A Distributed Channel Assignment Algorithm for Uncoordinated WLANs

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Abstract: Campus and enterprise wireless networks are increasingly characterized by ubiquitous coverage and rising traffic demands. Efficiently assigning channels to access points (APs) in these networks can significantly affect the performance and capacity of the WLANs. In this paper, communication efficiency can be improved significantly by using a distributed channel assignment algorithm for uncoordinated WLANs, where APs can self-configure their operating channels to minimize interference with adjacent APs. We first formulate the optimization problem on channel assignment which overcomes some of the weaknesses encountered by uncoordinated WLANs. We show that the problem is NP-hard, and propose efficient, simple, and distributed algorithm .The clients feedbacks traffic information to their APs. This leads to better network condition knowledge and better channel assignment decisions at the APs. We conduct extensive simulation study and comparisons using Network Simulator 2 (NS2).

Keywords:Wireless,channel assignment, client-assisted, traffic awar, Access pointse.

I. INTRODUCTION

To meet the growing demands for wireless data services, many companies have started deploying the IEEE 802.11b wireless local-area-networks (WLAN) in places such as airports, hotels, coffee shops, etc. The 802.11 technology is particularly attractive due to its maturity and low cost. The 802.11 capability has been included as standard equipment in many laptop computers and handheld devices. The 11b WLAN supports data rates up to 11Mbps, far exceeding that of the third generation (3G) Wireless networks such as EDGE and W-CDMA networks. [2] Generally wireless LAN operate in the unlicensed industrial, scientific and medical (ISM) bands at 915 MHz, 2.4 GHz, 5GHz.The original WLAN standard IEEE 802.11 allows either direct sequence spread spectrum or frequency-hopping spread spectrum to be used in the 2.4 GHz band. The higher rate WLANs standard IEEE 802.11b provides operation at speeds up to 11Mbps in the 2.4GHz which uses a modified version of high rate WLAN standard, operates a unlicensed infrared frequency band [4]. WLANs infrastructure includes network adapters (NAs) and (AP) Access points. Network adapter available as a PC cards and access points is having the potential to forwarding the incoming packets/data. WLAN suffers from the following challenges.

I) The WLAN networks are deployed by network non specialist who cannot be expected to know how to configure the appropriate network to minimize interference in their network.

In traditional LAN, such as campus or enterprise networks, the system administrators can calculate the APs placement. But in case of uncoordinated WLANs APs are placed without any planning; if some areas have high density means it offers high interference and it leads to poor performance.

Due to the prevalence of inexperienced users, the deployment of uncoordinated WLAN is simple. The AP of different WLANS should operate independently without any direct communication

The co channel interference is increases with number of uncoordinated WLAN increases. IEEE 802.11 WLAN has totally 14 channels, only three (namely, channels 1, 6 and 11) are non-overlapping and can be used simultaneously without causing interference. With the limited number of non-overlapping channels, channel assignment becomes a critical problem in uncoordinated WLAN [1]. Figure 1 presents a scenario of uncoordinated WLAN in a residential environment. For channel auto configuration APs traditionally use client assisted channel assignment algorithm, in which each client query their associative Aps about the traffic information. Based on this traffic information Aps choose a interference free path. By using single hop communication and fixed (constant) data rate. Such feedback may be obtained using the proposed IEEE 802.11k standard for radio resource management, which defines a series of measurement requests and statistical reports between an AP and its clients [5]. This algorithm is scalable and completely distributed where mobile clients help their APs to detect interference on networks. Each Aps simultaneously query their associative clients to collect traffic information on each channel, based on this traffic information it chooses a interference free path to operate on a best channel to reduce interference among Basic service set(BSS).We implement algorithm using NS2 (Version 2.30) with support of multiple non overlapping channels, and conduct an simulation.. Our simulations show that networks using distributed algorithm experiences lower interference, higher throughput and fairness.

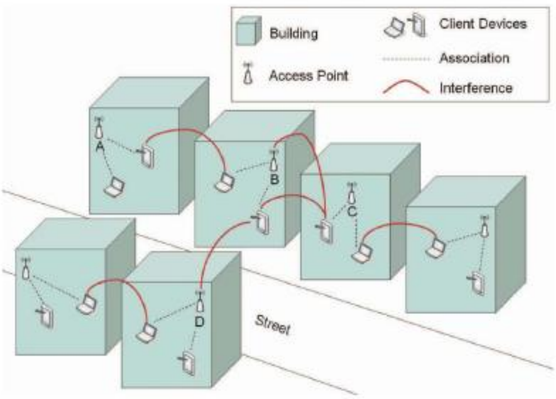

Fig.1. Interference in uncoordinated WLANs

II. RELATED WORK

Assigning channels to APs in WLANs has been a static, one-time approach. First, network administrators conduct an "RF site survey" of the campus and determine the location and number of APs for adequate coverage, Then, the administrators manually configure the APs with 802 11 's no overlapping channels to ensure that close-by APs operate on different channels when possible. Our work shows that such static approaches can result in poor performance in the face of shifting traffic demands. There are several research proposals for channel assignment in campus WLANs

