International Journal of Future Innovative Science and Engineering Research (IJFISER)
Volume - 2, Issue - II ISSN (Online): 2454- 1966

Research Manuscript Title

A Cross Layer Protocol Design Approach for Cognitive Machine to Machine Communication for Internet of Things

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JUNE – 2016

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ABSTRACT

A cross layer design approach for protocols of cognitive machine to machine communication has been presented in this paper. The power allocation using iterative water filling algorithm in the MAC layer and a modified Energy Efficient Threshold Sensitive Hierarchical Routing Algorithm (ETSHRA), considering alive nodes and dead nodes into account , in the network layer have been implemented. The performances have been analyzed and it is found that the modified ETSHRA improves throughput by 3.55 x 10^4 packets/sec and tremendous improvement in network life time compared to the LEACH routing protocol.

Keywords- *Cognitive machine to machine communication, Internet of Things, Cross layer protocol design,* **Medium Access Control** *protocol, Routing protocol.*

I. INTRODUCTION

The direct communication between devices using any communication channel, including wired and wireless is referred to as the Machine to Machine (M2M) communication. The modern communication is often by means of the Internet of Things (IoT). Any technology that enables networked devices to exchange of information without any human intervention is often referred to as the machine to machine communication. In industrial instrumentation Machine to machine communication is implemented by enabling the sensors to communicate the data it records to application software. The physical objects such as devices, sensors, computers, and vehicles, that are connected to form a network which are embedded with sensors, electronics and software that enables these objects to collect the data and exchange of that data is the internet of things [1]. The internet of things first senses the objects and then controls remotely across the network which creates more opportunities for direct integration of the physical world into the computer systems which results in an improved accuracy, efficiency and more economic benefits. The IoT applications in smart grids [2], smart buildings, and smart cities, smart homes and intelligent transportation are the class of cyber physical systems which are augmented with sensors and actuators [1]. The IoT has a wide range of applications in the media, management of energy, healthcare and medical systems, transportation, building and home automation, environment monitoring, and management of infrastructure. As the number of wireless devices increases and with the emerging new technologies the radio spectrum is becoming increasingly congested every day [3]. Spectrum scarcity becomes a major problem when a large number of connected devices are envisioned for the internet of things. Most of the wide ranges of the spectrum are not used majority of the time while the other bands are heavily used. However because of the Fixed Spectrum Assignment (FSA) regulation policy the spectrum that are unused are licensed and they cannot be used by the systems other than the licensed users. Cognitive radio is a novel technology to address spectrum scarcity and spectrum under utilization problems. Cognitive Radio Networks allow SUs to use the Primary Users (PU) frequency bands opportunistically without any harmful interference to the PUs.

A large number of sensor nodes are placed randomly over a geographical area to form a wireless sensor network. Every node in the wireless sensor network has the ability of communicating with each other and to the base station. The sensor nodes are small, inexpensive and they are the building blocks of the wireless sensor networks. Each of the nodes in the wireless sensor network has the ability to sense the data from the environment process it and then send it to the base station.

Energy utilization and Reliability is the key concern in wireless sensor networks [4]. In order to maximize efficient utilization of resources and to utilize least amount of energy of the sensor nodes for improving the network lifetime and reliability, cognitive wireless sensor networks are designed. As the sensor networks are dense in nature the redundant information are transferred to the base station. Since the communication energy per bit is very high compared to computing energy per bit, this redundant information causes the energy of the nodes to get dissipated quickly. The clustering algorithm and data aggregation technique together can overcome this problem. The network is divided into clusters. Data aggregation is performed with the clusters and then transmitted to the base station. This results in improvement in the lifetime of the network.

