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Design and Analysis of Energy-efficient Algorithm for Wireless Networks

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Abstract

The Industrial, Scientific, and Medical (ISM) frequency spectrum is used by the Wireless Local Area Network (WLAN) for its operation. Due to a limited number of available channels for WLAN operation, frequency channel assignment becomes very difficult. In WLAN, the access points (APs) are widely deployed, and because they share the same frequency, they start interfering with each other and causing more energy consumption. So WLAN frequency channels should be managed and assigned carefully to increase the energy efficiency of the wireless network. This paper proposes an energy-efficient channel assignment algorithm (EECAA) to improve the performance of the network. The suggested approach improves the network's energy efficiency in terms of global delay, packet data loss, and the count of data retransmissions. The extensive simulation study demonstrates that, when compared to the channel handoff scheme and D2MD channel allocation algorithm for various traffic and network conditions, the proposed EECAA method greatly increases network throughput.

Keywords: Energy-efficiency; Algorithm; Interference; Channel assignment; WLAN; Performance analysis.

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1. Introduction

In dense wireless network operation, the frequency channel interference reduces the network's performance and produces energy loss [1,2]. Interference generally degrades user performance by reducing throughput and causing packet loss. As a result, understanding the impact of interference on network performance and energy efficiency is crucial. When the energy of the interferer signal in the targeted channel is undesirable, changing the frequency channel might be a straightforward solution to the problem of increased energy consumption [3]. The frequency channel of the WLAN network can be assigned suitably to decrease the network's energy consumption [4] if the frequencies of operations and bandwidths of interfering signals in surrounding channels are known [5]. The energy consumption and data transmission rate ratio is known as energy efficiency [1]. The following connection is obtained from the notion of energy efficiency:

$$\mathrm{EE} = \frac{\mathrm{DT}}{\mathrm{EC}} \tag{1}$$

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Where the data transmission rate is represented by DT and the energy consumption is denoted by EC.

The following are the primary contributions to this paper:

I. A new energy-efficient channel assignment algorithm (EECAA) model is being developed to measure network interference.
II. The results of the proposed algorithm are computed for various network parameters.
III. The EECCA simulation results are compared to previous studies to confirm its operation.

2. Channel Assignment Problem

Only 14 frequency channels are available in IEEE 802.11b/g WLAN, while channels 1, 6, and 11 are non-overlapping [6]. The frequency range of Channel 1 is 2.401 to 2.423 GHz, with 2.412 GHz as its center frequency. Because of a 5 MHz frequency gap between two neighboring channels, interference and channel frequency overlap occur [7]. Fig. 1 represents the difficulty of channel assignment in WLAN because of the limited number of non-overlapping channels.

The number of edges represents the access points (APs), and the arrow between these APs shows the interference between them. From the Fig. below, it is clear that with limited non-overlapping channels, some channels need to be recycled, which causes interference between APs and consumes more energy in data transmission [8]. This section highlights recent research in the field of energy-efficient channel allocation for wireless networks. A sensor network-assisted cognitive radio network is presented, and a backup channel strategy in which SU should alter the channel to maximize throughput while conserving energy [9].

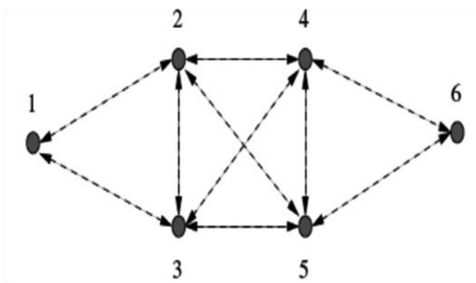

Fig. 1. Channel assignment problem.

3. Related Work

Avallone *et al*. [10] suggests a technique based on MP-CARA (minimal power channel assignment and routing), which maximizes channel use while using the least amount of power. For the energy-efficient network, a formulation is proposed to optimize channel allocation in cognitive radio mesh networks (CRMN) [11]. Baidas *et al*. [12] studies the difficulty of steady association of the clients and channel allocation in multi-cell (NOMA) networks to maintain the quality of service (QoS) and interference between the users. Energy-efficiency improvements in device-to-device multicast (D2MD) communications are provided on cellular networks. The results were carried out for energy efficiency and rate of transmission [13]. In order to decrease the long-distance transmission of data, a cluster-based routing system called Energy-Aware Threshold Sensitive Stable Election Protocol (EATSEP) was introduced for wireless sensor networks (WSNs) [14]. For performance measurement, the MATLAB simulation results are compared to various protocols under several well-known performance criteria.

There are six sections in this paper. Section I introduces the theory of energy efficiency, and Section II presents the channel assignment problem. The existing work on the topic of energy-efficient channel allocation is presented in Section III. The suggested EECAA algorithm is presented in Section IV. The simulation results and comments are presented in Section V. The paper concludes with Section VI.

