Cooperative Spectrum Sharing Scheme for Wireless Sensor Networks

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Abstract**:** *The ultimatum for greater user traffic capacity and enhanced service quality for wireless communications has been growing radically over the past years. The availability of spectrum, wireless sensor networks enable users to move seamless in areas that are covered by network providers. While users are moving, ensuring less congestion and packet loss is challenging. As a results, we end up with poor network performance. In this paper, a Cooperative Spectrum Sharing (CSS) algorithm is designed by transferable bandwidth allocation and interlay mode in order to cooperatively share the available spectrum, optimize network performance, reduce congestion, packet loss and end-to-end delay. Experimental results showed that the proposed model can achieve a significant reduction in congestion and packet loss when compared with Media-Independent Handover (MIH) and Location-Based Handover algorithms.*

Keywords: *wireless sensor networks, network performance, congestion, packet loss, end-to-end delay.*

1. Introduction

Over the past decades, we have seen an increasing number of users with the need and desire to be connected and reachable anywhere at any time. As a result, we have seen a growing number of wireless technologies and services providers in order to fulfil users' needs. Wireless sensor network technologies such as Long-Term Evolution (LTE) and Wi-Fi communication systems increase the need for Internet access anywhere anytime. Mainly, because users can use their mobile devices (i.e., smartphone, tablet PC and vehicle) to access network services at all times, even when they are out of the coverage of their subscribed networks. Access points (AP) of different networks that have channels that overlap allow users to move around the coverage area with an active session without being interrupted. This is made possible by the existence of spectrum sharing, which allows a user to use another wireless network infrastructure that is not subscribed to access the Internet [1-3, 12, 14-15, 17, 19-20]. However, congestion and end-to-end delay cause packet loss

Therefore, it is very important to ensure that mobile technologies can operate in an optimized manner without experiencing unreasonable end-to-end delay, packet loss and congestion. In this paper, interlay mode and transferable bandwidth allocation are integrated and the new designed algorithm has been named Cooperative Spectrum Sharing (CSS) algorithm. The proposed CSS algorithm lessen the number of lost packets and end-to-end delay while reducing congestion [9, 11-14, 18-20].

Cooperative spectrum sharing is allowed using interlay mode which allows both Primary Users (PUs) and Secondary Users (SUs) to transmit simultaneously without limiting the transmit power of SUs in the Primary Network (PN) or home domain of the PUs. As a result, the number of packet loss, congestion and end-to-end delay is abbreviated.

This was done in order to optimize the utilizing of the obtainable spectrum and bandwidth in order to reduce congestion, end-to-end delay and packet loss in wireless sensor network. As we know that it is vital to provide better Quality of Service (QoS).

The rest of the paper is organized as follows: In Section II, spectrum sharing modes overview is presented. Related work is presented in Section III. In Section IV, the proposed network architecture is presented. In Section V, simulation results are provided. The paper is concluded in Section VI.

2. Spectrum Sharing Modes Overview

Spectrum sharing improves spectrum utilization efficiency in a wireless sensor network, allowing PUs and SUs to get better QoS. SUs are users that are unlicensed to use spectrum provided by PN for licensed users (PUs). Spectrum sharing is divided in to three basic modes namely: underlay, overlay, and interweave. In underlay mode, SUs can transmit simultaneously with Pus. However, for both Pus and SUs to transmit concurrently in the same area, SUs must limit their interference to PUs who has a higher priority to use the spectrum provided by PN. In overlay mode, SUs can transmit concurrently with PUs; however, SUs have to use dirty paper coding to know what PUs are transmitting packets in the network, thereafter SUs can use the spectrum.

As a result, there is high interference and poor utilization of the available spectrum as it is not shared cooperatively. In interweave mode, simultaneous transmission is not allowed. In this paper, interlay mode was used to allow wireless sensor network to share spectrum cooperatively in order to all users roam between the different networks without services i.e., VoIP being interrupted. In interlay mode, both PUs and SUs can transmit concurrently in the same area, without limiting the transfer power of SUs in the PN. In the proposed algorithm PUs and SUs cooperatively share the spectrum provided by PN [3, 10-14, 18-20].

3. Related Work

Over the past, there have been many improvements in wireless sensor networks in order to reduce end-to-end delay, packet loss and congestion [4-10]. However, currently there remains a need for the overview produced in this paper.

