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КРОС-ПЛАТФОРМЕННА РОЗРОБКА ПРОГРАМНОГО ЗАБЕЗПЕЧЕННЯ ДЛЯ МОБІЛЬНИХ ОПЕРАЦІЙНИХ СИСТЕМ (ANDROID, IOS, WINDOWS 8 RT)

У роботі зроблено огляд технологій, що використовуються в розробці програмних продуктів під мобільні операційні системи (Android, iOS, Windows 8RT). Проведено порівняльний аналіз проблем, які постають перед розробниками. Також пропонується один з підходів до вирішення знайдених проблем.

Ключові слова: Android, iOS, Windows 8RT, розробка під мобільні операційні системи.

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OPTIMIZED CHANNEL SELECTION FOR MULTI-RADIO IEEE 802.11 BACKBONES

This paper presents the Simple Backbone Channel Allocation (SBCA) algorithm. It is used to optimize the channel assignment in IEEE 802.11 wireless backbone networks. We point to some specifics in channel assignment of backbones. It differs from channel assignment of single APs which is a node colouring problem of graph theory. Backbone channel assignment needs new strategies to cover all general conditions. We declare the SBCA algorithm and show its operation on an example. Our measurements show that it is very fast, correct in result and finite.

Keywords: IEEE 802.11 channel assignment, wireless backbone, mesh networks, network optimization.

I. Introduction

The use of IEEE 802.11 wireless LANs (WLAN) has been grown rapidly for the last ten years, promoted by inexpensive IEEE 802.11 capable PDAs, smart phones, laptops and WLAN routers. WLAN is used for business and private networks. Now the WLAN technology is increasingly used for wireless backbones to connect networks in countrified areas without broadband service or to cheaply connect different departments of a company which are located in different parts of a town [1].

Backbone networks

The backbone is an essential part of complex network topologies. Larger networks are often separated into different network segments (LANs), connected to each other and the wide area network (WAN) by the backbone. Due to its important aim to achieve the connection between many network segments, it has to realize special quality requirements. Backbones in general must guarantee high bandwidth, high availability and common *Quality of Service* (QoS) parameters.

The connection of different network segments to the backbone is done by *ingress*- and *egress*-nodes. An end-user station is never directly connected to a backbone network. It has to use the ingress gateway. If necessary, ingress- and egress-nodes also perform a media conversion (e.g. from IEEE 802.3 to IEEE 802.11 and vice versa). Backbone nodes themselves have only the task to route all network traffic. We denote them \emph{forwarding}-nodes or just routers.

Backbones with their ingress-, egress- and forwarding-nodes basically form a fixed network typology without frequently changes. Thus, the administration has special capabilities in network planning. Due to the fixed ingress- and egress-nodes it is possible to plan the data flow between different network segments. Therefore, special routing protocols like *Multi Protocol Label Switching* (MPLS) are used. Thus, the route between different network segments and the used capacity (bandwidth etc.) can be reserved in advance.

Wireless backbone networks

Wireless backbones in general have the same functionality and aim like common wired backbones. However, wireless backbones underlie some constraints. Wireless connections have many parasitic couplings, e.g. weather (rain, fog, snow) has a diffusion or absorbability influence, moving vehicles or an inauspicious architecture of buildings have influences called *Small Scale Fading* and *Large Scale Fading* and of course reflexion, flexion and refraction.

IEEE 802.11 backbone networks have an extra parasitic coupling by other 802.11 stations and access points. Because everyone can provide its own WLAN without respect of other WLANs and their used channels. This kind of parasitic coupling will be especially serious in urban areas. Thus, a channel assignment algorithm must plan the backbone connections and the ingress/egress-APs (Access Points) channels with respect of influences to the nodes in the own administrative domain and to foreign wireless APs. Additionally, it must observe the whole environment to react on topology changes in foreign wireless networks to guarantee the best possible quality persistently.

The problems and aims of wireless backbone networks can also be found on wireless mesh networks and wireless sensor networks [2].