4. Energy-Efficient Channel Assignment Algorithm (EECAA)

This section describes an energy-efficient channel assignment algorithm (EECAA) for wireless networks. The working process of the proposed EECAA can be roughly divided into two phases: the initial phase, which includes the calculation of interference t_n on channels C_n assigned to access points (n). In the second phase, the channels assigned to adjacent access points AP_N and AP_M are switched based on an interference calculation to manage the network. The flow chart of the EECAA is presented in Fig. 2.

Proposed Algorithm *EECAA*
1. Initialize Access Points
2. Assign C_n Channels to AP_j Where $1 \leq n \leq 14$
3. Let X is an arbitrary variable
Beginning of the outer loop,
For
$1 \leq a_M \leq z$ where z is a positive integer
    Initialize $t_M = 0.0$
    for n = 1 to 14
    do
    $a_N = n;$
    $\gamma_{MN} = (1 - |a_M - a_N| \times t_p / \beta_{MN}^p);$
    $t_M = t_M + \gamma_{MN};$
    end for
    $X = t_M;$
    $t_{NI} = t_{NI} + X;$
end for
Display the final value of t_{NI} of all APs
Exit

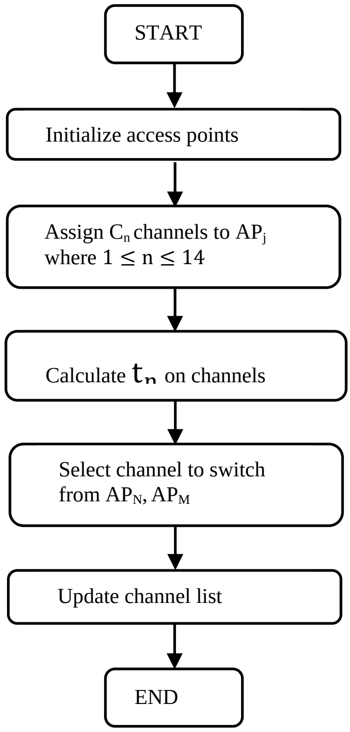

Fig. 2. Flow chart of EECAA.

Fig. 2 depicts the computing phases of the proposed energy-efficient channel assignment method (EECAA). First, all access points (APs) are set to a balanced state, and then available channels are assigned to the Access points. EEFCA computes the interference on available access points and chooses the channel to transition between AP_N and AP_M. The algorithm then updates the channel list and restarts the interference calculation procedure.

5. Results and Discussion

The proposed Energy-Efficient Channel Assignment Algorithm (EECAA) is simulated using the Riverbed Modeler Simulator [15]. The collected results are compared for two scenarios with 4 APs, 8 APs, and 40 nodes in the networks. The following parameters are considered to be the energy efficiency function of the wireless local area network (WLAN).

- Global Delay
- Packet Data Dropped
- Data Retransmission Count

Table 1. Interference on access points.

Name of AP	Interference
AP1	0.00106
AP2	0.00066
AP3	0.00089
AP4	0.00089
AP5	0.00107
AP6	0.00106
AP7	0.00066
AP8	0.00125
Total Interference (Watts)	0.00704

The interference on all channels is computed using EECAA and is presented in Table 1.

5.1. *Global delay*

The global delay (sec.) results are shown in Fig. 3. It reflects the time it takes for all WLAN nodes in a wireless LAN to receive packets. The delay in data transmission is defined as the period between initiating data transmission at the source MAC and receiving the acknowledgment.

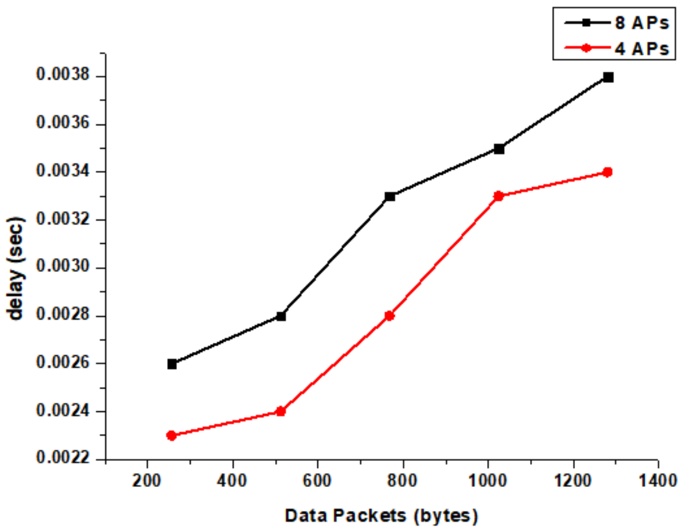

Fig. 3. Global delay statistics.

5.2. *Packet data dropped*

Fig. 4 depicts the total higher-layer data traffic (bits/sec) lost by WLAN nodes as a result of retransmission discrepancies. Due to the following scenarios, network data dropped reports the discard of data packets in WLAN.

a) When the MAC does not acknowledge the retransmission of data packets.

b) If the MAC's retry count limit is exceeded by the data packet's retry count limit.

