decreases, improving the possibility of spectrum reuse by multiple secondary users.

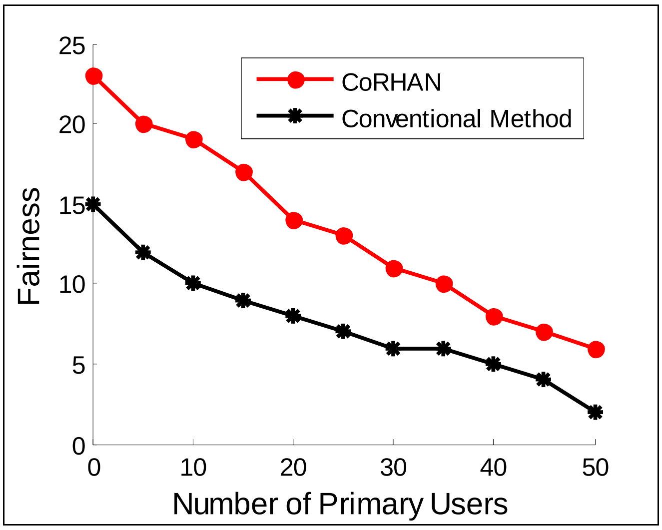

Fig. 13. (a) Spectrum utilization with varying number of Primary Users

The final impact on system utility depends on the tradeoff between the two, which in turn depends on the settings of channel reward and interference constraints. Figure 13(a) shows that in the current setting, increasing the number of primary users would degrade all three utilities. Overall, results in Figure 13(a) shows that CoRHAN outperforms Conventional method in terms of improvement in fairness by

7% to 9% since they depend heavily on poor user's performance. A "poor" user's available channels diminish quickly due to its small available channel list and large number of interference constraints. This limits the system utility. Figure 13(a) shows more accurate characterization of the primary user's contribution to system utility.

Impact of the Number of Secondary Users:
We examine the performance of CR device's sensing capability in CoRHAN for different configurations of secondary user deployment. We start by varying the number of secondary users in the area, i. e. user density. Increasing density clearly creates additional interference constraints. Hence, Figure 13(b) shows degradation as the number of secondary users increases.

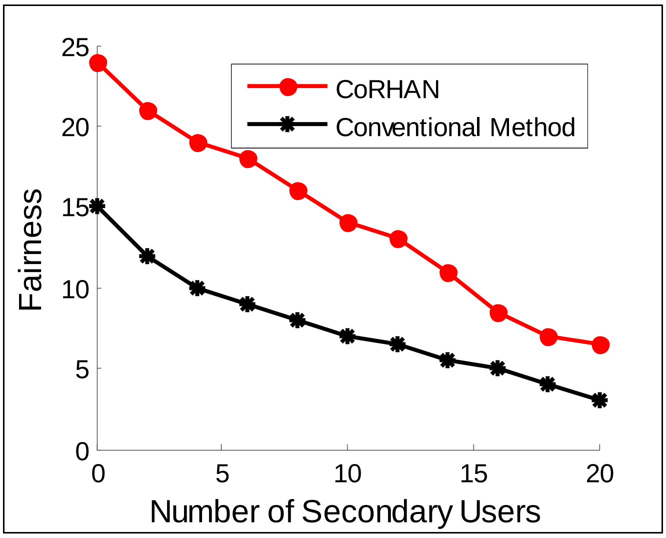

Fig. 13. (b) Spectrum utilization with varying number of Secondary Users

While the performance of CoRHAN proves to be better compared to conventional method with an improvement of 8% to 9% as shown in figure 13.

d. ***Average Probability of Error:*** The bit error rate is affected by transmission channel noise, interference, distortion and fading at the receiver side i. e., the sink. The performance of CoRHAN was evaluated in terms of varying channel conditions and Signal to interference noise ratio (SINR) ranging between-15 dB to 15 dB. Verification with experimental set-up of Data Transmission rate to be 1Mbps with number of bits per frame (F) as 40 bits and number of information bits per frame to be 32 bits, the results were analyzed. Figure 14 shows the average probability of error for different values of SINR (dB) alleged by CR device in CoRHAN. The result shows that with improvement in channel condition, the average bit error rate decreases i. e., in all the cases, the average probability of error decreases monotonically with SINR.

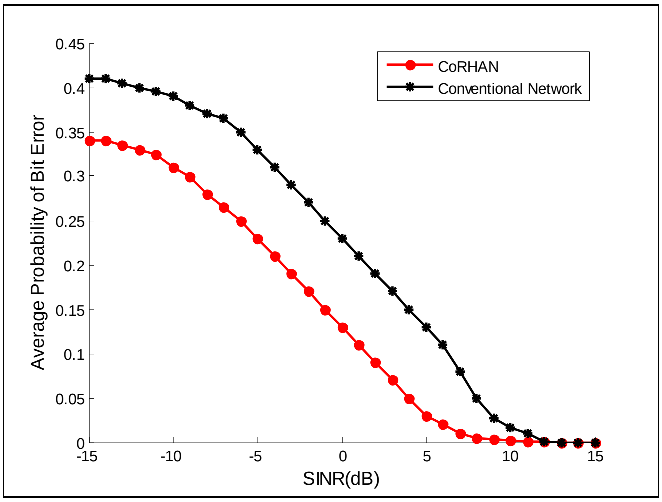

Fig. 14. Average Probability of error in CoRHAN and Conventional Network

4. Conclusion

Proposed spectrum sensing technique performed by the Cognitive Radio enabled node in CoRHAN environment enhances the performance under fading and shadowing conditions improving the reliability of true positive data transmission rate. CoRHAN model defined in this paper drastically reduces computational complexity and delay during radio access network selection phase, optimizing spectrum utilization and fairness by introducing CR enabled device among HWSNs. Our experimental results and analysis shows that the heterogeneity factors affecting the CoRHAN were dealt with real factors causing the change management. Future Wireless sensor networks with CR device enabled networks would certainly demand a faster and efficient spectrum sensing and utilization protocol updates, so as to provide a ubiquitous connectivity with higher data delivery ratio.

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Bibliography

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