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Theoretical Channel allocation for SDRs in Smart Grid neighbourhood area network

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***Abstract*— Smart Grid (SG) is an intelligent power supply system. It is a new emerging concept to increase the features of local grids. Till now local grids were only providing electricity; but now they will also take part in exchanging information. Data as well as power communication can take place between a Smart Home (SH) and Smart Grid (SG). Real time data can be sent from SH to SG through neighborhood area network (NAN). There can be different wireless medium for data transmission in NAN. Our wireless medium is based on Cognitive Radio (CR) technology which is also called as Intelligent Software Defined Radios (SDRs) network. Cognitive radio network works in unused spectrum that is the frequency available at the time of need. In this paper, we are presenting a theoretical channel selection method for SG neighborhood area network. Our work is novel in terms of single hop communication and SDRs, which have not been explored much. In SG, research focus is on wireless sensors network and multihop communication. But we are supporting direct communication between smart home and smart grid; that will increase delivery ratio and throughput and decrease end to end latency. In future, we will be providing simulation of this model and enhancing it for secure communication**

***Keywords*— cognitive radio network; software defined radios; smart grid; channel allocation; routing protocol; NAN**

INTRODUCTION

Smart Grid (SG) is a major enhancement over the local power supply grid system. It is an intelligent power grid system. It not only provides electricity to the users, but also performs various other tasks. It can sense its own working conditions as well as monitors the outside environment. Smart Meter enabled home can communicate with Smart Grid. And can provide real time data to the SG. Smart grid differs from the conventional grid in bidirectional communication and automatic mode of operation. Moreover a secure path is required for to and fro of data from Smart grid.

A Smart grid consists of three main networks: - Home Area Network (HAN), Neighborhood Area Network (NAN) and Wide area network (WAN). HAN is the network of devices inside a home which makes it a smart working home. NAN is the communication between the smart homes and the Smart Grid. NAN communication can be wired or wireless, but for modern and efficient working, wireless concept should be used. WAN is data exchange between Smart Grid with the outside world. These networks differ by the size and sensitivity of the data. Data can be simple text or image and graphs based text. Different types of data can be communicated through separate channels based on their transmission capacity. We have used this concept for deriving a routing protocol for NAN in Smart Grid. It is expensive and difficult to have dedicated spectrum for communication in smart grid networks. In alternative choice, we have the answer in cognitive radio based communication for smart grid infrastructure.

Cognitive Radio wireless technology provides dynamic communication method between two entities. In Smart Grid's NAN one entity may be users and another entity may be an intelligent grid. A network needs a routing protocol to reach from one entity to another. In a cognitive radio based Smart Grid; there can be two types of routing protocols. One for cognitive radio based sensor networks and another for general cognitive radio networks. A lot of research has been done in cognitive radio based sensor networks. Our focus area is general cognitive radio networks.

The rest of the paper is structured as follows. The next section reviews the related works and briefly describes some of the routing techniques in SG using cognitive radio networks. In Section III we describe the motivation behind this work. Section IV contains the proposed model. In Section V we evaluate the proposed model with an example. Section V contains the conclusion and future work.

II. LITERARTURE SURVEY

RPL [1] is an IETF standardized protocol for Smart Grid communication. Further RPL has been enhanced to CORPL [2] for cognitive radio environment. RPL is based on graphs creation, which is used to maintain the network information. RPL works on distance-vector and source routing phenomenon. It uses an objective function to assign a rank to each client node. Here the main concern is selection of a client node and assigning a rank to it. In cognitive radio networks, primary users (PUs) who are the licensed users should not face any difficulty in communication due to the secondary users (SUs). CORPL did the modifications as per the cognitive radio networks working in the RPL. In RPL, a significant amount of time was elapsing in channel sensing. At the time of channel sensing, cognitive radio nodes were not doing data forwarding; hence affecting the overall performance of the protocol. CORPL reduces this affecting factor by gathering sensed information at particular interval of time. The main drawback of CORPL is that in this each participating node will find out the route to reach Smart Grid and also stores this route even if this node has nothing to send. The work [3] and [4] have shown the concept of RPL for advanced meter applications of Smart Grid.

The above discussed protocols are multi-hop supported mechanism. While SG networks focuses on single-hop. Our work is for single-hop communication and there is no overhead of creation and maintenance of DAGs as in above protocols.

In work [5], authors have studied cognitive radio as communication medium for SG, they have proposed two types of radios; stand-alone and secondary radio for CR networks. Their focus is on to develop an effective spectrum sensing method. Similarly in work [6], another spectrum sensing process is proposed which is based on both licensed and unlicensed spectrum bands. They have studied two types of spectrum sensing: periodic and on-demand. Deng et al. in [7] balance the real time power demand and also perform scheduling for the peak load requirement, by using CR technology in SG environment. In spectrum sensing mechanism, the main challenge is to protect the primary user.

