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A CROSSLAYER PROTOCOL DESIGN APPROACH BETWEEN PHY AND MAC LAYER FOR COGNITIVE RADIO NETWORKS

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ABSTRACT

To design OFDM based Cross layer design for cognitive machine to machine communication for IoT. The Spectrum sensing is done in the Physical layer and Scheduling and Power allocation to the subcarrier is done in the MAC layer is provided to develop a standardized protocol stack for internet of things. OFDM is a multi-carrier transmission technique that divides the available spectrum into subcarriers. OFDM has the ability for combating inter symbol interference in frequency selective channels and for avoiding interference among scheduled users by assigning different subcarriers to different users. Each time-slot the scheduling is done selecting a subset of users for transmission, determining the assignment of available subcarriers to selected users. Spectrum sensing is done in the physical layer based on energy detection technique. Scheduling in the MAC layer using Round Robin scheduling method. Power allocation to the Subcarriers is done using the Greedy Power Allocation Algorithm. To analyze the performance using MATLAB.

KEYWORDS: Internet-of-Things (IoT), Medium access control (MAC) protocol, Orthogonal Frequency Division Multiplexing (OFDM).

INTRODUCTION

Machine-to-machine (M2M) communications is an emerging communication technology that provides connectivity between devices along with an ability to communicate requiring no human intervention, where billions of objects can sense, communicate and share information, all interconnected over public or private Internet Protocol (IP) networks. In the IoT, things are expected to become active participants in business, information and social processes where they are enabled to interact and communicate among themselves and with the environment by exchanging data and information 'sensed' about the environment, while reacting autonomously to the 'real/physical worlds events and influencing it by running processes that trigger actions and create services facilitate interactions with these 'smart things' over internet, query and change their state and any information associated with them, taking into account security and privacy issues [2]. Internet of Things represents a general concept for the ability of network devices to sense and collect data from the world around us, and then share that data across the Internet where it can be processed and utilized for various interesting purposes. Internet of Things (IoT) and Machine-to-Machine (M2M) communication are the essence of smart productivity and living. IoT and M2M is a worldwide network of interconnected objects. The objects can interact anywhere and anytime and can interoperate and collaborate heterogeneous range of entities. A large number of connected devices, as envisioned for the IoT, will create a major challenge in terms of spectrum scarcity and therefore creates the need for cognitive radio. The best way to improve the utilization efficiency of the spectrum allocations is the cognitive radio (CR) technology, and the definition of cognitive radio can be expressed as: "Cognitive radio is a radio of an intelligent wireless communication system that senses and is aware of its surrounding environment and capable to use or share the spectrum in an opportunistic manner without interfering the licensed users". Machine to machine application areas in security and public safety [1] , in Building & home automation in Access control, Light & temperature control, Energy optimization, Predictive maintenance, in smart cities, Residential E-meters ,Smart street lights, Pipeline leak detection, Traffic control, Surveillance cameras, Centralized and integrated system control. In healthcare remote monitoring, ambulance telemetry, smart grids, vehicular telemetric, healthcare manufacturing and remote maintenance. A large number of connected devices, as envisioned for the IoT, will create a major challenge in terms of spectrum scarcity.

CHALLENGES OF COGNITIVE RADIO

Some of the major challenges of cognitive radio are:

Challenges in Spectrum Scarcity:
As the number of wireless devices increases creates a major problem of spectrum scarcity. In order to avoid the problem of spectrum congestion and to efficiently utilize the spectrum using dynamic spectrum access capability of cognitive radio. And this application in Broadband services, intelligent transportation systems.

Challenges in interference:
OFDM is a promising transmission technology for Cognitive radio systems. OFDM has the ability for combating inter symbol interference in frequency selective channels and for avoiding interference among scheduled users by assigning different subcarriers to different users.

Challenges in coverage issues:
Cognitive radio-equipped machine to machine communication networks can effectively overcome the situation where wireless propagation is not always guaranteed through dynamic spectrum access in ISM band.

Challenges in Green requirement:
A fundamental requirement in machine to machine communication is energy efficiency. As the devices can adaptively adjust their transmission power levels based on operating environments.