This paper is organized as follows. After reviewing our related work we describe the problematic nature of channel use and channel access in IEEE 802.11. Then we describe an algorithm for channel assignment in wireless backbones. Section IV shows how the algorithm works on an example network topology. Section V presents measurement results for our algorithm. We summarize our findings in section VI.

II. Related Work

The most work in the field of optimizing Channel Assignment focused on single APs in chaotic networks or APs within an Extended Service Set (ESS) like in [3; 4; 5; 6]. The APs in these papers had usually only one wireless interface and a wired connection to the ESS. In [7] we presented a study of different algorithms for channel assignment in chaotic WLANs. In this paper we classified centralized and distributed class of channel assignment algorithms. We also developed an optimized version of the algorithm in [8], which we evaluated as the best solution for chaotic networks. In this paper, we will focus on backbone networks, the terms and conditions of channel assignment are completely different.

Raniwala et.al. presented in [9; 10] their *Hyacinth* architecture, which is a wireless backbone architecture with complete channel assignment and routing solution. They were able to maximize the overall ingress-egress throughput by a factor of 6 to 7 compared to a single channel configuration. The main problem of *Hyacinth* is the cross layer dependence between MAC- and Routing-Layer because their channel assignment is based on channel load estimation generated by the routing algorithm.

In [11] was proposed a channel assignment method for wireless mobile ad hoc networks (MANETs). It uses the *ad-hoc on-demand distance vector (AODV) routing*}protocol to determine the best route in the ad hoc network immediately. During the discovery of the best route, they do also a channel assignment on the routing nodes to optimize the throughput for the path.

In our opinion, the channel assignment has to be independent of the Routing-Layer to ensure flexible backbone architecture. In this paper, we present an approach to make the channel assignment independent from routing, which is necessary if the topology and/or the data traffic are not fixed. The channel load is dependent on many factors like time (daytime, weekday, etc.), restrictions to traffic classes or protocols (firewalling), the behaviour of the users and connected networks. This implies that the best routes are dependent on time.

The papers [12; 13; 14] are describing only mesh routing. The proposed routing algorithms are using the channel utilization as load metric. So, a good channel selection is also related to mesh routing.

III. Principles of IEEE802.11 Data Exchange

The air interface in IEEE 802.11 networks is a shared medium. Both data- and control-frames and up- and down-link share the same channel, in contrast to other wireless networks like GSM, EDGE or UMTS. Furthermore, the IEEE 802.11 frequencies are license free, therefore everyone can provide its own WLAN network.

The next two paragraphs III-A and III-B show in short the channel division and the channel access method.

A. *Channels in IEEE802.11*

IEEE 802.11 wireless LANs can use two different frequency ranges in 2.4GHz (IEEE 802.11b/g) and 5GHz (IEEE 802.11a/h) [15]. The frequency ranges are split into different channels. Every channel has a bandwidth of 20MHz. A frequency gap of 5MHz is between the centre frequencies of neighbouring channels. Channels 1 to 11 in the 2.4GHz range may be used in the USA, whereas in most parts of Europe channels 1 to 13 are available. This means that there are only three non-overlapping channels within 2.4GHz range. The 5GHz band ranges from 5.0GHz to 5.725GHz. The first available channel in Europe is channel 36 (5180MHz), the last is channel 140. In 5GHz range, only channel numbers may be used that are a multiple of four (e.g. 36, 40, 44). That implies all available channels in 5GHz band are non-overlapping. Nevertheless, the 2.4GHz range (IEEE 802.11b/g) is often used.

B. *Access to the Wireless Network*

The access to the wireless interface in IEEE 802.11 is coordinated by the *Carrier Sense Multiple Access* with *Collision Avoidance* (CSMA/CA) protocol. Any transceiver must sense for some microseconds (*backoff time*) for a free channel. This avoids simultaneous access to a channel. The backoff time is calculate before a frame will be sent. The backoff time is a multiple of a time slot and a random number within the range of 0 to *Contention Window* (CW). At start-up, CW is initialized with CW_{min}. After each collision (*collisions*), the CW will be increased from the initial value (*init*) by a power of 2, but with maximum of CW_{max}. The contention window ranges from

$$CW_{min} \leq CW \leq CW_{macx}$$

and is set to

$$CW = \min(2^{init+collision} - 1, CW_{max})$$

If a frame was send successfully, CW is reset to CW_{min}.