Mishra et al. propose a dynamic channel assignment algorithm called CFAssign-RaC to achieve load-balancing based on a “conflict set coloring” formulation. Ahmed et al. propose an algorithm using successive refinement to solve a joint channel assignment and power control problem. Kauffmann et al. propose a measurement based self-organization approach for channel assignment. Later proposed traffic-aware approaches in [19] and [20] consider the changing traffic patterns to make channel assignment decisions. Being traffic-aware, these approaches are able to reduce interference dramatically

Mishra et al. propose a distributed algorithm called MAXChop [9], which addresses channel assignment problem based on standard graph coloring formulation and calculates a channel hopping sequence at each AP to reduce Interference. However, such hopping sequence needs to be periodically communicated among APs, and frequent hopping introduces much overhead into the system. Moreover, the MAXChop algorithm has not considered the changing traffic pattern. As a result, it is possible that heavily loaded adjacent APs are assigned to the same channel at some hopping slots, leading to high interference. Arbaugh et al. propose Hminmax [10] and formulate the channel assignment problem as a weighted colouring graph. Their approach is based on the interference experienced by clients.

III. AP CHANNEL PLACEMENT AND CHANNEL ASSIGNMENT PROBLEM

A. Process Flow

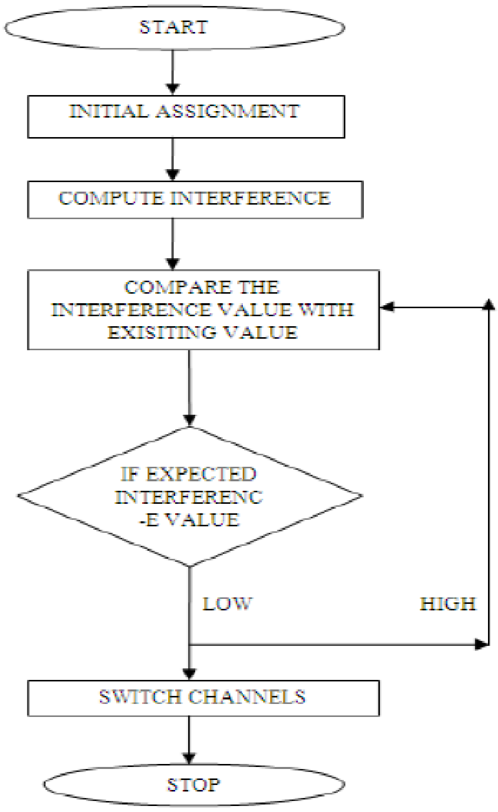

Fig 2. Process flow of optimization of interference

Algorithm follows the following flow to assign channels into the network. The channel assignment has two routines.

1. Initialization routine 2. Optimization routine.

During the initialization routine Aps initially assign the k non overlapping channels randomly.

In Optimization routine it has three phases.

1. GATHER STATICS () 2.COMPUTE INTERFERENCE () 3.SWITCH TO ()

(1) GATHER STATICS (): In this phase all Aps assist their associative clients to collect the traffic information

about the various paths. Due to this, all Aps collect the traffic information and storing it to the database.

(2) COMPUTE INTERFERENCE (): Based on the Traffic information the interference level will be calculated for each path and the interference will be compared with previous path. With this information the path can be allocated.

(3) SWITCH TO (): With this interference value the interference free path can be calculated and the channel will be switch to that path.

B. Interference Calculation

First, we calculate the weight of each edge and then we calculate the Boolean function interference map then expected interference level will be calculated by multiplying weight with interference map.

In Eq. (1) The potential level (weight) will be calculated by using the T_m &T_n. T_n represent that bit rate of outgoing traffic from node n and Tm represent that bit rate of incoming traffic from node m.

$$W(api, apj) = \sum_{n \in APSi, m \in APSj, i \neq j} (Tm + Tn) \quad (1)$$

Next we consider a interference map using Boolean function I(api,apj),

$$I(api, apj) = \begin{cases} 1, & \text{if api, apj are on the channel} \\ 0, & \text{Otherwise} \end{cases}$$

The total interference level will be calculated by,

$$I = \sum_{\forall \in (api, apj) \in E} W(api, apj) \times I(api, apj) \quad (2)$$

Based on this interference value the least interference path will be calculated. Then we switch our channels to the path which is having interference free.

