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Review of Algorithms minimizing channel interference in WLAN

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Abstract— This paper reviews the techniques for one of the unsolved problem of tackling channel management and deciding which one is most efficient in proper channel management technique and employs better usage of wireless Spectrum (which includes assigning APs, Detecting interference among clients/APs etc.).The main reason for the interference is improper channel assignment with access points and clients in WLAN. The common solution to this complication is assigning different channels to the access points which are having common areas across the range. In this paper we study CACAO: Distributed Client-Assisted Channel Assignment Optimization for Uncoordinated WLANs and Minimum Interference Channel Assignment Algorithm for Multicast in a Wireless Mesh Network. In this we are going to study multiple interfaces with multiple channels having interference in them and problems associated with the channels like less bandwidth, throughput and channels reusability. One approach is LCCS (Least Congested Channel Search) based approach which is AP-centric in nature and involves an AP monitoring its channel for interference from other APs sharing the same physical space. Another approach which has a better chance for channel management over LCCS is based on "Conflict Set Coloring" formulation. This approach breaks down channel management into two different sets of tasks, Load balancing and channel assignment. CACAO (Client Assisted Channel Assignment Optimization) is another efficient algorithm since it is distributed as well as it enables the APs to automatically configure their channels depending on their local traffic log. MICA (Minimum Interference Channel Assignment Algorithm) algorithm is also reviewed which is having better efficiency than others.

Keywords— channel interference, congestion, channel assignment

I. Introduction

WLANs or wireless LANs (Local Area Networks) are popular under the trademark name, Wi-Fi which uses IEEE802.11 protocols for operation. WLANs are one the most highly affordable and accessible connectivity solution. Their range of operation is between 2.4 GHz and 5GHz where there is a limited unlicensed spectrum. Owing to this increase, Network Administrators has to provide better bandwidth and resources to the distributed clients. There are a total of 14 channels of which, 13 are available to most of the world and among these, non-overlapping channels like one, six and eleven are mostly exercised. If an AP assigned with same channel number is located in the range set of an AP assigned the same channel number inference between two APs occurs. Our main purpose in this paper is to analyse the various algorithms and evaluate their performance in various conflict scenarios. In some situations, such as cellular networks majorly used technique is vertex coloring. But in case of WLANs, such techniques are inefficient since a lot of vagaries might occur in indoor RF environment (such as, reflection, diffraction and scattering).

II. Existing Approaches

Initially any AP operates on particular channel that is being assigned by the administrator. Majorly clients in WLAN environment are mobile and in order to connect to WLAN connection the client scans the physical space to identify the AP with the strongest connection. After a client is being assigned to AP the interaction between the AP and client is done in a BSS (Basic Service Set) with the channel assigned to it. APs within each other's range are set to non-overlapping channels which are 1, 6 and 11(as already stated)[1][2].Detailed Radio Frequency (RF) site assessments are conducted (using RF spectrum analysers) before setting up APs in a physical space. The main purpose of such a move is to assign the channel with a particular channel number so the AP cover the maximum possible range. When a channel is being assigned with a channel number the channel is being monitored for all the data transmission by corresponding APs and the clients connected to it. The monitoring of the channel is done to check the capacity of traffic corresponding to the channel to identify the threshold limit and it violation. When threshold of a channel is being crossed the channel looks for a least congested channel and shifts to it. This technique is called Least Congested Channel Search (LCCS). As stated earlier, LCCS is an AP-centric technique which means that interferences among the clients will be hidden from the APs.

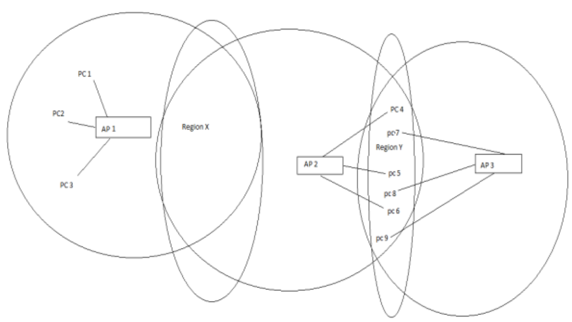


Figure 1: Channel assignment should be client driven so that channel reusability could be encouraged.

