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Comparison between Vertex Merge Algorithm and Dsatur Algorithm

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Abstract: Problem statement: In this study, the channel allocation problem in direct sequence spread spectrum was investigated. First, Coloring in channel allocation has been discussed in detail. Second; a new graph model is proposed that namely Vertex Merge Algorithm (VMA). **Approach:** VMA try to solve channel allocation based on graph theory. **Results:** The problem is to assign channel to Access Point (AP) in such away that interference among access point is eliminated and the total number of channel is minimized. The proposed algorithm is also compared with Dsatur algorithm by input three graphs that are graph1, graph2 and graph3. **Conclusion/Recommendations:** Simulation results shows that the new graph model can provide minimum needed channel compared to Dsatur algorithm.

Key words: Spread spectrum, channel allocation, Dsatur algorithm, frequency hopping, coloring admissible, adjacency matrix

INTRODUCTION

The spectacular development of network and internet has a big impact to the companies in various types and sizes. The advanced wireless technologies support the development of network, internet and intranet capability for the mobile workers, isolated area and temporary facilities. Wireless networking expands and increases the capability of computer networking. The new technologies enable the wireless networking as one of access in higher velocity and qualified for the computer network and internet.

Wireless Local Area Networks (WLANs) have gained importance in the recent years as an Internet-access technology. As competition has driven down costs of WLAN equipment, wireless Internet access mechanisms are increasingly available in numerous public hot spots like coffee-shops, airports and hotels. Today numerous public places such as airports, cafeterias and even complete city centers are equipped with numerous Access Points (APs) to offer almost ubiquitous wireless connectivity. At the same time the increased density of WLAN access points has started to highlight the negative effects or shortcomings of the original IEEE 802.11 standards. Most importantly, no standard channel allocation method exists for WLAN access points. This has lead to the situation where large majority of APs is using default channel settings, leading to highly inefficient use of the already crowded spectrum in the ISM bands. This situation is especially critical in the 2.4 GHz band, due to the small number of non-overlapping WLAN channels available and coexistence problems with several other wireless technologies.

ISM bands are unlicensed frequency bands. These bands can be used freely and therefore there is only a slight control over them, so when selecting a channel to build a WLAN it is can expect that other devices may be using it. Although different spread spectrum techniques are defined (DSSS or FHSS) in order to minimize the effect of interferences and although the legal limits for low power transmissions are respected, the coexistence of different types of devices in nearby channels can seriously degrade the performance of a WLAN.

The problem gets worst in the 2.4GHz ISM band, where according to European regulatory bodies, 13 channels are defined, whose carriers go from 2.412 (channel 1),-2.472 GHz (channel 13), as shown in Fig. 1. Consecutive carriers are spaced 5MHz, whereas the spread signal bandwidth is about 24MHz, so it is only have as much as three non-overlapping channels (1, 6 and 11). It seems clear that in regions with a great density of nodes, three channels shall not be enough.

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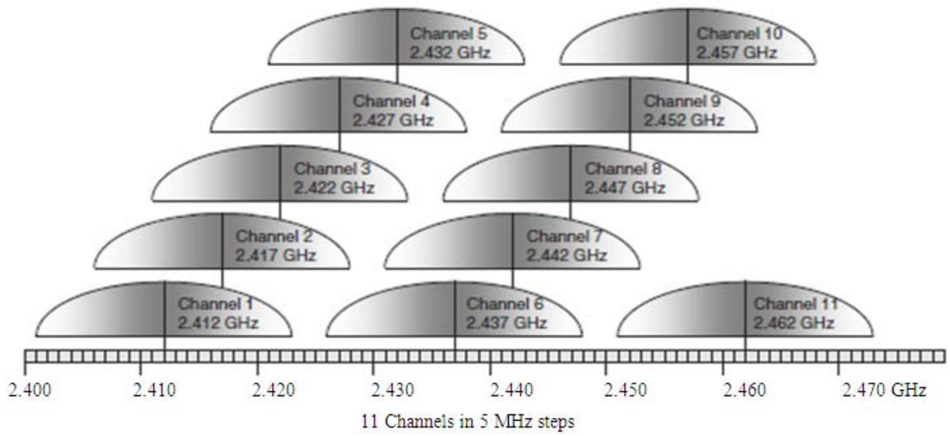