Default values for CW_{min} and CW_{max} are 31 and 1023. A time slot is 9μs or 20μs long, depending on modulation used [15]. Overall, the CSMA/CA algorithm shares the medium fair between all transmitting stations.

Therefore, high channel load, collisions and interferences decrease the throughput per channel and increase the latency.

IV. Algorithm

In contrast to the channel assignment of single APs which is a node coloring problem of graph theory, new strategies are needed in backbones. Single AP channel assignment has only the aim to find the best (few used) channel with respect to the environment. However, the wireless nodes of the backbone must be connected with each other. Thus, they need the pairwise best channel for their communication. This channel must minimize interferences with other APs next to the communicating nodes. Another particularity is the need of two or more wireless network interfaces by every forwarding node (see figure 1).

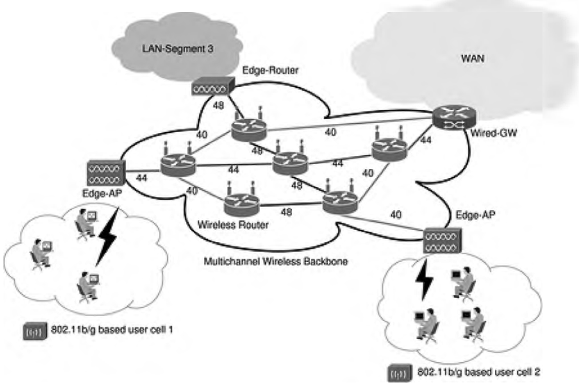

Fig. 1. Example of a wireless backbone

Due to the multi-radio nodes the whole channel consumption increases and the wireless network interfaces of one multi-radio node can interfere with each other. The problem of optimally assigning channels in an arbitrary mesh topology has been proven to be NP-hard based on its mapping to a graph-coloring problem [9].

A. *Aims and general conditions*

Before we are describing the algorithm, we have to describe the network's conditions assumed and the terms the algorithm has to use to reduce the complexity of the problem.

At first, we need to know the complete network topology. That means, we have a graph which nodes are the backbone routers and the edges between nodes, describing which router can connect with an other. We assume that only directly connected nodes can interfere each other thus we know that the interfere range can be up to two or more times higher than the normal communication range as showed in [16; 17]. We already noted that a wireless backbone node will use more than one radio interface. In this study, we always assume the use of undirected antennas so that a node *A* which is connected with node *B* can talk to *B* over every radio interface it has.

Now we can talk about the aims and conditions the algorithm has to fulfil when searching for an optimal channel setup.

1) Avoid neighbour interferences.
2) Respect the multi radio architecture and use a grouping strategy. Grouping describes the strategy to determine over which interface to talk to which neighbour. If we have a node which has got more neighbours than interfaces, each of its interfaces forms a group and we have to associate each neighbour to one of the groups.
3) Respect nodes with a high node degree and prioritize them. A node which has got many neighbours to talk to, must use channels with a low reuse ratio.
4) Solve the *neighbour-of-neighbour* (NN) problem. This problem means that the algorithm has to look at all neighbours of the neighbours of node A when assigning A's channels. Figure 2 illustrates the NN problem. The connection between nodes C and D is already assigned to channel 1 and we want to assign A's interfaces. Viewing from A node C is neighbour of A's neighbour B and we can't use channel 1 again between A and B, because B will interfere with C.

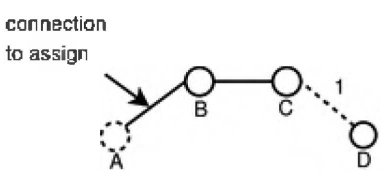

Fig. 2. Neighbour-to-neighbor problem

5) Find a good strategy for channel reuse.

B. *SBCA Algorithm*

Our algorithm for channel assignment in wireless backbones is called *Simple Backbone Channel Allocation* (*SBCA*) algorithm which is based on our statements in section IV-A. It is a centralized, greedy algorithm. This means the whole network topology is needed to calculate the channel assignment. Because of its greedy character, the SBCA algorithm is fast but does not guarantee that the result is the best solution of the problem, but it is not far away from that.