Li, et al. [19] proposed spectrum sharing between primary and secondary systems by using two-phase spectrum sharing protocol with Analogy Network Coding (ANC). Where the secondary (cognitive) user acts as a relay to assist with the bidirectional primary transmissions. When ANC is employed for two-way relaying between the two primary users and spectrum sharing is achieved by superimposing the secondary signal on the network-coded primary signals at the secondary relay. The simulation results showed that two-phase spectrum sharing protocol with Analogy Network Coding (ANC) can achieve higher (or at least equal) outage performance for the primary system than direct transmission without spectrum sharing. In paper, interlay mode is used in order to cooperatively share the available spectrum.

Duan, et al. [18] proposed cooperative spectrum sharing, a Contract-Based Approach (CBA) scheme in order to reduce end-to-end delay in a wireless. The scheme was designed based on incomplete information between the primary and secondary users. Where SUs' wireless characteristics are private information and not known by a PU. As a result, system performance was improved. However, CBA scheme does not provide security while users are roaming between multiple networks. In the proposed CSS algorithm transferable bandwidth allocation and interlay mode is used in order to cooperatively share the available spectrum.

Liu, et al. [20] proposed a non-real-payoff cooperative spectrum sharing between one primary user (PU) and one secondary user (SU) over multiple time slots where the channel conditions are changeable due to the channels fading. Where Markov decision process (CMDP) was used to make a decision whether a user should cooperate or not. The objective was to maximize the overall reward with the access cost constraints including the users' energy constraints and the PU's quality of service (QoS) constraints. In this paper, the QoS is improved by using interlay mode and transferable bandwidth allocation in order to cooperatively share the available spectrum.

In 2013, Khan [1] proposed the use of Multimedia Independent Handover (MIH) to assist mobility across heterogeneous networks. This model allows a user to get authenticated both from network provider as well as service provider using AAA protocol. As a result, handover delay increases delays, which lead to performance degradation. The proposed CSS algorithm solves this problem by introducing interlay mode in order to cooperatively share the available spectrum.

Li, et al. [11] proposed the use of MIHSec which uses MSK (Master Session Key) to maintain key hierarchy and removes MIH authentication process in order to reduce handover delay. MIHSec diminishes handoff delay by eliminating IKE/DTLS authentication procedures, confidentiality and message integrity. However, MIHSec does not provide secured roaming for network users. The proposed algorithm uses transferable bandwidth allocation and interlay mode in order to cooperatively share the available spectrum.

Taniuchi et al. [13] proposed the use of Media Independent Handover layer to achieve mobility of end user devices by enabling the handover of IP sessions from one access layer technology to another. However, the model is limited to the initiation and the preparation phases of the handover process. However, the CSS algorithm uses interlay mode in order to cooperatively share the available spectrum [14].

4. Proposed Solution

Interlay mode was designed using spectrum sharing method namely, inter-operator non-orthogonal spectrum sharing which is illustrated using Figure 1.

Fig 1: Inter-operator non-orthogonal spectrum sharing

The inter-operator non-orthogonal spectrum sharing method presented using Figure 2. Allows different wireless service providers to achieve higher spectral efficiency when they share the spectrum non-orthogonally, i.e. they concurrently use the same frequency bands in the same geographical location. Equation (1) was used to avoid interference between co-channels of wireless sensor network services.

$$I(b) = P_a \sum_{a \in T} H_{a,b} \left(D_{a,b}^{-\alpha}\right) \quad (1)$$

5. Simulation Results

To measure the influence of introducing one handoff procedure between the inter-domain and inter-technology experiments were carried using Network Simulator 3 (NS3) version 3.21 [21]. ConstantSpeedPropagationDelayModel and LogDistancePropagationLossModel channels were configured with Ipv4Interface, NqosWifiMac, YansWifiPhy and YansWifiChannel. The performance metrics analysed during simulations include:

- End-to-end delay
- Packet loss ratio
- Throughput

- **End-to-end delay**

The average end-to-end delay that occurred during packet transmission is demonstrated using Figure 2. The three algorithms' performance was monitored from 1 packets/s to 550 packets/s

