Efficient Channel Assignment Schemes in 802.11 WLAN

Prof. Gundale A.S[1] Ms. Akki P.M[2]
[1,2]Department of Electronics Engineering
[1,2]Walchand Institute of Technology, Sholapur, Maharashtra, India

Abstract— A wireless local area network (LAN) is a flexible data communications system implemented as an extension to, or as an alternative for, a wired LAN. Wireless Local Area Networks (WLANs) are having tremendous growth & becoming increasingly popular. The planning of wireless local area network (WLAN) infrastructures that supply large buildings or areas requires the consideration of many aspects (coverage, different traffic densities, interference, cost minimization, network throughput) and therefore is a difficult task if done manually. The performance of WLAN can be greatly improved by efficient channel assignment. This paper presents a survey on efficient channel assignment algorithms in WLAN's. The survey is concluded with various research issues open for further study.

Key words: WLANs, LCCS, PACA

I. Introduction

Communication has become very important for exchanging information between people from and to anywhere at any time. We have different types of networks for communication. They are wired and wireless. Our concentration is on wireless networks. The wireless local area network or WLAN was originally intended to provide local area network connections where premises wiring systems were inadequate to support conventional wired LAN. Due to use of the unlicensed frequency spectrum & the inexpensive network equipment has encouraged the deployment of WLANs. The increase in deployment of access points (APs) has led researchers to develop channel assignment algorithms in order to reduce co-channel and adjacent channel interferences from neighbouring APs, which causes an overall throughput degradation of the network. As the number of WLANs is increasing the co-channel interference is also increasing. Wireless Local Area Networks (WLANs) are subjected to interference because of their working in Unlicensed Spectrum. For smaller scenarios with only a few access points (AP) to be installed, no complex network planning is needed. However, network solutions supplying larger areas like public hot-spots, university campus, office buildings etc. need much more sophisticated planning. Wireless Local Area Networks (WLANs) are subjected to interference because of their working in Unlicensed Spectrum. Channel management strategies are methods of combining the transmission characteristics of a wireless channel so as to achieve a certain level of communication performance. Intelligent channel management strategies will consider efficient methods of exploiting the transmission characteristics; these strategies will ensure that a group of access points (APs), are assigned channels so as to maximize channel reuse and minimize interference, i.e. to improve efficiency. Due to the number of features available in 802.11n, there is a need to develop a comprehensive channel management strategy that can address each feature available in 802.11n wireless technologies so as to maximize gains in channel capacity. Channel allocation schemes can be divided in general into Fixed Channel Allocation schemes, Dynamic Channel Allocation schemes, and Hybrid Channel Allocation schemes.

1) WLAN Can Configure In Two Basic Modes:
   1) Peer-to Peer (Ad-hoc) mode: This mode consists of two or more clients are equipped with wireless network adapter with no connection to wired network.
   2) Client/Server (infrastructure networking): This mode offer fully distributed data connectivity. This mode generally consists of multiple stations liked with central hub.
2) IEEE 802.11 Channels:

There are two unlicensed frequency bands available for 802.11 WLANS

1) 2.4 GHz Industrial, Scientific, and Medical (ISM) band, and
2) 5 GHz Unlicensed National Information Infrastructure (UNII) band.

The 802.11a specification today specifies 4 channels for the UNII1 band, 4 channels for the UNII@ band, and 4 channels for the UNII3 band.

These channels are spaced at 20MHz apart and are considered non- interfering, however they do have a slight overlap in frequency spectrum. It is possible to use adjacent channels in adjacent cell coverage, but it is recommended when possible to separate adjacent cell channels by at least 1 channel. Fig 1 shows the channel scheme for the 802.11 bands.