IV. CHANNEL ASSIGNMENT

In this section, we propose, a distributed algorithm to achieve high throughput to all BSSs in Section 4.A. We then discuss its implementation issues in Section 4.B.

A. Distributed algorithm

The distributed algorithm utilizes information gathered by APs and clients on interference conditions to minimize the local objective function by switching to a channel that has least expected interference. As mentioned, the algorithm is very simple, and does not require any communication among neighboring APs. It adaptively settles to some minimal interference among the BSSs depending on network traffic.

We illustrate distributed algorithm for api in Algorithm 1. Firstly, every AP runs the initialization routine when it boots up. During boot-up period, each AP randomly assigns itself to a channel chosen from the k non-overlapping channels, because there is no previous traffic information gathered to decide on channel assignment. Then, an AP periodically runs the optimization routine. It computes the sum of expected interference level with regard to each nearby BSS for each channel to be used for the next time interval. Due to the fact that many online applications (like video streaming) have rather steady data transfer rate, the amount of traffic observed for the current time interval is a good estimation for the traffic in the next time interval. After the calculation and comparison of expected interference level for each channel, the AP chooses the channel that yields the least total interference and switch to that channel. At every time period, each AP independently chooses the channel assignment to minimize the objective function locally. Clearly, the whole network does not need any synchronization.

Algorithm 1

```
algorithm(api)
    1. Initialization - Initial Assignment
        api.c ← rand(k)
    2. Optimization - Repeated for each AP
        2. A GatherStatistic()
        2. B Ct = ComputeInterfere()
        2. C SwitchTo(Ct)
```

GatherStatistic() is a procedure that is used to gather statistics from clients. It returns the traffic information collected by clients. Then the AP performs computation and comparison to decide which channel it will use for the next time period by procedure ComputeInterfere(). This routine computes the expected value of interference level that the entire BSS will likely experience for the next time interval. The channel with the least interfered traffic will be chosen. Finally the SwitchTo() routine assigns the AP and its associated clients the channel.

B. Implementation Issues

A client sequentially switches to a channel to measure and collect the channel utilization information (channel utilization query process). We consider only non-overlapping channels. While the node ”snoops” another channel, the AP buffers packets for it. This can be done by using the Power Saving Mode (PSM) available in IEEE 802.11 [15]. As mentioned, the query process can be done by any protocol, such as the currently discussed 802.11k (Radio Resource Management specification for interoperability).

After a client finishes its channel utilization query process, it switches back to the original channel and sends the report to its AP. We show in Table 4.a the major elements of statistic report used in algorithm. The report mainly contains four fields, Channel, Load Observed, Num of Neighbor and My Load. Channel (CH) is the reporting channel number. Load Observed (LO) stores the total amount of traffic observed (in kbits/s) from other networks in the recorded interval. Num of Neighbor (NN) stores the number of nodes (both clients and APs included) contributing to Load Observed. My Load (ML) stores the client’s own out-going traffic load in the time interval.

Table 4.a: Major elements of the static report used

Channel	Load Observed	Num of Neighbors	My Load

Regarding traffic measurement, some work has made convincing argument that client side approach will be able to probe and get good information on the wireless environment [8]. In this algorithm, interference reports at client side are created by ideally idle clients. They enter a interference measurement process, collect information, generate statistics and send the report back to APs for further calculation. A client that performs such action randomly picks a channel and switches to it. At the same time AP needs to buffer packets that are designated for the specific client. There are two conditions when the client needs to switch back to the original channel, one is if the client needs to send data to the AP and other is if the predefined interval of interference measurement ends. While the client is operating on another channel, it only listens and records the amount of the traffic during the specified time interval. There are two things that we need to pay attention.

(i) The interval of a client listening to another channel needs to be reasonably short, mainly because the AP has limited memory space and cannot buffer large content for the client; (ii) There may be situations where all the clients are always actively communicating using the channel. This means that the previous mentioned random channel measurement approach by idle client cannot be applied. To ensure that there is always some clients doing channel measurement, we assign randomly selected clients to switch to other channels for a small fixed period of time. AP only measures its operating channel for efficiency.

V. ILLUSTRATIVE SIMULATION RESULTS

In this section, we evaluate the proposed algorithm using packet-level simulations with NS-2 network simulator. We compare the performance of algorithm with three other channel assignment algorithms namely, LCCS which is commonly implemented on APs, MAXChop algorithm and Hminmax algorithm.