OFDM BASED CR

With emerging new wireless technologies and with the increasing number of devices, the radio spectrum is becoming increasingly congested. Hence, there is a need for Cognitive radio to overcome the problem of spectral crowding. To dynamically adjust its radio operating parameters the physical layer (PHY) needs to be highly flexible and they need to be adaptable. Orthogonal Frequency Division Multiplexing is an efficient technique for achieving high-speed communication. Therefore creates the need for Cognitive radio based OFDM design. In current wireless communications systems a multicarrier transmission known as orthogonal frequency division multiplexing (OFDM) is widely used. OFDM is a multicarrier modulation technique that can overcome many problems that arise with high bit rate communications, and the time dispersion. OFDM is the best transmission technology for Cognitive radio systems underlying sensing capabilities with flexibility and adaptively. The data bearing symbol stream is split into several lower rate streams and these streams are transmitted on different carriers. The Cognitive radio system identifies available or unused parts of the spectrum.

SYSTEM MODEL

A. System model for OFDM based CR system:
Consider the OFDM by which the whole spectrum is divided into N subcarriers. A system model where QPSK signal is sent to a few subcarriers of the OFDM and the noise is sent for the remaining subcarriers. Let $H_{k,n}$ be the channel gain of the mobile k on the n-the subcarrier and $X_{k,n}$ be the symbol to be transmit to the k-th mobile on the n-th subcarrier, then the received symbol $Y_{k,n}$ (when there is no primary user activity on this subcarrier) can be expressed,

$$Y_{k,n} = H_{k,n} X_{k,n} + Z_{k,n}$$

Where $Z_{k,n} \sim Cn(0,1)$ is the noise

B. Physical layer design:
Spectrum sensing aims to determine spectrum availability and presence of the licensed users. Spectrum sensing promises secondary users, to efficiently utilize the spectrum. Spectrum sensing in the physical layer is done using energy detection technique. A system model where QPSK signal and noise is sent to a few subcarriers of the OFDM detects the presence of Primary users and the noise alone is sent for the remaining subcarrier detects the presence of secondary users. The secondary system could utilize the spectrum only when the primary users are inactive.

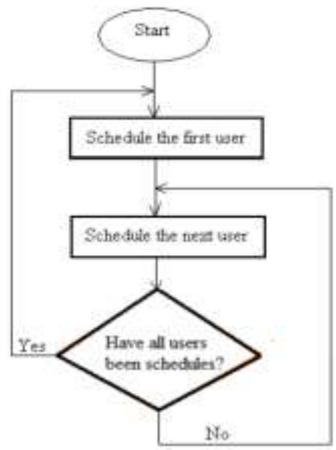
$$H0 \quad = \quad y(n) = v(n)$$
$$H1 \quad = \quad y(n) = s(n)+v(n)$$

where H0 stands for no signal is transmitted and the primary user is absent and H1 stands for signal is transmitted and the presence of primary user. And the s(n) is the signal waveform, and the v(n) is a zero-mean AWGN.The decision test statistics for Energy detection is,

$$T = \sum_{n=1}^{N} (Y[n])^2$$

Now set a threshold value,
If T>λ Decision = Signal is present
If T< λ Decision = Signal is absent

C. MAC layer design:
Moreover, OFDM tends to provide the ability to manage the resources efficiently as sub-carriers are assigned to users over certain time slots. Each time slot the scheduling is done selecting a subset of users for transmission, determining the assignment of assignment of available subcarriers to selected users, and for coding and modulation scheme used. Round Robin scheduling algorithm is used.



Round Robin scheduling Flowchart

D. Greedy power allocation:
Greedy algorithm is a low complexity technique for power allocation to the subcarriers.
Step 1: Determine the number of subcarriers Nk to be initially assigned to each user k.

Step 2: Calculate the power of each user in the OFDM system as follows:

$$p_k = \sum_{n=1}^{N} c_{k,n} p_{k,n} \cdot$$

pk,n is the amount of power allocated to the nth subcarrier ck,n is the subcarrier allocation indicator such that ck,n =1 if and only if subcarrier n is assigned to user k.