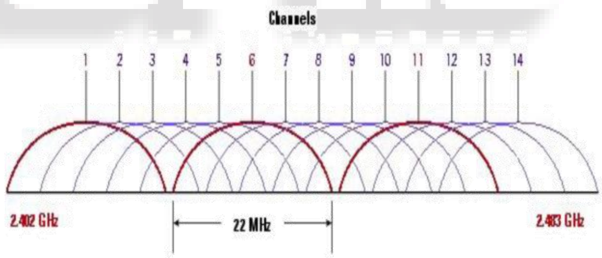

Fig. 1: 802.11 Channel Allocations

A. *Overlapping Channel Interference:*

802.11b/g networks operate between 2.4 GHz and 2.5 GHz. In 802.11b/g, transmissions between APs and demand clusters do not use a single frequency. Instead, the frequencies are divided into 14 channels, and use a modulation technique, direct sequence spread spectrum, to spread the transmission over multiple channels for effective uses of the frequency spectrum. Channel 1 is assigned to 2.412 GHz. There is 5MHz separation between the channels. Thus, channel 14 is assigned to 2.484 GHz. In the United States, channels 1-11 are used. Europe uses channels 1-13. Japan uses channels 1-14. An 802.11b/g signal occupies approximately 30 MHz of the frequency spectrum. As a result, an 802.11b/g signal overlaps with several adjacent channel frequencies. Use of overlapping channels degrades network throughput. Interference in 802.11b causes APs and stations to send frames over and over again to increase the odds of successful transmission. Typically, if devices were to send one copy of a frame, data is transmitted at 11 Mbps (54 Mbps for 802.11g). However, if the efficiency were to drop to 50%, for instance, because of interference, the devices would still be transmitting at 11 Mbps, but it would be duplicating each frame, making the effective throughput 5.5 Mbps. Therefore, 802.11 networks will have a significant decrease in network performance because of interference.

B. Overlapping Channel Interference Factor:

An overlapping channel interference factor, *wij*, to be the relative percentage increase in interference as a result of two APs *i* and *j* using overlapping channels. Thus overlapping channels assigned to APs must be chosen carefully. The overlapping channel interference factor is defined as:

$$w_{ij} = \begin{cases} |Fi - Fj| \times c & \text{if } wij \geq 0 \\ 0 & \text{otherwise} \end{cases}$$

Where Fi is the channel assigned to AP i. Fi belongs to the set of available channels. c is the overlapping channel factor. In 802.11b/g, c is 1/5 where 5 is the maximum number of overlapping channels.

For instance, if channel 1 is assigned to AP *i* and channel 1 is also assigned to AP *j*, the overlapping channel interference factor between AP *i* and AP j, wij , is 1.0 or 100%. If channel 5 is assigned to AP j, wij is 0.2 or 20%. If channels 6 or higher is assigned to AP j, wij is 0 or 0%, which means there is no interference between AP i and AP j.

II. PROBLEM DEFINITION

The popularity of WLAN is increasing day by day. WLAN takes help of access point to forward the message. The increase in deployment of access points (APs) leads to co-channel interference from neighbouring APs degrading the network throughput on way to improve performance of WLAN is to reduce co-channel interference the co-channel interference can be reduced by efficient channel assignment

III. CHANNEL ASSIGNMENT SCHEMES

A. Least Congested Channel Search:

In LCCS [1] every AP finds channel with least number of clients associated with it and switches to a channel with least number of clients .For this every AP scans each channel for beacons published by neighboring APs. Beacon is a management frame in IEEE 802.11 based WLANs containing information such as number of clients associated with each AP, traffic information etc. Based on this an AP comes to know the number of APs and the total number of clients associated with each channel. Then it switches to channel with least number of clients.

1) Limitations of LCCS:

It cannot detect interference in some situations. For example as shown in Fig 2., AP1 and AP2 are not within transmission ranges of each other but clients associated with them interfere. This situation is called hidden interference problem which is not detected by LCCS.

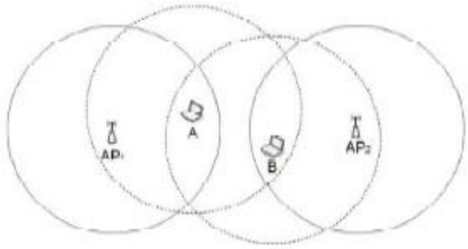

Fig. 2: Hidden Interference Problem

B. Dynamic Channel Assignment Algorithm

Channels should be assigned to each AP in such a way that minimizes interference between APs. The closer the overlapping frequencies, the higher the interference. dynamic channel assignment problem using the following variables is defined as follows:

- A_i is the set of neighboring APs to AP i.
- c is the overlapping channel factor.
- d_{ij} is the distance between AP i and AP j.
- F_i is the channel assigned to AP i.
- I_{ij} is the interference that AP j causes on AP i.
- K is the total number of available channels. 802.11b/g has 11 channels.
- Loss is a function that captures the attenuation loss based on the propagation model used.
- m is a pathloss exponent
- P_i is the transmit power of AP i.
- Q_i is the cardinality of **Ai**.
- w_{ij} is the overlapping channel interference factor between AP i and AP j