In this case (fig. 1), there are three different APs sharing same physical space i.e., AP1, AP2 and AP3.We see that there are three users connected to AP1, four connected to AP2 and 5 to AP3.But, none of the users of AP1 and AP2 are in the area which is shared by both the APs (area marked with X).This means that same channel has been given to Access Point (AP1) and Access Point (AP2) since there is no interference among the clients of both the APs which encourages channel reusability. We can also see that all of AP2's clients as well as those of AP3 lie in the same region that both the APs share which means that there is interference among clients of both APs and that's why both the APs should be on separate non overlapping channels.[3][4][5].

Disadvantage of LCCS and Hidden Interference:

LCCS technique fails to identify region marked with 'X' in fig. 1 which discourages channel reusability and completely ignores interference among the clients which highlights an important disadvantage of not only LCCS technique but also AP-centric approaches as a whole and this is where need for a client-centric approach comes in. And since the interference among the clients is hidden from the APs, this problem is denoted as Hidden Interference Problem.

The case shown in this paper is not the only one where this problem is an issue. It has been noted that this is a problem for many similar cases where complete channel utilization and channel reusability are required. Such problems motivate a need for innovations for client centric-models in case of WLANs to provide better service to the clients.

The end goal of this effort is to evaluate performance of various algorithms tackling channel management so that the most efficient one may be recognised and put forward.

As discussed above, client-based channel assignment is only first half of channel management problem, other one is proper *load balancing* in order to find a complete solution. Load balancing requires to equally distribute the load among all the APs so that on single unit has to handle the complete load.

Hence, a solution to channel management resides in channel assignment. To achieve complete solution load balancing also plays important role [6].

The Conflict Set Colouring Model:

Conflict involves framework where different BSS(Basic Service Set) consists of any two Access Points or any two clients which interfere with one another while sharing the same channel.

In this model we consider, (Y, Cl) denote a WLAN where,

Y is the bunch having access points (Aps) and Cl is the bunch having clients. Every client cl belongs to set Cl and is represented by the tuple <rcl, icl>Where, rcl is the range set that comprises of access points (Aps) in communication range i.e., APs from which client can connect and obtain service. And, icl is the interference set. Now, let T= {tcl =<rcl, icl>|V clients cl} And so, (Y, T) is the Conflict Set System. Since there are two entities communicating with each other i.e., APs and clients (BSS) and there can be interference at either of the two points, we consider both of them in this model in order to keep interference as low as possible. One such case is depicted in fig. 2.

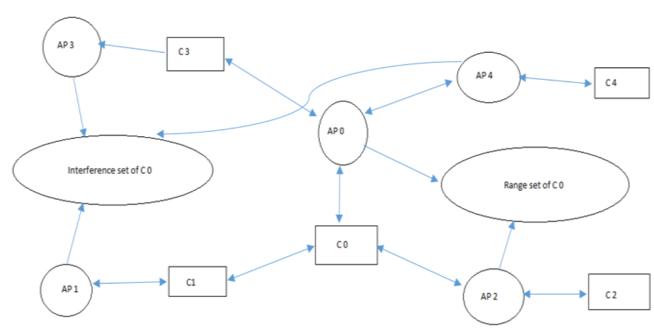


Figure 2. Depiction of range set and interference set of the client-AP link under observation.

In this case there are five APs and five clients as well forming client-AP links. Now, we keep AP0 and C0 under observation.

Here, C0 is in the range of two APs, AP0 and AP2 respectively hence, range set of this link is, {AP0, AP2}.

