Efficient Energy Consumption Approach in Cognitive Radio Network using Dynamic Channel Access.

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Abstract— In these modern days wireless communication has been used extensively in all different fields of domestic and industrial applications. There are two major problems faced by cognitive radio network namely, limited spectrum and inefficient spectrum allocation policies. Therefore, it is very much important to utilize available wireless spectrum efficiently without affecting the existing performance of the system. The enormous growth in rapid development of wireless networking technology demands more spectral bands. But spectrum allocation policies have resulted in improper spectrum allocation and inefficient use of spectrum. In case of license free spectrum, there are lot more devices using the spectrum for one or other applications. This has resulted in increased traffic and congestion in unlicensed spectrum. There will be lot of interference and sensor nodes have to contend for getting the channel. This congestion will result into increased packet loss and in turn loss of sensor energy. The battery life continuous to decrease and the sensor node will shut down quickly. The increased packet loss also results in inefficient use of unlicensed spectrum. This project work concentrates on increasing the energy efficiency by decreasing the wastage of energy involved in packet loss. The idea is to dynamically access licensed channel whenever it is free. This will ensure reduced congestion in unlicensed spectrum, drop in packet loss and in turn reducing the energy wastage. Decide when to sense and switch between unlicensed and licensed channel. This will lead decrease in energy wastage and increases the life-time of sensor node.

Keywords—Spectrum allocation, Traffic congestion, Energy wastage, Energy efficiency and Cognitive radio network (CRN).

I. INTRODUCTION

These days wireless communication has been used extensively in all different field right from domestic to industrial applications. There are two major problems faced by wireless networks, namely, limited spectrum and inefficient spectrum allocation policies. There has been lot of development in the field data transfer rate using different technologies; but there is a limitation in the speed at which data can be transferred. This limitation is inherent as the time allocated to represent a symbol or a bit cannot be zero. It can be reduced to very smaller extent but can never be made zero. Therefore it is very much important to utilize available wireless spectrum efficiently without affecting the existing performance of the system.

There is continuous development in wireless networking technology the spectrum available is getting insufficient and the improper spectrum allocation policies have resulted in a pool of unused spectrum. One of the major wastage found in existing CRNs. The service providers buy the part of spectrum or bandwidth to operate in a particular region. This bandwidth will be used as per the number of customers in that cellular network. For example, consider that there are three cellular network operators namely, A, B and C. Assume that the services given by B is excellent which has resulted in more number of customer to B. Also assume that C has moderate customers and A has less number of customers. As number of users in a particular network will increase, the spectrum will be busy most of the time. If there are less number of users, as in case of 'A', the spectrum will be free most of the time. During peak hours, users of network B may not get channel to complete their calls because of no free channel during that time. But A might be having many free channels, which cannot be used by users of network B. This results into big wastage of precious spectrum and also the waste of customer time.

Therefore we require effective and efficient schemes to utilize the available spectrum. One such way to overcome the problem is the usage of cognitive radio networks which follow dynamic spectrum allocation. The entire wireless network constitutes of several cells. Every cell is considered to serve two requests one is initial access request and the other is hand-off request. Once communication is established, it is not necessary that the user has to stay at one place while communicating. When any user changes his/her cell from one to another he/she enters a new cell leaving the old; such transfer is called inter cellular hand-off. When the user is leaving the old cell the new cell provides it some part of the spectrum for communication. If the new cell does not have any free available spectrum the call is terminated.

II. RELATED WORK

The increase in the demand for wireless communication has made the technologists and developers to think of the wireless spectrum. It is the fact that, wireless spectrum is very much limited and also whole spectrum cannot be used for communication. There are many applications of wireless technologies in social, industrial and agricultural fields. There are wide variety of researches going in this filed to increase the rate of data transmission and to increase the spectral efficiency. This chapter discusses the work that has been carried out to increase the spectral efficiency.