The dynamic channel assignment problem is given as:

$$\min_{F_i} \sum_{j=1}^{Qi} Iij,$$

subject to

$$I_{ij} = \frac{w_{ij} P_j}{Loss(d_{ij,m})},$$

$$w_{ij} = \begin{cases} |Fi - Fj| \times c & \text{if } wij \geq 0 \\ 0 & \text{otherwise} \end{cases}$$

For j ∈ Ai,
For *Fi ∈{*1, ...,*K}*.

Each AP would periodically (or when the amount of interference is above a threshold) run the above given dynamic channel assignment problem. Each AP would in turn pick its own channel that would minimize that amount of interference it receives from its neighbors.

C. GDCA Algorithm

GDCA algorithm focuses on Channel Assignment (CA) problem. This mechanism for channel assignment on multi-radios, i.e., forming grid-loops via Minimum Spanning Tree (MST) and forming group channel, which provides a novel mechanism to the Multi-Radio Multi- Channel Wireless Mesh Networks (MRMC-WMN) for assigning channels to different loops and the related maintenance and renewing. Channel Assignment in a MRMC-WMN environment recognizes efficient channel utilization and minimizes intervention but limited number of channels accessible to the network [2].

D. PACA (Peer Assisted Channel Assignment for Home Wireless LANs):

PACA [3] is scalable as it is completely distributed. Each AP collects the local information from its peers to do channel assignment. PACA is an algorithm which helps AP continuously gathers channels information and switches [9] channel when a better channel is needed. When a client in network becomes idle, i.e., it has no communication with the AP, it enters a process called channel utilization query process, which is shown in Algorithm. When the client enters the process, it randomly selects a channel (including its current operating channel) and switches to that channel to gather the channel utilization information.

E. Channel Hopping Approach

In [4], a distributed channel assignment algorithm based on the concept of channel hopping is specifically proposed for an uncoordinated WLAN. In particular, each AP is assigned a unique sequence of channels, and hops through this sequence over time so as to average out the throughputs of all APs in a long run. Each AP is within the transmission ranges of three other APs. Each AP hops to the next channel at the end of each time slot. Suppose that only three non-overlapping channels, namely,1, 6 and 11, are available for assignment, and that each AP always has data to transmit. The goal is to average out the throughputs of all APs in a long run.

F. Measurement Based Algorithms

The three proposed algorithms on Measurement based all have an iterative nature and weighted interference is a metric is used to capture the overall interference in the cell.. At each point in time (predefined, randomly chosen, or determined at runtime), say every 1, 2, or 5 minutes, one iteration of channel switching takes place where one or more APs switch their frequency channels according to mechanisms that are specific to the proposed algorithms, while other APs stay on their current channels. The channel switching time in hardware is several milliseconds and is thus negligible as compared to the interval between two iterations. APs and clients measure and average their in-situ interference between very two successive iterations. Iterations keep taking place on different AP(s) until the channel allocations converge. Below we describe the different conditions of the three algorithms that a representative AP am can switch from channel k = fm to k' = f'm . The denotes a vector of channels selected by APs after the representative AP am moves from channel fm to f'm .

1) The No-Coord Algorithm:

If am switches from its current channel fm to f'm only if the weighted interference on the new channel f'm is lower, i.e., the following condition holds:

No-Coord Condition:

$$W^{m}_{f_m}(\bar{f}) > W^{m}_{f'_m}(\overline{f'})$$

This algorithm is denoted No-Coord, because am makes a greedy channel selection without coordination with other APs.

2) The Local-Coord Algorithm:

This algorithm is denoted Local-Coord, since am needs to locally coordinate with the APs indexed by Gm;k(f) and Gm;k' (f) via wired backbone network for the channel switching.

$$\max_{i \in H_{m,k,k'}(\vec{f})} W^{i}_{f_i}(\vec{f}) > \max_{i \in H_{m,k,k'}(\vec{f})} W^{i}_{f'_i}(\vec{f'}),$$

3) The Global-Coord Algorithms

In this algorithm, AP will switch to a new channel only if the sum interference on the new channel is lower (after am switches there) than the sum interference on its current channel, i.e. the following condition holds.