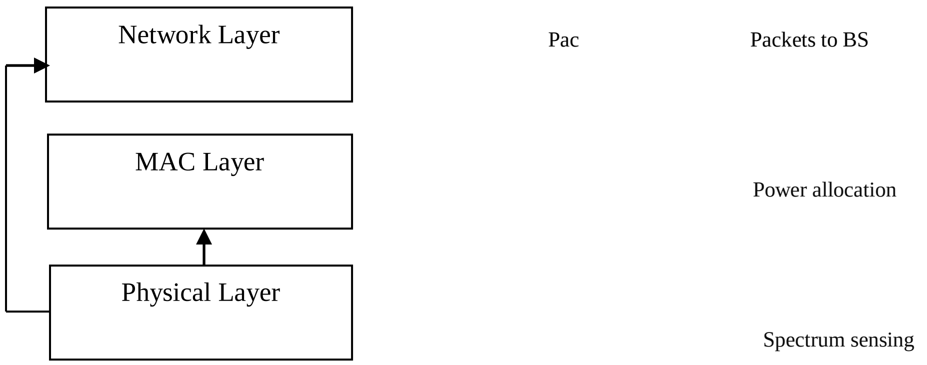

Fig.1 Block diagram of the Cross Layer design structure

II. POWER ALLOCATION

OFDM (Orthogonal Frequency Division Multiplexing) can overcome many problems that arise with high bit rate communications. It is a multicarrier modulation technique in which the data symbol stream is split into several lower rate streams and then these streams are transmitted on different carriers. In terms of spectral shape of the transmit signal cognitive radio system needs to be highly flexible. OFDM is a promising technique for cognitive radio systems. OFDM is suitable for cognitive radio system because of its reconfigurable subcarrier structure. Water filling algorithm is used to allocate the optimal power allocation for OFDM systems that maximizes the channel capacity.

The SU has the ability to fill up the spectral gaps that are not used by the primary users. Iterative water filling algorithm allocates optimal power so as to maximize the channel capacity on the subcarriers with the total power constraint. Water filling algorithm is the general name given to the equalization strategies on communication channels design and practices [8]. The sub channels are allocated with the equal power by the iterative water filling algorithm.

III. ROUTING IN COGNITIVE WIRELESS SENSOR NETWORKS

The proposed routing protocol for cognitive wireless sensor networks responds to sudden changes in the sensed attributes is the Energy Efficient Threshold Sensitive Hierarchical Routing Algorithm. It is based on a hierarchical approach and uses a data centric method. It is a reactive protocol and operated based on two threshold values suitable for time critical applications. Energy Efficient Threshold Sensitive Hierarchical Routing Protocol separates the Cluster Head into the second level of cluster head after the formation of the clusters and uses the hard and soft thresholds to detect the sudden changes [5]. The absolute value of an attribute to trigger on its transmitter is the hard threshold and report to its cluster head. If the information occurs in the product range of interest the hard threshold allows nodes to transmit data. The little change in the value of the sensed attribute is the soft threshold. When there is a small change occurs in the sensed attribute once it reaches the hard threshold the next transmission occurs.

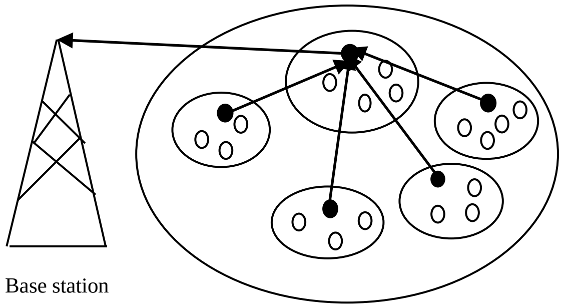

Fig.2 WSN demonstrating the clustering and the aggregation

○ - Sensor nodes

● - Cluster head

IV. PROPOSED WORK

A. Iterative Water filling Algorithm

The sub channels with the negative power will be eliminated by the iterative part of the algorithm. The sub channels with the positive power will be present by initializing negative index to zero and the iteration is done using while loop. The power allocated to each sub-channel is computed. Shannon capacity theorem is used to determine the total capacity of the channel. As per Shannon capacity theorem, error free transmission of the data is possible when the rate is less than the channel capacity. Power is allocated to each sub-channel and carrier to Noise Ratio (CNR) is also calculated. The communication model of the OFDM is of the form,