Given a set of possible channel numbers in *c*, we outline the algorithm as follows:

1) Choose node k with highest vertex degree.
2) Detect all neighbour nodes n of k.
3) Choose a neighbour node n_i with unassigned channels. Check if k, n_i and other nodes of set n form a clique.
4) Lock every channel in c used by neighbours of k, n_i and all clique members.
5) Choose the first not locked channel c_j of set c. If all channels are locked, choose the least used channel.
6) Allocate the chosen channel c_j to k, n_i and all clique members. Decrement their remaining vertex degree by one.
7) If the remaining vertex degree of k is greater then null, goto step 3.
8) Choose the neighbour node of k with highest remaining vertex degree as new node k, if any, or choose the next node with highest vertex degree from remaining nodes as new node k. Goto step 2.

The first step is a greedy step, because it reduces the solution space when assuming the highest vertex degree as start node. The choose of the next node in step *8* is also a greedy one.

Step *3* reduces the amount of used channels according to point *5* in section IV-A. We assume that nodes which form a clique can use the same channel to communicate with each other and also need only one interface to do that. With this strategy, we have a simple *grouping* (according point *2*, section IV-A) and also safe the remaining interfaces and channels for other connections. At this point, we accept that the clique's members interfere each other but we will address this problem with an iterative refinement described in section IV-C. The channel locking in step *4* accords to point *4* in section IV-A and makes the channel assignment sensible to the *NN* problem.

The algorithm is stable and finite, because it traverses each node and each edge only one time. Its complexity is $O(n^2)$ but the real runtime is dependent on the amount of nodes and the amount of edges. So its better to say $max(O(n^2), O(m^2))$ where n are nodes and m are edges.

Our example in section V shows the algorithm's steps in detail and punctuates the explanations made in this section.

C. *Iterative Refinement*

As mentioned in the description of the *SBCA* algorithm in section IV-B, nodes which form a clique are using the same channel to connect each other. This reduces the overall amount of used channels. After the *SBCA* completes and we already have nodes with unused interfaces, we can do an iterative refinement. This step is independent of the rest of the algorithm but should always be done. It searches for cliques and checks for all clique members if all interfaces are used. If not it tries to reassign the affected edges with another channel if possible. After iterative refinement the clique members use as much interfaces as possible according to the given *SBCA* solution.

We outline the iterative refinement algorithm as follows:

1) Choose a node k not yet visited.
2) If k has no unused radio interfaces left, goto step 1. If k has equal number of neighbours and used radio interfaces, goto step 1.
3) Search a neighbour n_i of k which has also unused radio interfaces left, if any, or goto step 1.
4) Lock every channel in c used by neighbours of k and n_i.
5) Choose the first unlocked channel. If all channels are locked, choose the least used channel. Allocate the chosen channel to k and n_i. Goto step 2.

V. Example

This section shows the channel assignment with the SBCA algorithm on an example graph with 15 nodes and 19 edges. Figure 3 shows the graph, the adjacency matrix in the middle and the vertex degree of every node in the vector on the right, at start-up.

In the first iteration, the algorithm chooses the node with highest vertex degree. In this example, it is node 3 (k). Its neighbour nodes (n) are node 0, 1, 4 and 5. Node 0 (n_i) is used for the first channel assignment. The nodes 0, 1 and 3 form a clique. The whole clique of node 0 (n_i) allocates the first free channel in channel list, channel 1. Then the vertex degree of all three nodes is decremented by 2. The algorithm is proceeding by choosing the next untreated node 4 (n_i). Channel 1 is locked because it is already used by node 3 (k). Thus, the next free channel is assigned – channel 2, then the vertex degree of node 3 and 4 is decremented by 1. The last neighbour node to handle is node 5 (n_i). Its assigned channel is channel 3 because channel 1 and 2 are already in use. After the last decrementation of the vertex degree, node 3 (k) has a vertex degree of 0 and the next node k is chosen. Figure 4 shows the graph, and the modified vertex degree vector after first iteration.