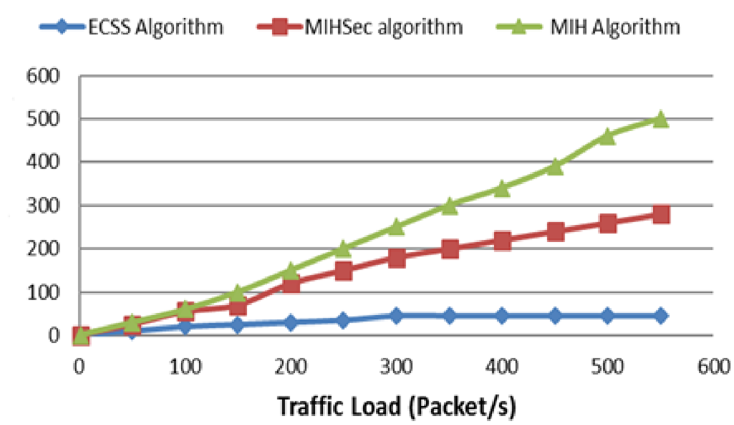

Fig 2: Average end-to-end delay

The simulation results demonstrate that the three algorithms performed well while the traffic load was low. However, when the traffic load increases CSS algorithm produced low Average end-to-end delay. This is mainly because, in CSS algorithm uses transferable bandwidth allocation. While both MIH and MIHSec algorithms produced higher handoff latency during packet transmission.

- **Packet loss ratio**

Packet loss ratio is defined as the ratio between the number of packets sent and received in a network. Mathematically, it is given by equation (2).

$$PLR = (\frac{S_1}{S_2}) \times 100 \quad (2)$$

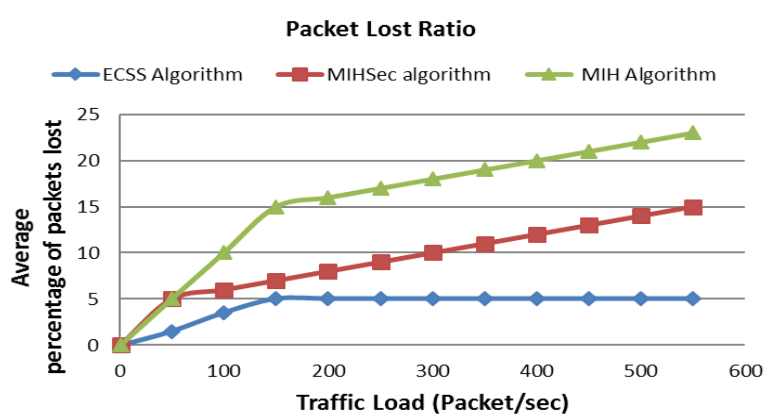

Fig 3: Average percentage of packets lost

The performance of the three algorithms was monitored under different traffic load as demonstrate by Figure 3. CSS algorithm produced a lower average percentage of packets lost as compared to MIH and MIHSec algorithms. Mainly because, the proposed CSS algorithm uses transferable bandwidth allocation to reduce packets loss.

- **Throughput**

Figure 4 demonstrate the average network throughput of the compared algorithms. The proposed CSS algorithm produced better average network throughput as compared to both MIH and MIHSec algorithms. This is mainly because; CSS algorithm allows PUs and SUs share the same spectrum between the wireless sensor networks.

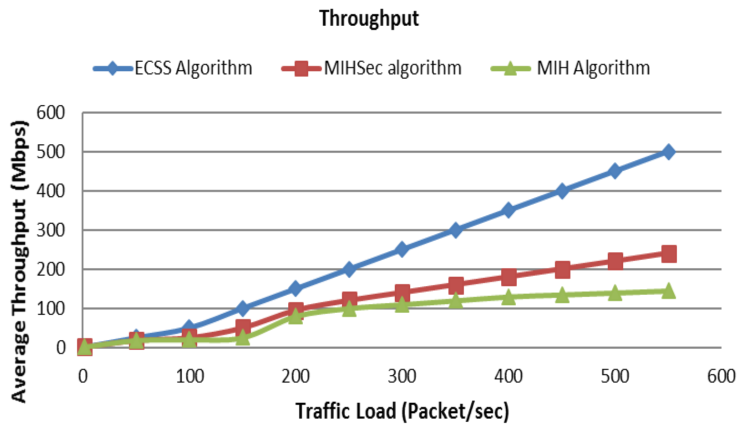

Fig 4: Average Network Throughput

6. Conclusion

This paper, presented the design of Cooperative Spectrum Sharing (CSS) algorithm is designed by transferable bandwidth allocation and interlay mode in order to cooperatively share the available spectrum, optimize network performance, reduce congestion, packet loss and end-to-end delay. Experimental results showed that the proposed model can achieve a significant reduction in congestion and packet loss when compared with existing algorithms.

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