$$y_n[m] = h_n x_n[m] + w[m]$$

$$n = 0,1,\ldots.,N-1$$

Where,

the input is $x_n[m]$, output is $y_n[m]$, noise is $w[m]$, channel gain is h_n and Lagrange multiplier is λ. After power allocation using water filling algorithm the capacity is expressed as:

$$C_n = \max_{P_0,\ldots P_{N-1}} \sum_{n=0}^{N-1} log(1 + \frac{P_n|h_n|^2}{N_0})$$

Under the constraint the P_{total} ,

$$\sum_{k=0}^{N-1} P_n = P_{total}$$

P_n-The transmit power in each subchannel

$$P_n = \begin{cases} 0 & f\ \frac{1}{\lambda} < \frac{N_0}{(|h_n|)^2} \\ \frac{1}{\lambda} - \frac{N_0}{(|h_n|)^2} & otherwise \end{cases}$$

$$P_n \geq 0, n = 0,1,\ldots,N-1$$

The algorithm of power allocation to each sub channel is given by,

Step 1: Determine N_k - the number of subcarriers to be initially assigned to each user
Step 2: Assign each user k, the total power P_k to maximize the capacity
Step 3: Assign the powers $P_{k,n}$ for each user subcarriers subject to the total power constraint P_k
The Power allocated to each subchannel is given by,

Power Allocated = (P_tot + Σ (1/CNR))/H - 1/CNR

Shannon Capacity = B/H * Σ (log2 (1 + Power Allocated*CNR))

Where,
P_tot = Total power in OFDM
CNR = Carrier to Noise Ratio
B = Bandwidth
H = No of subchannel

B. *Proposed Modified Energy Efficient Threshold Sensitive Hierarchical Routing Protocol*

We have assumed that, the nodes are scattered uniformly in the sensor field. All the nodes have equal amount of energy and base station transmits signals at same power level. In this paper, we have proposed a modified ETSHRA by incorporating alive and dead node concepts to improve network life time. In the proposed protocol, the following steps have been carried out:
1. Formation of clusters
2. Assignment of hard and soft threshold
3. Rotation of cluster head, event detection, and data aggregation.

1. Formation Of Clusters

The operation of ETSHRA is broken up into rounds where each round begins with a setup phase followed by a steady state phase. Each node in the network decides whether to become a cluster head for the current round or not and each round begins with a cluster head selection. Once the cluster head has been chosen, the advertisement is provided to the remaining nodes and the nodes decide based on the signal strength to which cluster head it should join. The threshold equation for CH selection is given by,

T (n) = P/ 1-P*(r mod 1/P)

If n€G, T (n) -0 otherwise

P - Cluster head at the desired percentage
r - Current round
G- Set of nodes that have not been CH in the last 1/P rounds.

2. Assignment Of Hard And Soft Threshold

Hard Threshold: The threshold value for the sensed attribute. The node sensing this value must report to its cluster head and switch on its transmitter and it is the absolute value of the attribute.
Soft Threshold: The small change in the value of the sensed attribute that the node triggers to switch on its transmitter and then transmit.

3. Event Detection, Data Aggregation And Rotation Of Cluster Head (CH)

Assume that an event has occurred and has been detected by the sensor nodes and send the data to the base Station. The sensor nodes send the data to their cluster heads. The cluster head combines the data if there are any similar packets arrived from multiple nodes, sending a single packet of data in the direction of the base station. Data Aggregation uses the nodes as its parameter joining to form a cluster so that the data attributes are used for evaluation and usage in an aggregated form and are stored. Thus the flooding of messages has been avoided at the maximum extent to achieve energy efficiency and optimization. Assume that the cluster heads and all the sensor nodes are homogeneous.