5.3. *Data retransmission count*

The data retransmission count in packets is depicted in Fig. 5. It reflects the number of retransmission attempts made by WLAN nodes in the network while waiting for packets to be successfully sent or deleted due to retry limitations that are too short or too lengthy.

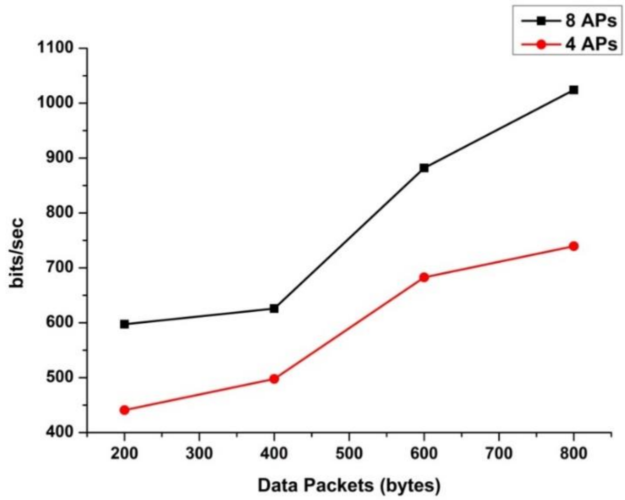

Fig. 4. Packet data dropped.

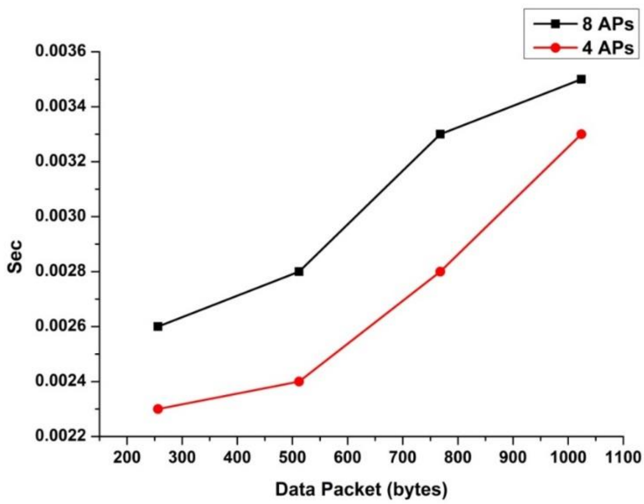

Fig. 5. Data retransmission count.

Fig. 6 displays a graphical comparison of the energy-efficient channel allocation algorithm with existing schemes in data transmission (DT) achieved with the network's energy consumption (EC) ratio. The statistical results are shown in Table 2, demonstrating that the proposed EECAA achieves a greater data transmission rate than the existing channel handoff method [9] and D2MD channel allocation algorithm [13]. In comparison to previous schemes, the EEFCA algorithm consumes less energy. The result validates the energy-efficient operation and suitability of the proposed algorithm.

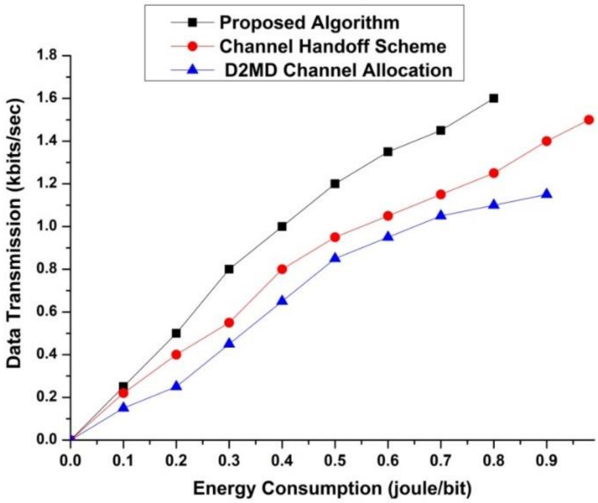

Fig. 6. Comparison of proposed algorithms with existing schemes.

Table 2. Comparison of data transmission and energy consumption.

Parameters	D2MD channel allocation algorithm	Channel handoff scheme	Proposed EEFCA
Data transmission (kbits/sec)	1.15	1.5	1.61
Energy consumption (joule/bit)	0.9	0.98	0.8

6. Conclusion

In this paper, an EECAA algorithm is presented to highlight the impact of frequency channel interference on the energy efficiency of wireless local area networks. In addition, two common wireless network scenarios are established to test the accuracy of the proposed algorithm in the simulated network. The results demonstrate that the algorithm EECAA can accurately predict the data transmission and energy efficiency in a WLAN system and that it can be used to reduce network energy consumption. According to the riverbed simulator results, the suggested approach delivers lower global delay, reduced packet drop, and fewer retransmission counts. The comparative analysis of the data transmission rate and energy consumption with the existing algorithms validates the efficient operation of the proposed algorithm.

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