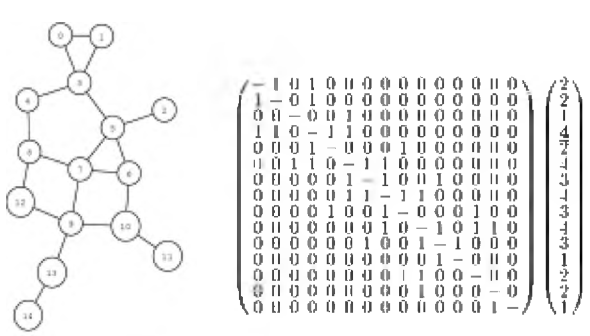

Fig. 3. SBCA algorithm at startup

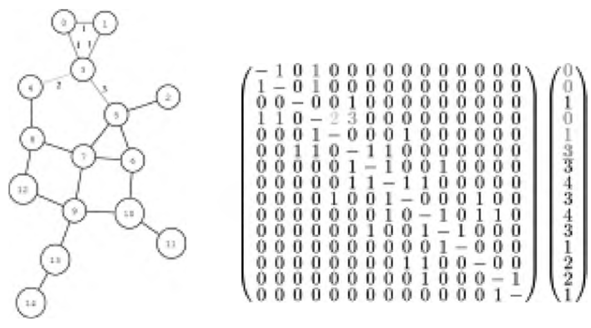

Fig. 4. SBCA algorithm after first iteration

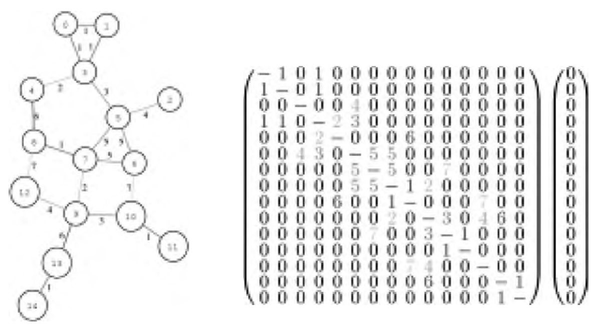

Fig. 5. SBCA algorithm after completition

Next node k is node 5, because it is node 3's neighbour with highest vertex degree. It goes on with assigning of channel 4 to the edge to node 2 and channel 5 to the clique of node 5, 6 and 7. Figure 5 shows the final channel assignment before iterative refinement. The iterative refinement reassigns the channels of the cliques 0-1-3 and 5-6-7. Then the communication between all nodes is free of interferences.

VI. Measurement Results

To gather sensible measurement results, we implemented the SBCA algorithm in the C programming language. To determine accuracy and performance of this algorithm, we let it compute channel assignments for various random generated graphs.

To generate the test graphs, we used an algorithm that uses a weighted random metric. In fact, this means that at start-up an empty adjacency matrix for n nodes is created. With a probability of δ, the edge between two nodes is set in the adjacency matrix. That means this nodes can communicate with each other. Additionally, it prohibits single, isolated nodes. The probability δ was set to 20%. But the maximum amount of connected APs was set to 5. We determined this upper bound, because it is not thinkable in real world application that an AP is equipped with more than 5 wireless interface cards. Also the use of omnidirectional antennas is supposed, so that every interface can be used to communicate with a neighbour node.