In present traditional method, the spectrum allocation policy is static. Once the spectrum is allocated to certain application, such has TV or radio broadcasting; it cannot be used for any other purpose. The available wireless band is separated into two types; licensed and unlicensed bands. Licensed band will be given to particular user or group that cannot be used by any other persons or group. But most of the time this licensed spectrum will not be occupied fully, resulting in wastage of valuable bandwidth. This can be best utilized by making use of dynamic spectrum allocation policy.[1] In a paper titled “Exploiting Mobile Crowd sourcing for Pervasive Cloud Services: Challenges and Solutions” the authors have worked on the implementation of mobile crowd sourcing. The architecture used in this method cannot be applied on cognitive radio networks. This method will not address the issues with energy consumption during increased packet loss rate. [2] In a paper titled “Cooperative Spectrum Access towards Secure Information Transfer for CRNs” the authors have discussed the security of primary users while giving the access to the secondary users of the CRNs. In this method, the primary user will be involved in cooperating between two secondary users. As per the CRN, the methodology should not affect the primary user activities on its network. [3] This paper mention the problems of multimedia routing in CRN by proposing a cluster-based solution. Clusteringis exploited to manage dynamic spectrum access and QoS routing for multimedia CRSNs. This method will cluster the available spectrum based on the transmission power requirement. When adopted this method for CR networks, there will still be unused spectrum because of the clustering. Whenever there better channels in other clusters, it cannot be used even though the CR user has increased packet loss in its cluster. [4] In a paper titled “Data Gathering Optimization by Dynamic Sensing and Routing in Rechargeable Sensor Networks” the authors have used dynamic sensing and routing problems to balance the energy. There are several advantages in fixed allocation; the important one is no interference for the primary user from secondary users or unlicensed users. But it increases the waste of spectral bandwidth. There have been many studies which have proven inefficient use of spectral bandwidth [5][6]. As per the study in [7] most of the licensed bands are localized to the area and are not used throughout the national and international level. This leads to reduced use of that band. And these licensed bands are very much suited for communication giving high bit rate and low error rate.

III. PROPOSED WORK

In this chapter system design has been discussed assuming group of SNs given by N = {sn1, sn2, sn3, …., Snn}. These N nodes are spread over the cognitive area as shown in figure 1. The total cognitive area is divided into number of clusters as shown in figure 1. Every cluster will have a cluster head through which all the data of sensor nodes has to be forwarded to sink node. There is one sink node in area of interest considered. Channel Head is short called as CH, Cluster Member is called as CM and primary user in short called as PU.

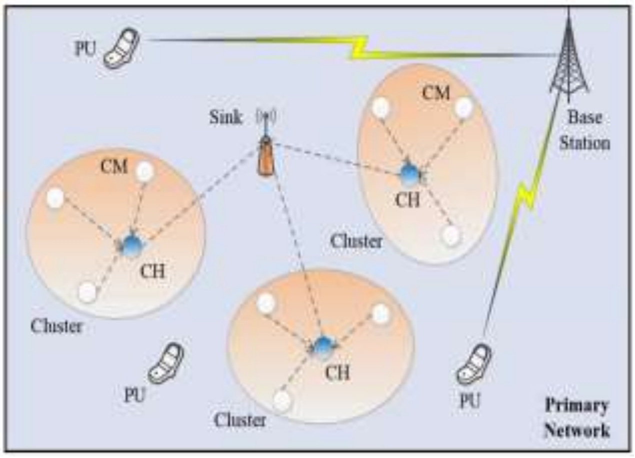

Figure 1: Architecture of cognitive radio sensor network

As per the application necessity, every SN continuously senses surrounding atmosphere and regularly sends the messages to sink node. The time duration between sensing the data to forwarding the same to the sink node will be categorised into different data periods. The data periods are the datasensing, data-transmission, and sleeping durations. All the sensor nodes are grouped into number of clusters given by L=_L1, L2, …. Lm}.Each and every sensor node will be a member of one or other cluster and will send the data to the sink node through the particular cluster head.

The significant objective of project work is to save the energy consumed by the sensor nodes of the cognitive radio network. The energy consumed by the sensor nodes is divided into four parts.

First part is the energy consumed for spectrum sensing

Second is energy consumed in spectrum switching

Third is energy consumed in data transmission

Fourth and last part is energy consumed in data reception

Sensor nodes also need energy to configure the radio channel and to switch to new one. Let es be the energy consumed by the sensor nodes to sense the licensed channel and ew be the energy consumed in switching the channel. The energy consumed in data transmission is given by the equation (2),

$$E_{j,t} = (P_j + P_{j,c}) . t_{j,x} \quad ---------- \quad (2)$$

where $t_{j,x}$ is the data transmission time. P_j is the transmission power $P_{j,c}$ is the circuit power at the sensor node j.

Dynamic-Channel-Sensing and Accessing Scheme

Figure 2 shows the time flow of cognitive radio sensor network. As discussed earlier in this chapter, there are 3 important phases, as data sensing, transmission and sleeping. Initially a sensor node undergoes into first phase and sense the environment around it and generates sensed data Aj and sends to the sink node. After properly sending the data generated by the sensor node, it foes into sleep mode to save the energy. The sensor node will be in sleep mode till the beginning of next data period.