In work [8], authors are protecting the primary users as well as fulfilling the requirements of secondary users. They have enhanced RPL to improve efficiency and reliability of cognitive radio enabled SG networks.

Wang et al. [9] provide the solution for multimedia data communication over cognitive radio networks for SG applications. Several papers [3, 4, 10] have studied NAN communication as having mesh like topology, due to the presence of smart homes and gateways to transmit data. In NAN, one of the major challenges is high volume of data and its various variations. Cognitive radio technology supports large-scale data transmission.

Some papers [11, 12, 13] have discussed sensor networks approach for SG environment. These papers have presented solution for communication between smart grid and sensors.

But the sensor nodes in a sensor network are usually resource constrained as they have limited energy, processing and memory. So for better approach we can have cognitive radio networks.

III. MOTIVATION

A modern transmission grid having SG system supports two types of transmission, one is the flow of electricity and other is data flow. Cognitive radio networks are wireless medium of data transmission from smart homes to SG in NAN. In SG the focus is on single hop direct communication. Cognitive radio transmission is based on three techniques: - spectrum sensing, channel selection and data transfer. Our aim is to develop an effective channel selection approach in cognitive radio network.

IV. SYSTEM WORKING

In a cognitive radio network there are primary users (PUs) having licensed channels and Secondary Users (SUs) having no licensed allocated channels. Table 1 is representing four primary users with their channels PUc1, PUc2, PUc3 and PUc4. Out of four, one channel is never used, one is used half of its capacity and another two are most frequently used by a primary user.

PU channel	**Usage priority**	**Usage**
PUc1	1	Never
PUc2	2	50%
PUc3	3	Frequently used
PUc4	3	Frequently used

Table1. PU channel usage list.

Each PU has been assigned a priority based on its usage and this represents its availability to be reused. Secondary users base station keep scanning these primary channels and have Table I statistics for further use.

When a secondary user makes a request to base station for allocating a channel, it is placed in a queue. In our proposed model, channel allocation to a secondary user is dependent on the priority of data it carries and its rank in SU queue. Data can be prioritized as shown in Table 2. Lowest the priority, more important is data.

There are three secondary users queue as shown in figure 1. High priority queue (HP) to have secondary users having high priority tasks. Similarly there are medium priority (MP) and low priority (LP) queue.

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Data	Priority Range	Priority
Information asked by SG	1	High
Fault Information without image	1.1	High
Fault Information with image	2	Medium
Routine Information without image	2.1	Medium
Routine Information with image	3	Low

Table2. Several types of SUs Data.

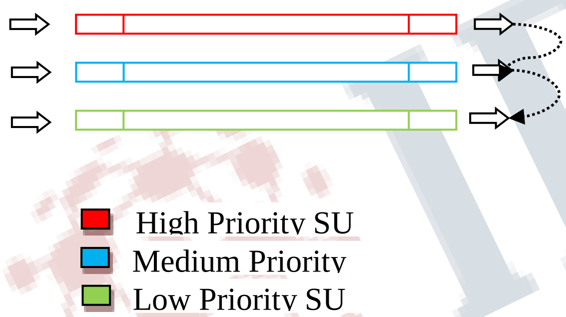

Figure 1. SU Queues.

Secondary user's base station maintains three queue structures. Secondary user base station will place a secondary user in a queue based on its data. BS will first entertain the requests of a high priority (HP) queue members. After HP queue, medium priority (MP) queue candidates request will be completed and then low priority (LP) queue will be emptied. Following sub-sections contains the detail description of our model for SG neighborhood area network.

Cognitive radio networks protocols consists of three parts:-

1. Spectrum Sensing
2. Channel Selection

In our model this part is divided into another three modules:-queue allocation, channel allocation and starvation problem

3. Data Transmission

A. Spectrum Sensing

This phase is to identify the idle channels that can be used by secondary users for data communication. For this we are using energy based channel sensing technique as given in work [14, 15]. Licensed channels will be used by primary users but they are not fully utilized, hence we can use these licensed channels for secondary users when primary users are in inactive state. These unused licensed channels are termed as idle channels, we can have list of these idle channels through spectrum sensing.

B. Channel Selection

This phase is to choose a channel from the available PU's channels. The selected channel will be then used by SU for data transmission to SG. In our scenario, smart home is acting as a SU. When any SU request the base station for channel, BS placed this requested SU in a queue using algorithm 1.

Algorithm 1: Queue allocation to secondary users.