Global-Coord Condition:

$$\sum_{n:f_n} W^{n}_{k}(\bar{f}) > \sum_{n:f'_{n=k'}} W^{n}_{k'}(\overline{f'})$$

This algorithm requires global coordination among APs using a central network controller that communicate with all APs, and is thus denoted Global-Coord.

G. ILP Approach

In [9], the problems of channel assignment and AP placement are solved. Instantaneously by using Integer Linear Programming (ILP).The methodology considers not only radio coverage but also load balancing between APs because the authors argue that the number of active wireless clients connected to the Aps affects network performance. That is, traffic congestion at the APs degrades the network performance such as throughput. The basic idea is therefore to distribute clients to the Aps in a WLAN such that congestion at APs is minimized. Correspondingly, the throughput is maximized. A floor plan is assumed to consist of traffic demand points, each of which is given an expected traffic demand volume. A set of AP candidate locations is also given. If a signal from the AP to the demand point is above a certain threshold, an edge is drawn between a traffic demand point and a particular AP. Similarly, an edge is drawn between two APs, whenever they are within a co-channel interference distance defined as a transmission range at which, if assigned the same channel, these two APs can interfere to some extent with one another. The objective is to minimize the maximum channel utilization at each AP, while keeping a certain level of traffic demand satisfied at each demand point. Each demand point is assigned to exactly one AP. If at least one demand point is assigned to an AP that AP will be included in the solution set. If an edge exists between two APs, each AP will be assigned a different non-overlapping channel. As mentioned earlier, the goal is to distribute clients throughout the network such that the overall network throughput tis maximized. This requires an accurate network layout containing the descriptions of demand points with estimated traffic, client distribution, and received signal levels at each demand location. In general, since such a network layout is very dynamic, new assignment of demand points to APs and Channels to APs are necessary.

H. Channel Assignment Algorithms

In IEEE 802.11 b/g WLAN, there exists 14 Channels. Only 11 channels are used in the US. Each channel spreads over 22 MHz due to the Direct Sequence Spread Spectrum (DSSS) technique employed by IEEE 802.11b/g. The overlapping channel interference factor wjk is defined as follows:

$$w_{jk} = \begin{cases} 1-|Ch_j - Ch_k| \times c & \text{if } w_{jk} \geq 0 \\ 0 & \text{otherwise} \end{cases},$$

where Chj is the channel assigned to APj, Chk is the channel assigned to APk and c is the no overlapping portion of two adjacent channels, expressed as a fraction of the frequency spectrum of a channel.

1) Channel Assignment Algorithm 1

The mathematical formulation of the first channel assignment algorithm, based on minimizing interference between APs, is given by the following NLIP formulation:

Min

For all j

Subject to

$$Interf_{jk} = \frac{w_{jk} P_k}{PL(D_{jk})}$$

$$w_{jk} = \begin{cases} 1-|Ch_j - Ch_k| \times c & \text{if } w_{jk} \geq 0 \\ 0 & \text{otherwise} \end{cases}$$

For $k \in Aj$,

For $j \in \{1, \ldots, M\}$,

For $Chj, Chk \in \{1, \ldots, K\}$.

This algorithm minimizes the total interference at each AP.

2) Channel Assignment Algorithm 2

The mathematical-programming formulation of the second channel assignment algorithm, based on maximizing the SIR for the users, is given below as

$$\max \sum_{i=1}^{N} \sum_{j=1}^{M} SIR_{ij}(k) \text{ for all } k, \text{ where } k \neq j,$$

subject to wjk= max (0, 1– |Chj – Chk| × c)

$$I_{ij} = \sum_{i=1}^{N} \sum_{j=1}^{M} (P_{ij} \bullet w_{jk}), \; k \neq j,$$

$$SIR_{ij}(k) = \frac{P_{ik}}{I_{ij}}, \; \forall \, i, j, j \neq k$$

For $j, k \in \{1,\ldots,M\}$,

For $i \in \{1,\ldots,N\}$,

For $Chj, Chk \in \{1,\ldots,K\}$.

The total SIR refers to the sum of all SIR values at the individual users in the network. This algorithm is used to maximize the SIR's for the users.