The energy of the cluster head may quickly drain. Since the cluster head performs most of the computation and communication, rotation of the cluster head is necessary to distribute load uniformly in every round based on the threshold equation for cluster head selection. When the sensed attribute is in the range of interest the nodes are allowed to sleep there by reducing the number of transmission.

V.SIMULATION RESULTS

A. Iterative Waterfilling Power Allocation

Simulations have been conducted using MATLAB (R2013a). Fig 3. Shows the equal power allocation to different subchannels using iterative waterfilling.

Table 1. Describes the simulation parameters.

Simulation Parameters	**Value**
Channel model	Rayleigh fading
Number of subcarriers, N	32
Bandwidth	1MHZ
Number of primary users considered	16
Number of Secondary users considered	16
Modulation technique	QPSK

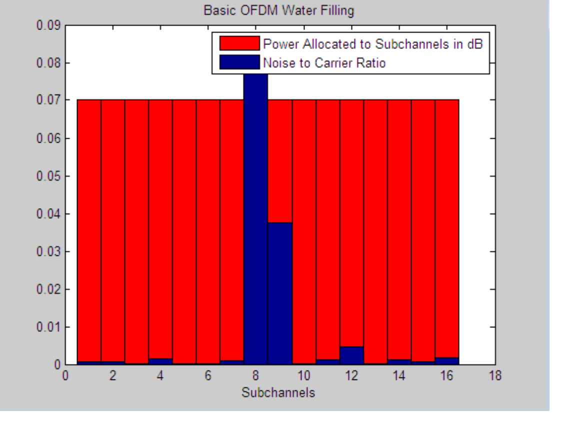

Fig.3 Plot of Sub channel Vs Power allocation

B. Cluster Formation without Dead Nodes

The cluster formation of a cognitive wireless sensor network when all the nodes are alive is shown in Fig. 4. The network consists of 100 nodes with the field dimensions of 200m in x and in y direction.

Table 2. Describes the network parameters

Network Parameters	**Value**
Network Size	200 X 200 m^2
Number of nodes	100
Probability of cluster head	0.1
Initial Energy	0.5 J
Data Aggregation	5 nJ

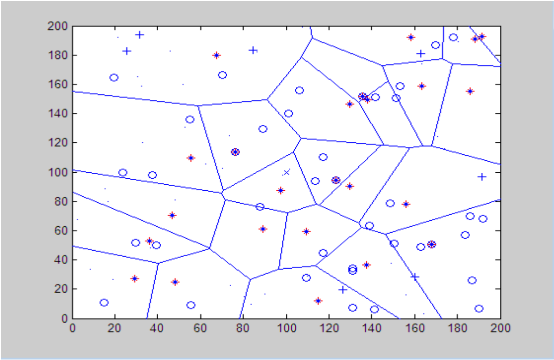

Fig.4 Snapshot of cluster formation when all nodes are alive

O - Normal node
+ - Advanced node
* - Sink

C. Cluster Formation with Dead Nodes

Fig.5 Describes the cluster formation with dead nodes after the completion of 7500 rounds.

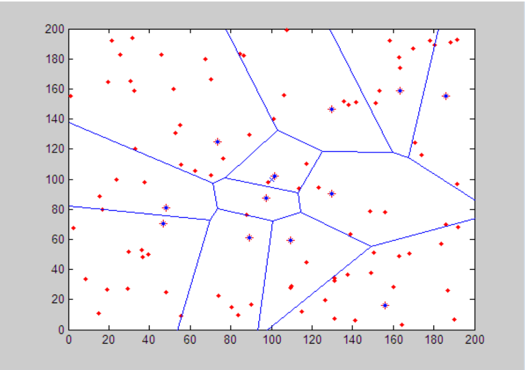

Fig. 5 Snapshot of cluster formation with dead nodes

D. Network Life Time without Dead Nodes

The simulation result of Fig.6 shows that the number of nodes that are alive is maximum at the beginning of the round and decreases as the number of rounds increase.