Input: BS accepts SU request.
Output: Requested SU assigns a queue based on its data priority.
Step1: BS checks SU's data priority.
    If priority 1 , goto step 2.
    Else If priority 2 , goto step 3.
    Else If priority 3 , goto step 4.
Step 2: BS Check if HP queue is full.
    IF full, goto step 3.
    Else, add in HP queue, goto step 5.
Step 3: BS Check if MP queue is full.
    IF full, goto step 4.
    Else, add in HP queue, goto step 5.
Step 4: BS Check if LP queue is full.
    IF full, goto step 3.
    Else, add in HP queue, goto step 5.
Step 5: STOP

Each HP, MP and LP queue have a upper bound. A limited number of users could be entered in these queues. If the required queue is full then add the SU at front position of the next priority queue.
BS will be serving these queues using algorithm 2.

Algorithm 2: Channel allocation to secondary user.

Required: SU has been put in a queue
Output: Requested SU allocated a channel for

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communication
Step1: BS checks the queues.
First a High Priority queue is checked.
If HP queue is empty, goto step 2.
Else, goto step 4.
Step 2: BS Check if MP queue is empty.
If empty, goto step 3.
Else, goto step 4
Step 3: BS Check if LP queue is empty.
If empty, wait for any SU request.
Else, goto step 4.
Step 4: Select a SU from the respective queue.
Step 5: Check if any PU channels are free
If yes, goto step 6
Else, goto step9.
Step 6: Select a PU channel based on its usage priority as given in Table 1.
Step 7: Send data on the selected PU channel.
If PU returns for its channel, then goto step8.
Else goto step 10.
Step 8: Free the required PU channel and find another PU channel for transmission. Goto step 6.
Step9: Send the data through wireless radio channel.
Step 10: STOP

Starvation problem:
Starvation problem is when high priority users are having channel allocation and low priority users are waiting. And this waiting could be too long, as high priority users are coming in queue again and again.
To avoid starvation problem between secondary low priority users request, we would have a TimeToWait (TTW) attribute. TTW is assigned to each requester in the queue. If TTW expires then the associated secondary user will be assigned a higher priority.
C. Data Transmission
This is the final phase when data is transferred from one entity to another one. After suitable channel selection, SH will unicast its data to SG.

V. SIMULATION USING AN EXAMPLE

In this section the simulation of the proposed model is shown theoretically with the help of an example. In this model three cases have been considered viz. Best case, Worst case and an Average case.

A. Best Case

In our proposed model the best case will be satisfying following two conditions:-
1. Smart home (acting as a SU) allocated a channel by secondary user BS on its immediate request.
2. PU does not return back on the allocated channel and SU completed its transmission successfully.

This situation may arise when SG is asking for the information from the SH or SH needs to send some routine data to the SG. In best case, SH waiting time will be negligible. Queue are empty, hence secondary user received primary position in the queue and selected for channel allocation immediately. Only time taken for communication from SH to SG will be accounted. Delivery ratio and throughput will be near to 100%.

B. Worst Case

In neighborhood area network communication, the worst scenarios are following:-
1. Unused licensed channels are not available for allocation.
2. HP, MP, and LP queues are full.

In both cases, requested user can wait for free channel or either switch to another wireless transmission medium for data delivery instead of waiting for channel allocation. Delivery ratio and throughput will be affected by the congestion in the medium.

C. Average Case

Let us take an example. The step by step simulation will be as follows:-
Step 1: The source S (SH) wants to transmit some data to the Smart Grid.
Step 2: The node S sends the request to the secondary users BS.
Step 3: BS will analyze the data of S and assign a priority to S based on its information.
Step 4: BS will place the S in a queue based on its priority, either in a HP, MP or LP queue.
Step 5: BS periodically performed channel sensing activity and have list of available unused licensed channels that PUs are not utilizing. BS categorizes these PUs channels on the basis of their usage as shown in Table 1.
Step 6: S has to wait if there are more request in queue before it.
Step 7: On S turn arrival in queue, BS selects a channel from the PUs that is least used and assigned it to S.
Step 8: After channel allocation, S will send data to SG. If PU returns for communication on same channel then S will switch to another free channel and s

tart data transferring.

The proposed channel selection technique will perform efficiently in terms of:-

Memory Saving – As direct communication between SH to SG will take place, hence does not require saving the whole route on each node as in case of multihop protocols.

Available Channel Handling – The unused licensed channel information can be updated in a timely manner by the BS.

No Graph Creation – Most of the SG neighborhood area network algorithms rely on directed graph, which results in graph creation and maintenance overhead in the network, but the proposed algorithm uses no such approach hence saving memory as well as time.

End to end latency – The packets will reach faster from SH to SG or vice-versa due to direct end to end communication hence will improve the end to end latency.

Delivery ratio and Throughput – Smart Grid system works and even prefers single hop approach, which we are using hence have high delivery ratio and throughput.

CONCLUSION

In this paper, we have presented a novel single hop approach to select a channel for secondary user in the cognitive radio network, for SG neighborhood area network. The proposed model uses a data priority list, a secondary user priority list based on the user data and a primary user priority based on user channel usage. In future we will implement this model and perform simulations and compare results in terms of packet delivery, end to end latency and control overheads.

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