Step3: The problem of subcarriers and power allocation for the multi users in OFDM system is simplified as,

$$\max_{p_{k,n}} \frac{B}{N} \sum_{n=1}^{N} c_{k,n} \log_2(1 + p_{k,n} H_{k,n}), \ \forall k \in \{1, 2, \ldots, K\}$$

N = Number of subcarriers

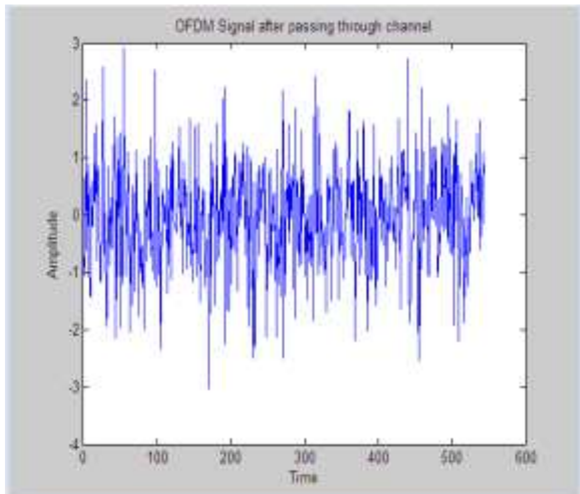
Hk,n = channel gain of the mobile k on the n-th subcarrier.

pk,n = amount of power allocated to the nth subcarrier

SIMULATION RESULTS

A. OFDM signal after passing through the channel

The result has been analyzed and the simulation shows a random signal which is qpsk modulated is given as input to serial to parallel converter, followed by inverse Fast Fourier transform(IFFT). The frequency domain is converted into time domain. Then adding a cyclic prefix to reduce the occurrence of ISI between the OFDM symbols. Then the OFDM signal is passed through the AWGN channel.



The simulation shows OFDM signal after passing through the channel

B. Output of Spectrum Sensing:

The result has been analyzed and the simulation result shows the output of the spectrum sensing in the physical layer. Considering 32 subcarriers, the QPSK signal is sent to a few subcarriers detects the presence of the primary user in the corresponding subcarrier and the noise alone is sent to few subcarriers detects the absence of the primary user in the corresponding subcarrier in an AWGN channel.

```
primary user is absent   in subcarrier 1
primary user is absent   in subcarrier 2
primary user is absent   in subcarrier 3
primary user is absent   in subcarrier 4
primary user is absent   in subcarrier 5
primary user is present  in subcarrier 6
primary user is present  in subcarrier 7
primary user is absent   in subcarrier 8
primary user is absent   in subcarrier 9
primary user is absent   in subcarrier 10
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primary user is absent   in subcarrier 11
primary user is absent   in subcarrier 12
primary user is present  in subcarrier 13
primary user is present  in subcarrier 14
primary user is present  in subcarrier 15
primary user is absent   in subcarrier 16
primary user is absent   in subcarrier 17
primary user is present  in subcarrier 18
primary user is present  in subcarrier 19
primary user is absent   in subcarrier 20
primary user is present  in subcarrier 21
primary user is present  in subcarrier 22
primary user is absent   in subcarrier 23
primary user is present  in subcarrier 24
primary user is present  in subcarrier 25
primary user is present  in subcarrier 26
primary user is present  in subcarrier 27
primary user is present  in subcarrier 28
primary user is present  in subcarrier 29
primary user is present  in subcarrier 30
primary user is present  in subcarrier 31
primary user is present  in subcarrier 32
```
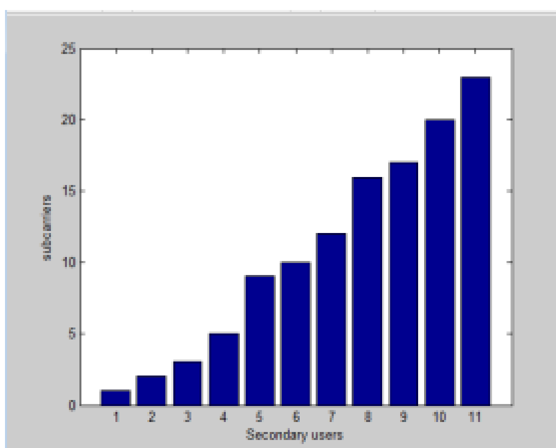