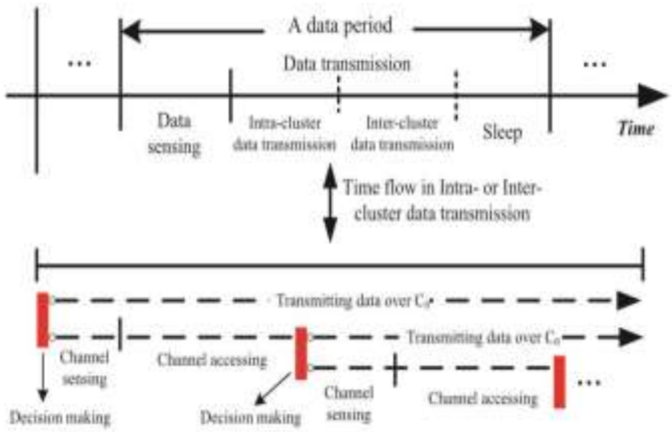

Figure 2: The time flow diagram of CRSN

As the data transmission does not depend on other periods, the efficient data transmission can be given by

$$A = \sum_{s_j \in \mathcal{N}} A_j$$

This efficiency can be achieved by finding better decision to sense channel and accessing the same. There are two problems in data transfer as discussed below

a) In case of intra-cluster data sending, every cluster Li needs to take decision whether to sense the channel or not. The channel sensing has to be initiated only when the packet loss rate is high on channel C0. When a Li takes decision to sense access the licensed channel, the channel sensing and accessing methodology has to be formulated to minimize the energy consumption. The energy consumption will be minimized using the probabilistic way.

b) In inter-cluster data transmission, the same method has previous needs to be adopted to reduce the energy consumption. One of the important thing in inter0cluster data transmission is, the cluster head can adjust the power as per the requirement. So, here power level and the accessing scheme needs to be considered together to reduce the wastage of energy.

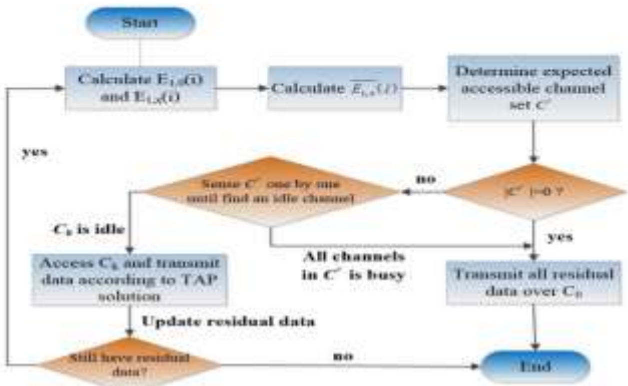

Figure 3: Procedures of the dynamic channel sensing and accessing scheme

The process of dynamic channel sensing and accessing has been shown in figure 3. Every cluster Li decides when to sense a licensed channel for sending intra-cluster data as per the packet loss rate of the default channel C0. Consider there are some channels C′ belongs to licensed channels in cluster Li those can be whenever packet loss in C0 is high. Here important thing is to find that channel which takes less energy for sending the sensed data in intra-cluster.

As shown in figure 3, initially the algorithm calculates the energy consumption Li by using the default channel C0. Later energy consumption of Li will be calculated by using the licensed channel Cx. Let E1,0(i) and E1,x(i) be energy consumptions of Li by C0 and Cx respectively. Once the energy consumption over all licensed channels in Li is calculated, next step is to find set C′ of better channels to send the data. If there are no channels in set C′ then all the data will be sent over the default channel C0 itself. In this case no channel switching will be done unnecessarily which will reduce the wastage of energy in channel switching compared to other methods. If set C′ is not empty then channels in C′ will be sensed one by one till an idle channel is found. If all the channels in C′ are busy, then as usual the data will be sent over the default channel C0.

Proposed work algorithm:

The algorithm runs on the sensor nodes which are responsible to take the decision of channel switching. The sensor nodes themselves start the process of channels switching. Mainly this process involves two parts; first one is channel selection and the second is channels switching. The detailed steps in the algorithm have been given below:

Step1: Take a cluster Li where i>0 and i<m m being the number of clusters

Step2: Find the energy consumed by intra-cluster data transmission using pre-assigned spectral band.