A. Simulation Environment

Unless otherwise stated, we use the values specified in Table 5.a in our simulation. First we generate topologies by random AP placement inside a rectangle bounding box. For each AP, the number of associated clients is randomly drawn from one to some maximum value. After the number of associated clients is determined, we randomly put them inside the coverage area of their associated AP. For simulations where UDP traffic is used, we generate CBR traffic with constant data packet size using the value set in the specification table.

For simulations with TCP protocol, FTP application is created, and no data rate is specified. RTS/CTS are turned off to better simulate the real environment. This is also the default setting in most commercial APs. Figure 5.1a shows network topology where AP's coordinate with the other AP's.

TABLE 5.a: SIMULATION SETTINGS.

Medium Access Protocol	IEEE 802.11k
Radio Propagation Model	Shadowing
Link Basic Rate	2 Mbps
Link Data Rate	11 Mbps
RTS/CTS	OFF
Bounding Box Size	1500m by 1500m
Maximum Clients for an AP	8
Client Association Range	100m by 100m
Transmission Range	250m
Interference Range	550m
Simulation Duration	45s
Packet Size	1000 bytes

B. Illustrative Results

In the following, we use a sample topology setting (2 APs and 8 clients) shown in Figure 5.2a. In this graph every solid dot represents an AP, big circles indicate the transmission range of the AP and the empty dots represent clients.

Figure 5.b shows Client assisting AP, where AP handoff takes place whenever there is interference. Some APs start to change their operating channels to avoid interference; as a result there are some small drops of the objective function value. Algorithm is able to adjust to the changes and reduce the objective function value. Also, after the traffic pattern changes, the objective function value does not fluctuate a lot and maintains at a relatively low level.

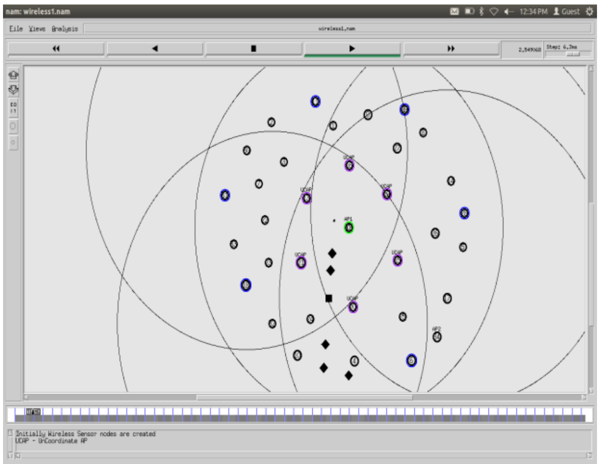

Fig. 5.a. An example of the topology under study.

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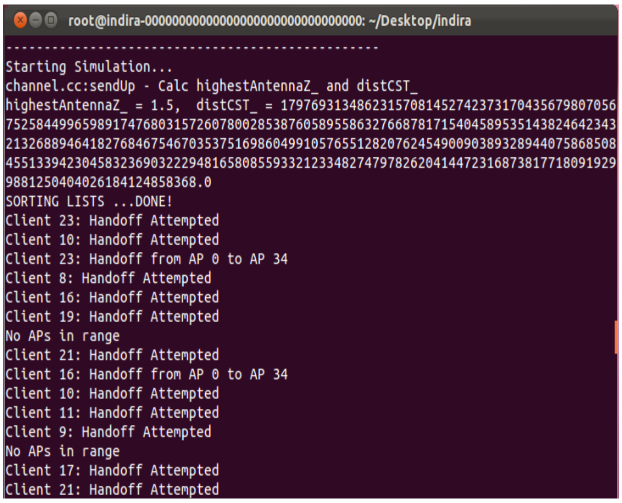

Fig 5.b: Client assisting AP, where AP handoff takes place

VI. CONCLUSION

Many of these WLANs are independently set up by novice users. Since these WLANs are set up by uncoordinated and inexperienced users, developing an automatic and yet efficient channel switching algorithm becomes very important to these WLANs. In this paper, we propose a distributed algorithm that tries to minimize interference level in the network. This algorithm overcomes the weaknesses of traditional approaches. It is simple, effective, completely distributed and hence scalable APs using CACAO algorithm gather channel and interference condition with other WLANs with the help of associated clients. This information helps the AP to make better decision on channel assignment. Through client reports of channel information, the APs can assign channel with minimal interference. Using NS, we implement LCCS, recently developed MAXChop algorithm and Hminmax algorithm and our algorithm CACAO and run extensive simulations to collect data. CACAO improves network throughput significantly with little compromise in fairness. It is also adaptive to traffic condition to keep interference at a low level.

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