IV. Classification of Various Channel Assignment Techniques in IEEE 802.11

For channel assignment various aspects are considered:

1) How often channel assignment is triggered (static or adaptive),
2) To which type of deployment a channel assignment is applicable (uncoordinated or centrally managed),
3) The type of frequency channels used (overlapping or non- overlapping channels),
4) The procedure in obtaining channel assignment solutions (heuristic or integer linear programming).

The main challenge would be how to capture the network dynamics as much as possible while maintaining the complexity of implementation of channel assignment algorithm at a practical level. Furthermore, when WLANs are deployed in an uncoordinated fashion by different network administrators, the scalability of the implementation of channel assignment algorithms becomes even more important issue. In such scenarios, a channel assignment scheme of choice should be cooperative and Scalable enough to orchestrate channel switching across the entire network without creating significant interference to the neighbors. Being aware of the neighboring networks located in different administrative domains, the scheme should also be able to interact and exchange necessary information with its neighbors in order to allocate appropriate channels to the APs.

V. Conclusion

Channel assignment is one mechanism to improve the performance of WLANs. In this survey we have discussed several existing channel assignment schemes applicable to either centrally managed or uncoordinated environments. This paper mainly provides an overview of the various channel assignment strategies used for WLANs. A lot of work is being carried out in this area. Adaptive techniques which consider network dynamics are considered. Ways of continually monitoring network dynamics are being worked on. Channel assignment can then be performed at a particular location during a particular period of time based on the prediction as well as the application requirements.

References

[1] M. Achanta, "Method and Apparatus for Least congested Channel Scan for Wireless Access Points," US Patent No. 20060072602, Apr. 2006.

[2] Yan Xia, Yingzhi Zeng, Zhenghu Gong, "A Distributed Channel Assignment Mechanism for Multi-radio Multi-Channel Wireless Mesh Networks" JOURNAOF NETWORKS, VOL. 6, NO. 2, FEBRUARY 2011.

[3] C.Wong S.-H. Gary Chan Jiancong Chen "PACA: Peer-Assisted Channel Assignment for Home Wireless LANs" Department of Computer Science The Hong Kong University of Science and Technology Clear Water Bay, Kowloon, Hong Kong, 2006

[4] A.Mishra and V. Shrivastava, D. Agrawal, S. Banerjee, and S. Ganguly, "Distributed Channel Management in Uncoordinated Wireless Environments inProc. International Conference on Mobile Computing and Networking, pp. 170–181, 2006.

[5] Lee, Y., Kim, K., Choi, Y. (2002). Optimization of AP placement and Channel Assignment in Wireless LANs. LCN 2002. 27th Annual IEEE Conference on Local Computer Networks, pp. 831-836.

[6] Y. Lee, K. Kim, and Y. Choi, "Optimization of AP Placement and Channel Assignment in Wireless LANs," in Proc. 27th Annual IEEE Conf. Local Computer Networks, pp. 831–836, Nov. 2002

[7] Eisenblätter, A., Geerdes, H. F., & Siomina, I. (2007). Integrated Access Point Placement and Channel Assignment for Wireless LANs in an Indoor Office Environment. 8th IEEE Intl. Symposium on a World of Wireless, Mobile and Multimedia Networks

[8] J. K. Chen, G. D. Veciana, and T. S. Rappaport, “Improved Measurement-based Frequency Allocation Algorithms for Wireless Networks,” in Proc. IEEE GLOBECOM’07, Washington, DC, USA, Nov. 2007.
[9] P. Wertz, M. Sauter, F. Landstorfer, G.Wolfle, and R. Hoppe, “Automatic Optimization Algorithms for the Planning of Wireless Local AreaNetworks,” in Proc. IEEE Vehicular Technology Conference, vol. 4, pp. 3010–3014, Sep. 2004.
[10] J. Park, S. Park, P. Cho, and K. Cho, “Analysis of spectrum channel assignment for IEEE 802.11b wireless lan,” The 5th International Symposium on Wireless Personal Multimedia Communications, vol. 3, pp. 1073–1077, October 2002.
[11] I. Papanikos, M. Logothetis, "A Study on Dynamic Load Balance for IEEE 802.11b Wireless LAN," Proc. 8th International Conference on Advances in Communication & Control, COMCON 8, Rethymna, Crete, Greece, June 2001.