Now, as we see the interference set, it is observable that {AP3, AP4, AP1} are observed in client-AP link as a part of the interference set. The main goal of this model is to assign channels to the APs (selected from the range set) in such a way that they have minimum conflict (or as much conflict-free as possible).And the algorithm here is CFAssign-RaC (Conflict Colour Assignment using Randomized Compaction) since this algorithm tackles the problem of channel management jointly (channel assignment along with load balancing).[7]

Client-driven approach

Hence we have demonstrated a client driven approach towards channel management problem by jointly tackling channel assignment and load balancing. That's why the client-centric approach towards channel management is better than LCCS or vertex colouring problem. The algorithm, CFAssign-RC [8] implicitly simulates the location and distribution of multiple wireless clients with respect to multiple APs while assigning channel and balancing the load among the APs equally.

Limitations of Existing Approaches:

LCCS- As already discussed in earlier section, whenever the volume of traffic in a channel crosses a certain threshold, the 1st access point (AP) searches and shifts to a 'Less congested' channel hence giving the name to the technique of Least Congested Channel Search. But this technique has a serious limitation that is, it is unable to detect interference from the clients which means that client based interference is hidden from the APs hence giving rise to the hidden interference problem which shows us the need for a client-centric approach which is more efficient for tackling channel management problem. Hence, AP-centric nature is a serious limitation for LCCS technique giving an edge to the Conflict Set Colouring model

Vertex Colouring approach[9]- Vertex colouring approach has been successfully and efficiently applied to assignment of frequency in cellular networks. This technique is totally inefficient in case of WLANs, we only discuss the shortcomings of this technique. This concept can be easily understood with a simple example, say,

There are 4 APs, AP1, AP2, AP3, AP4 along with 5 different clients C1, C2, C3, C4 and C5.

Now if C1 is connected to AP1, C2 to AP2 and so on. Let's consider c5 is interfering with C1 and is connected to AP1 too. Then we can easily figure out from the conflict graph that we need to assign colours to each vertex individually. But, in realityC1 and C5 can be assigned the same channel whereas, AP2, AP3, and AP4 can be assigned the same channel but such a solution cannot be realized in vertex colouring problem because the graph model that is created in this technique, lacks client representation.[10][11].

Conflict set Colouring and Load balancing[8]

As the limitations of the existing approaches has been discussed, it has been established that a client driven or client-centric approach is much needed to tackle the problem of channel management efficiently. Conflict set colouring is the perfect model to be followed when it comes to channel assignment and for other part of the problem, Load balancing can be tackled by distributing the workload among multiple entities (APs) in order to achieve optimal utilization, maximized throughput and minimized response time. RF load balancing over an area has the ability to reduce network congestion by distributing client sessions across access points with overlapping coverage.

CFAssign-RaC algorithm finds the solution for the allocation of channels to the clients and for the load balancing problems as follows: CFAssignRaC assigns the channel for each AP. With the use of the load-aware objective function which is used to provide the solution to the conflict set colouring, the CFAssign-RaC algorithm provide the solution having minimum conflicts between the access point and clients . This combination is a solution to the load balancing problem [14] as well.

CACAO (Client Assisted Channel Assignment Optimization Algorithm)[3]

In case of traditional WLANs (deployed in campuses and institutions), highly qualified and therefore knowledgeable network administrators are hired to make centralized decision on channel selection. But, APs belonging to these networks are deployed by total non-specialists in a completely un-coordinated manner leading to the following issues:

- Interference.
- Unplanned Topologies.
- Unsatisfactory throughput performance.

Hence, CACAO comes into play since it is a distributed channel assignment algorithm for un-coordinated WLANs.

Tasks to be undertaken in order to implement and evaluate the performance of CACAO include:

(i) The mere process of recognizing the problem of optimization in channel assignment that solves the problem of un-coordinated WLANs.

(ii) The well identified problem that is NP-hard and evaluate a rather simplified, efficient and distributed algorithm, i.e., ***CACAO*** (which leads to better knowledge about the situation of the network and better channel assignment decision at the APs)[2].

(iii) Conducting an extensive study involving simulation and comparison using NS2.

Expected result from the algorithm is, that CACAO can outperform other traditional techniques in terms of TCP and UDP throughputs.