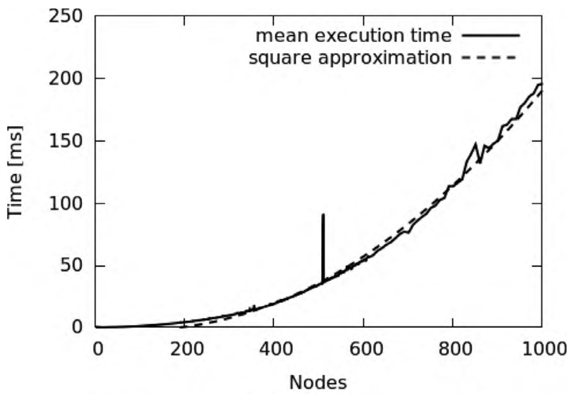

Fig. 6. Runtime of SBCA algorithm – nodes

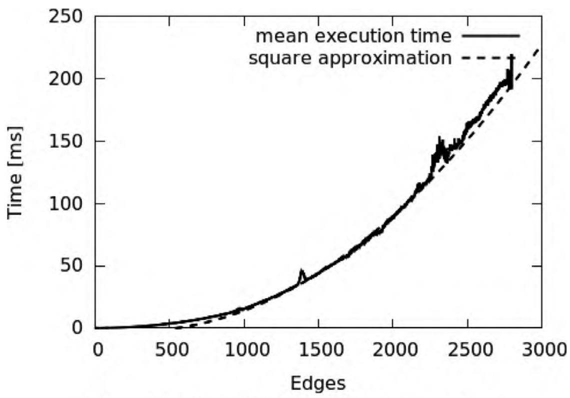

Fig. 7. Runtime of SBCA algorithm – edges

To measure the algorithm's accuracy and performance it had to compute the channel assignments for graphs with 4 to 1.000 nodes. For each amount of nodes, 10.000 random graphs were generated. The amount of edges varied in addiction to the random graph with 1 to 5 edges per node. The test run was performed on an IBM Thinkpad T43p laptop computer (Intel® Pentium® M CPU 2.13GHz with 2GB RAM, Linux Kernel 2.6.26).

The SBCA algorithm generated a valid channel assignment for every graph in a terrific time.Figure 6 and 7 show the results of the measurement. Under the test conditions, the SBCA algorithm has an approximately square runtime. It only needed 200ms to generate a channel assignment for a graph with 1.000 nodes or 2.800 edges, respectively. This is a really terrific result with respect to the performance of the node colouring algorithms determined in our former study [7]. With this results, we can say that the SBCA algorithm can be used for offline and online optimization of WLAN backbones, even if they tend to be huge.

VII. Conclusion

In this paper, we presented the SBCA algorithm for channel assignment on IEEE 802.11 wireless backbones. It is a centralized, greedy algorithm that computes the channel assignment steady and with high performance, which was showed by our measurement results. We also showed that the SBCA algorithm is finite. The SBCA itself is economical in usage of channels and interfaces with respect to cliques. However, with iterative refinement it is possible to generate a complete interference-free channel assignment. Thus, it can be used for offline and online channel assignment for wireless backbone networks of any extension. With its good performance, it can also be used in frequently changing network topologies.

Our future goal is to develop a overall solution for wireless backbones that collects all necessary topology information, deliver it to the node that calculates the channel assignment for the whole backbone and distribute it to all nodes in the backbone. Furthermore, it must also optimize the channel assignment for the ingress-/egress-APs with respect to the backbone and foreign APs.

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Фінстербуш М., Хенсген К., Шмідт П.

ОПТИМІЗОВАНИЙ ВИБІР КАНАЛУ ДЛЯ МУЛЬТИ-РАДІО IEEE 802.11 МАГІСТРАЛЕЙ

Ця стаття представляє Простий Алгоритм Магістрального Розподілу каналів (ПАМРК). Він використовується для оптимізації розподілу каналів в IEEE 802.11 бездротових магістральних мережах. У роботі відзначено деякі особливості у призначенні каналів магістралей і на прикладі показано роботу ПАМРК. Проведені дослідження доводять, що алгоритм працює дуже швидко і правильно.

Ключові слова: IEEE 802.11 призначення каналів, бездротові магістралі, mesh-мережі, оптимізація мереж.

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УДК 512.8

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GENERAL ASPECTS OF CORPORATION MANAGEMENT BASED ON INFORMATION SYSTEMS

The article discusses the problems in the integrated management of the contemporary business activities, and automatization of the activities in divided office-systems. The author gives the recommendations for the rational, management of the enterprise activities in the light of the modern information systems application.

Keywords: Information system, office-system, technological cycle, administrative management.

Nowadays a field that does not use computers is scarce to find. The state management bodies and political organization, private companies, industrial, economic, financial, transport, health care, etc. The complexity of the tasks, time limit of their implementation, and requirements for raising the results quali-