Step3: For a licensed channel Cx, find the energy consumed over the default channel for intra-cluster data transmission; where x>0 and x<kn. Repeat step 3 for all kn.

Step 4: Find the list of all the channels which can be used in connections with secondary users.

Step 5: Find the expected spectral band set C' according to lower energy requirements, and reorder C' according to increasing order of energy consumption by the channel.
Step 6: kn=1;

while kn<=number of channels in C' do

Sense the knth channel Ckn of C'

if Ckn is idle then

go to step --;

end if

kn=kn+1;

end while

Step 7: if C'=0 and kn > number of channels in C'

Send the remaining intra-cluster/inter-cluster data over the default channel $C0$;

Step 8: else:

Transmit the intra-cluster data over the channel $C\ kn$, and allocate the transmission time $t\ j,kn$ to each sensor node;

Step 9: if Ckn is expired and the intra-cluster data transmission of Li is not completed then

go to step 2;

Step 10: end of for

The above steps give the details of the proposed methodology adopted in this project. One of the very important assumptions that has been made in this project is the processing power SNs. If the SNs do not have the enough processing power, then this algorithm cannot be run to determine the good channel having less packet loss rate. Even though this algorithm is simple, sensor nodes needs to have at least enough processing power and the memory to store the channels' parameters.

IV. RESULT AND DISCUSSIONS

As per the implementation details, the tests are done using the NS2 and the result obtained so are shown using the various graphs. Figure 4 shows the first screenshot taken while executing the tcl script written towards implementation of the project methodology. The tcl script will be run on NS2 installed on Ubuntu 16.04 operating system. As shown in the figure 5, initially all the network parameters such as data transmission power level of sensor nodes, maximum power level of cluster head, power efficiency of RF amplifier, etc. will be set as decided by the user. Results of the proposed methodology can be obtained by using different set of parameters to check the advantage of the proposed methodology.

After entering the all required parameters, algorithm of this methodology will select two different bandwidths; one for licensed channels and the other for the license-free channels. Both bandwidths will be separated enough to avoid any interference. Later based on number of sensor nodes considered, they are grouped into different clusters as per the neighbour nodes and the energy associated with the sensor nodes. This process of grouping the sensor nodes has been shown in figure 5. Here there are six clusters having enough sensor nodes called the cluster member. Cluster head, sink node can also be observed in the screenshot of the figure 4.

Once the sensor nodes are grouped into different clusters, they will be allowed to communicate within or outside the clusters taking help of cluster head.

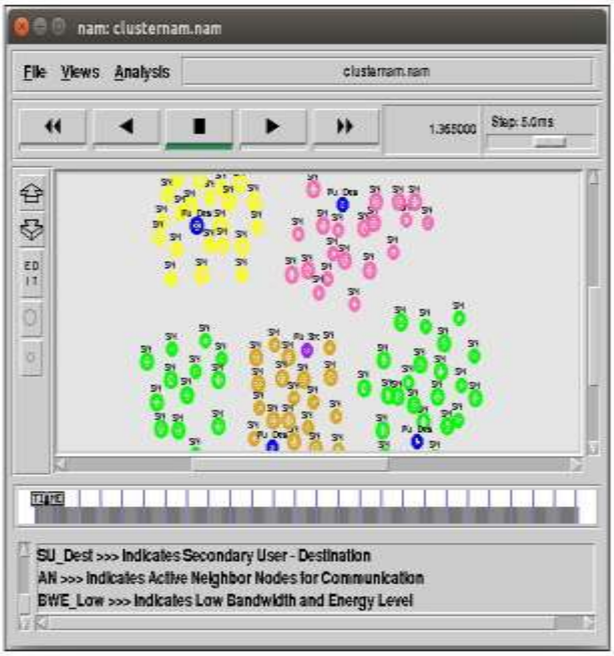

Figure 4 : Screenshot showing the clustering of the sensor nodes

If data has to be transferred within cluster, i.e. intra-cluster data transmission will be done directly by the cluster member itself. Whenever the data will be transferred to the sink node, cluster member will take help of cluster head. Any data outside the cluster will be transferred only through the cluster head. This has been shown in screenshot figure 5.