Some Advantages of CACAO over other traditional techniques include:

- It converges at a high speed.
- Decreases co-channel interference remarkably since the networks that use CACAO experience lower

rates of disturbance and results in efficient throughput compared to aged techniques.

- It is a scalable algorithm and completely distributed.

If we compare WLANs deployed traditionally (in campuses and institutions) with un-coordinated WLAN deployment (in residential areas), un-coordinated WLANs present the following challenges to channel assignment:

(i) Unexperienced Network Non-specialists: Un-coordinated WLANs are setup by inexperienced and independent users who do not possess any knowledge or information regarding network configuration which means that they use their devices in a plug-&-play manner therefore not knowing how to select a channel for minimum interference.

(ii) Unplanned Topology: In an un-coordinated WLAN deployment environment, APs are placed without thorough planning meaning; AP density becomes high resulting in high interference and poor performance.

(iii) Independent APs: Due to absence of any centralized decisions and presence of immature users, architecture of deployment of un-coordinated wireless LAN must be automatic as well as easier. All the included APs that belong to variety of WLAN networks should be able to freely communicate without any intervening communication between themselves.As the number of un-coordinated WLANs increase, Co-channel interference also increases. [12]

If we consider un-coordinated WLAN deployment in a casual environment (such as residence, public places etc.) since each of these location architect their WLANs according their requirement without keeping in mind the efficiency factors such as channel assignment and load balancing. In such cases, the concerned person has no prior information of agreement of channel assignment and access point placement.

For automatic configuration of channel, Traditionally, APs use LCCS (Least Congested Channel Search algorithm) which as discussed in earlier sections, suffers from hidden interference problem & non-uniform traffic distribution problem. Even if APs placed in residential environments do not interfere with each other directly, their clients in various ways do. And if these APs choose to operate on the same channel, there may be much more interference affecting client traffic and overall throughput.

CACAO makes use of feedback from the client to perform channel assignment and the feedback is obtained using the proposed IEEE 802.11k standards for radio resource management (which defines series of measurements required and statistical reports between an AP and its clients).

CACAO: The Algorithm [3]

In this algorithm we first consider a graph say, G= (V, E) where V is the set of n no. of APs i.e. V= {ap1, ap2, ap3……., ap_n}. When the interference map is referred, there is an edge between api and apj as long as long as two nodes from the corresponding Basic Service Sets interfere with each other. Now we consider W(api, apj) as the potential interference between APi and APj. With increase in value of W(api, apj) interference between APi and APj also increases as they use the same channel. The trick here is to sum up the total bitrate of each interfering flow included in two different BSSs (Basic Service Sets). We can calculate potential interference as,

$W(ap_i, ap_j)= \sum (Tn+Tm)$ where, n□ APS_i, m□ APS_j (Here, n and m are interfering with each other) and given that, i≠j.

T_n is the outgoing traffic in bitrate from node n over a time period.

Now we define a Boolean function interference map for every edge,

I(api, apj)= 1, if ap_i and ap_j are on the same Channel.
0, otherwise.