Output of spectrum sensing shows the presence and absence of Primary users in the subcarriers

C. Subcarrier allotment to the secondary users:

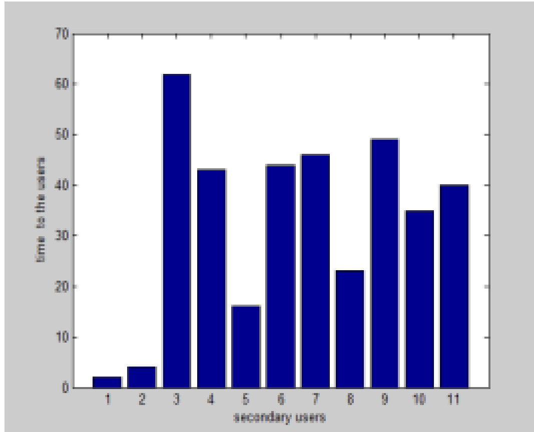
The result has been analyzed and assigning the subcarriers to each user is implemented. The subcarriers are allocated to each secondary user, to efficiently utilize the spectrum.



Simulation result shows assigning the subcarriers to each user

D. OUTPUT OF THE TIME ALLOCATED TO THE SECONDARY USERS:

The result has been analyzed and Round robin scheduling algorithm is implemented in each of the time slot selecting a subset of users for transmission, determining the assignment of available subcarriers to the selected users.



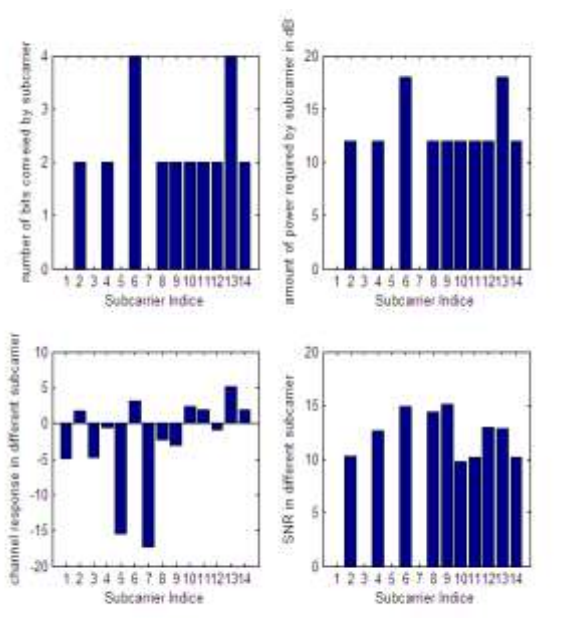
Simulation result shows that the scheduling is done in each of the time slot for the users

E. Output of the Greedy power allocation:

The result has been analyzed and the power allocation for the subcarriers in the OFDM system using $P_{k,n}$ is implemented using Greedy power allocation algorithm.

Simulation parameter

- CSI = 1/sqrt(2) * abs (randn(num Of subcarrier,1)+sqrt(1)*randn(num Of subcarrier,1)
- SNR = Pk*CSI^2
- [Subcarrier required Power] = greedyAlg (required Rate, CSI, modBitRate, req SNR)
- Amount of power required by subcarrier in dB: 10*log 10(subcarrier required Power)
- Channel response in different subcarrier: 20*log10 (CSI)
- SNR in different subcarrier: 10*log10 (subcarrier required Power/ (CSI. ^2))



Simulation result shows the Power Allocation to the subcarriers using Greedy Power Allocation algorithm.

CONCLUSION

Thus the ability for combating inter symbol interference in frequency selective channels and for avoiding interference among scheduled users by assigning different subcarriers to different users is achieved by designing a combined Spectrum Sensing and Scheduling design for OFDMA based Cognitive radio systems. Each time-slot the scheduling is done selecting a subset of users for transmission, determining the assignment of available subcarriers to selected .And the cross layer OFDMA Power Allocation to the subcarriers is designed.

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