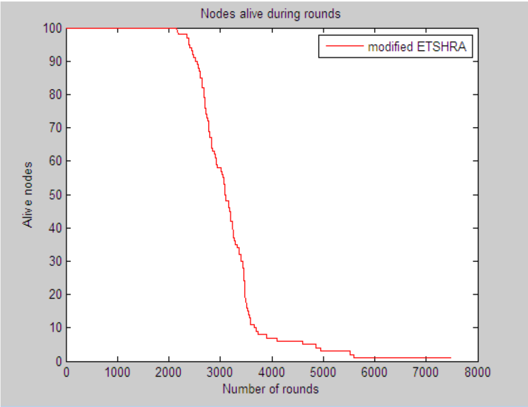

Fig.6 Plot of network life time without dead node

E. Network Life Time With Dead Nodes

The simulation shows that the number of dead nodes is minimum at the beginning of the round and as the round increases the number of dead nodes also increases.

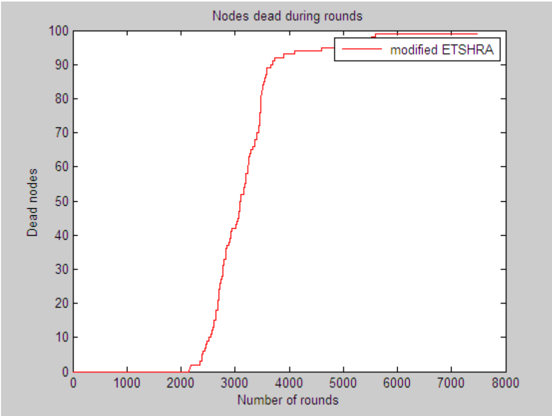

Fig 7. Plot of network life time with dead nodes.

F. *Throughput of Proposed Modified ETSHRA*

Fig.8, shows the number of packets that are sent to the base station.

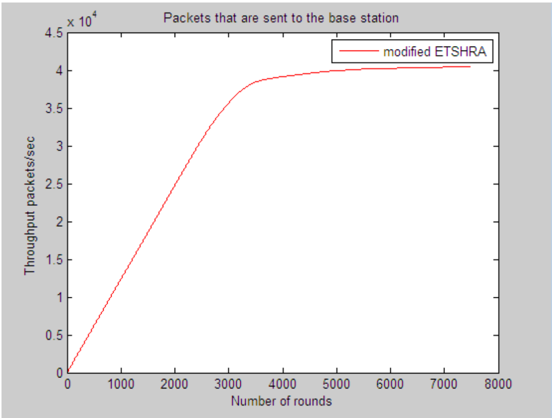

Fig.8 Packets transmitted to the base station

The proposed protocol provides a better throughput when compared to LEACH. Throughput is the numbers of packets that are successfully send to the base station from cluster head.

Table 3. Performance comparison

Parameters	**Proposed protocol**	**LEACH**
Throughput (packets/sec)	4 x 10^4	0.45 x 10^4
Network life time	100% alive nodes at round 500	25% alive nodes at round 500
	55% alive nodes at round 3000	0% alive nodes from round 900 onwards

Table 3, compares the throughput and network life time performances of the proposed modified ETSHRA and LEACH protocols. It is confirmed from the results that the modified ETSHRA improve throughput by 3.55 x 10^4 packets/sec compared to LEACH. The network life time also has been improved tremendously.

VI. CONCLUSION

A cross layer design approach between MAC and Routing protocols for cognitive machine to machine communication for Internet of Things has been demonstrated in this paper. The energy efficient routing protocol in network layer is supported with efficient power allocation in the MAC protocol of data link layer. The proposed modified ETSHRA outperforms in terms of throughput and network life time compared to LEACH protocol.

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