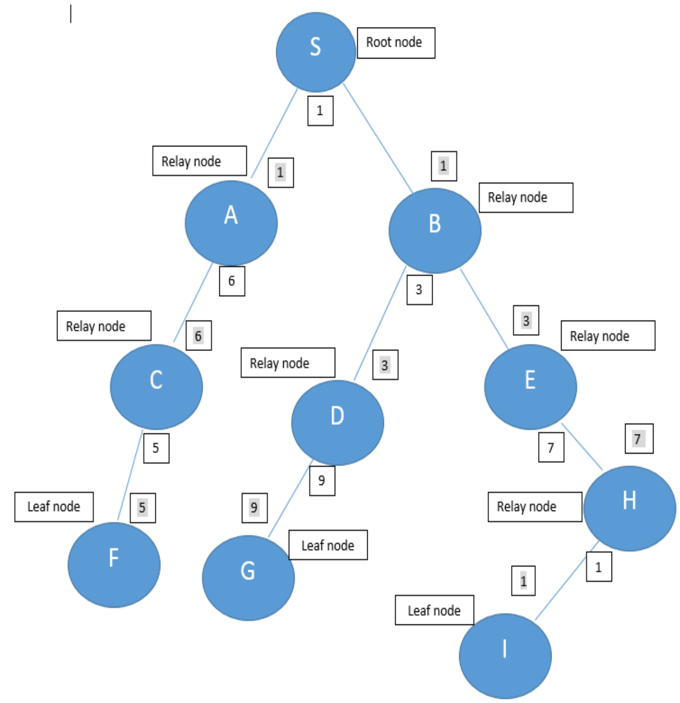
After evaluating both, $W(ap_i, ap_j)$ as well as $I(ap_i, ap_j)$ we may consider that their product provides with total interference level in BSS of ap_i as well as ap_j. Now that we have G(V,E) and W(ap_i and ap_j) we consider channel assignment, C : V {1,………,k} where k is the no of non-overlapping channels (which is 3).*Min L(G, C)* $= \sum W(ap_i, ap_j) \times I(ap_i, ap_j)$.[4]

Minimum Interference Channel Assignment Algorithm: MICA [7]

Since communication between clients and access points with different channels numbered from 1 to 11. So minimum interference channel assignment (MICA) algorithm works to assign these channels to client devices to minimize network interference between different nodes. This is achieved by maximizing throughput and minimizing end-to-end packet delay between multicasts in wireless mesh networks.

The MICA algorithm is divided into three parts. Initial input for the algorithm is a multicast tree and final output is the channel assigned in this multicast tree. Thus algorithm works in a multicast tree and does not solve interference issues between different multicast trees.

The first part is to calculate channel separation between all the pairs of nodes in the network in the network to avoid network interference. The second part is to find nodes where in channel separation is zero so that those nodes can be given the same channel number in the following steps. Last step focuses on providing channel numbers to rest of the nodes based on these zero separation nodes.



The final output of the algorithm in a multicast tree with root node and leaf nodes denoted by single channels and every other nodes by two channels indicating output and input connection channels. In the figure, the output channels are denoted by rectangular box with numbers and input channel by rectangular box with numbers in highlighted gray colour.

Usually these channels are same for one to one communication between the nodes for example S to A and S to B happens on channel 1. A major drawback on this algorithm is that it does not consider interference between two nodes having same input channel and placed too close to each other. In figure, there is a possibility of interference between nodes A and B due to same input channel and this can cause throughput decrease in the network. This problem is partially solved by providing different channels for input and output between these nodes thus creating the issue of increased amount of network bandwidth used between the nodes. [13].

III. Conclusion and Future Scope

WLANs have become a necessity not only in commercial buildings and educational institutions but also in average households where it is independently set up by uncoordinated and inexperienced users. Hence, development of an efficient channel assignment algorithm is necessary in order to manage coordinated as well as uncoordinated WLANs and it is all the more necessary to compare the performances of efficient algorithms present out there so that the best among them may be selected for efficient channel management. In this paper we have seen algorithms for both, coordinated as well as uncoordinated WLANs depending on the type of implementation. We read about two major algorithms that we have focused on in this paper. In this paper we have read about CACAO Algorithm and MICA Algorithm. We have studied about how both the algorithm are implemented and their pros and cons. Both the algorithm CACAO and MICA perform well in solving their individual problem area but none of them are sufficient enough to reach an optimized solution for problem of channel management. After performing literature survey on both the algorithm we have reached a conclusion that the problem of WLAN channel management is a very large domain that includes a large number of problem that need to be recognized and focused on. Hence, no single algorithm can tackle the problem of channel management and larger amount of research is yet to be done to reach a most promising solution.

In future, we may modify an existing algorithmic approach to tackle channel interference more efficiently and that could be implemented in client device chips that could be modified in a way to smartly ignore or reduce interference between WLAN devices.

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