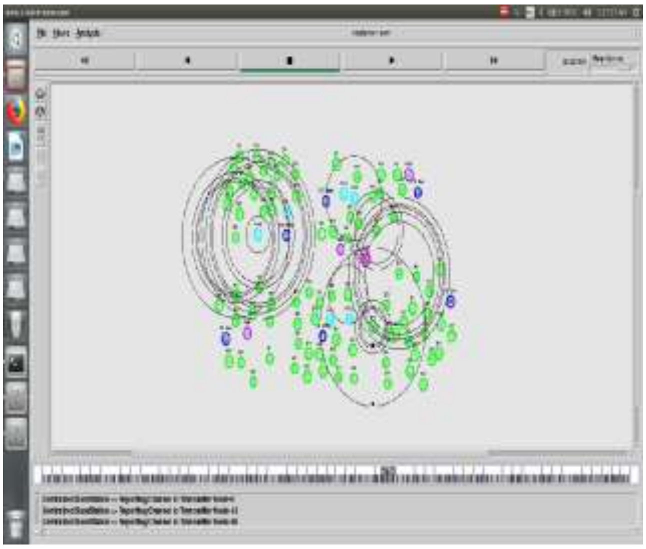

Figure 5 : Inter-cluster and intra-cluster data transmission.

Whenever packet loss is high on default channel, the secondary user senses the licensed band and if any channels are idle, it will access that and switch to that channel to transmit the remaining data. In case of existing methods, the channels will not be arranged as per their energy consumption, they will be accessed as per average energy consumptions of any cluster Li. As expected, this may result in getting a channel which is worse than the previous unlicensed band. Whereas in proposed methodology this will be overcome by listing the channels based on their energy level. Figure 6, shows graph using which one can compare the energy consumption in proposed methodology and the traditional methodology. The graph of energy consumption versus channel availability duration (CAD) has been plot using the values generated out of the proposed system and the existing system.

Referring to the graph of figure 6, energy consumption is lesser in the method used in this project than existing methodologies. The traditional methods use the average energy of the channel to find the energy consumption during the data transfer. The graph of figure 6 has been drawn considering both the situations of traditional methodology and the proposed methodology.

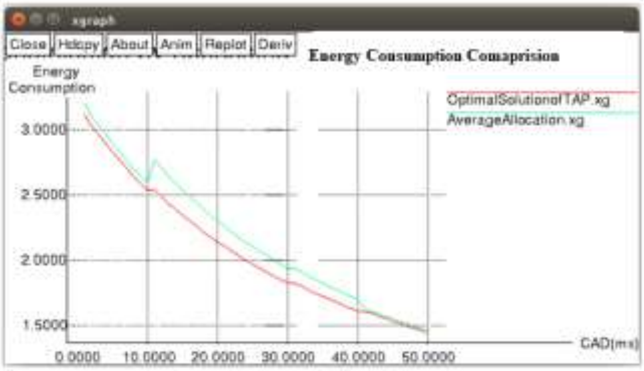

Figure 6: Comparison of energy consumption in average and optimal allocation scheme

Figure 6 show the energy consumption that occurs during the channel sensing. The traditional methods make often channel sensing because of repetitive channel switching. The repetitive channel switching is the result of wrong channel selection. All this leads to unnecessary wastage of energy in traditional methods. As per the proposed methodology, the channel sensing rate is less as the channel switching frequency is less. So the energy is saved in proposed methodology than in traditional methods.

Selecting good channel with good signal strength and reduced packet loss will also reduces the energy requirements of the sensor nodes. Low processing power is required to carry the computations, resulting in low energy requirements. Therefore the proposed methodology has advantage of energy efficiency over existing methodologies

V. CONCLUSIONS

The proposed project work has two important objectives of which first is to sense the channel whenever it is idle and second is to select the channel with least energy consumption. There should not be wastage of energy in sensing and switching the free channels. This has been achieved by arranging all the channels with their energy consumption in decreasing order. Instead of sensing all the primary channels, only those channels are sensed which are arranged in list and whose energy requirement is lesser than the current channel used by the sensor nodes. By this method, the sensor nodes can save the energy which will be wasted in sensing all the channels. The sensor nodes also blocked to access those channels whose energy requirement is more than the energy requirement of channel in use. This will reduce unnecessary wastage of energy in degraded channel in use.

Cognitive user will start the process of switching the channel, only when the packet loss in the current channel is more than the predetermined value. When the cognitive user gets a better channel than the current channel then only it is allowed to switch to another channel of better quality. This will ensure wastage of energy because of chances in getting switched to lower quality channel. The results of proposed methodology have shown that, this method will increase the energy efficiency by reducing the wastage of energy incurred in data transfer through the noisy channel. The algorithm gives better performance without high level of computations. This is greater advantage in using the proposed methodology in all the devices having less computation power and memory storage.

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