Fig. 1: DSSS channel allocation (Handrizal *et al*., 2009)

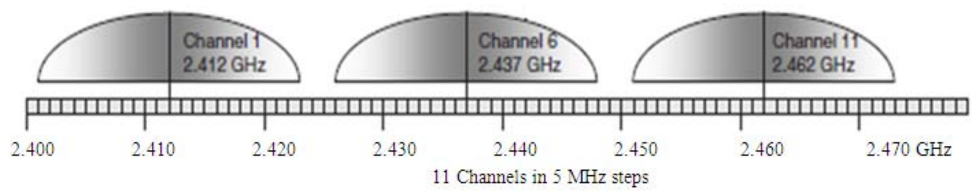


Fig. 2: DSSS non-overlapping channels (Handrizal *et al*., 2009)

With the common DSSS technology, only three non-overlapping channels are available, see Fig. 2 and no standard mechanism exists for the access points to dynamically select the channel to be used as to minimize interference with other APs.

Usage DSSS systems with overlapping channel (e.g., channel 1-2) in the same physical space would cause interference between the systems. DSSS systems using overlapping channel should not be co-located because there will almost always be a drastic or complete reduction in throughput. Co-located channel can be applied if as many as five separate channels.

Several research articles have been published regarding allocation channel. Among them were those by Al Mamun *et al*. (2009), Andre *et al*. (2005), Duan *et al*. (2010), Wang (2009), Juhos and Hemert (2006), Riihijarvi *et al*. (2005; 2006). Those articles revealed that channel allocation for DSSS is one of the current issues that still unsolved in channel allocation. Therefore, the study on this basis in initiated. One of the simplest algorithms is namely Dsatur algorithm (Riihijarvi, 2006). This algorithm determines the channel base on high degree of access points. It not always provides the minimum number of colors required to access point. This algorithm is enough practice for simple graph. However, this algorithm is not enough practice for complex graph.

MATERIALS AND METHODS

In this section it is shall formulate the channel allocation problem for DSSS in terms of graph-theoretic coloring problem. First it is recall shortly the statement of the coloring problem based on graph theory (Diestel, 2006) that is of interest in the channel allocation context.

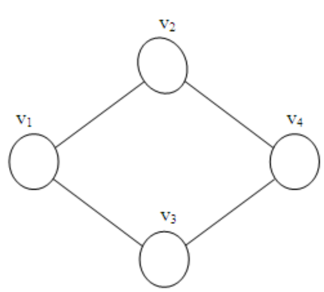
Suppose it is are given a simple graph G = (V,E), that is, a graph consisting of a set of vertex V and set of edges E connecting the vertex so, that loops (edges connecting a vertex to itself) and multiple edges between vertex are not allowed. Then a vertex coloring of G is a map: $V(G) \rightarrow F$, where F is a set of colors, usually some small subset of positive integers. It is shall call a coloring admissible, if $C(V_i) = C(V_j)$ for all adjacent V_i and V_j (that is, for those vertex connected by an edge). It is call an admissible coloring minimizing $|C(V)|$ an optimal coloring. The number of colors used by the optimal coloring is called the chromatic number of the graph.

Interference graphs: It is shall now formulate the channel allocation problem in terms of the terminology introduced in the previous section. Given a collection $\{v_i\}$ of access points, it is shall form an interference graph $G = (V_G, E_G)$ as follows. The vertex set V is simply identified with the set $\{v_i\}$. The set of edges E is constructed as the union of those pairs $\{v_k, v_l\}$ of vertex, that correspond to access points v_k and v_l that would interfere with each other's radio traffic should they be assigned to use the same channel. Finally, it is let F, the set of "colors", to be the collection of channels available to the access points. Now the channel allocation problem is simply finding of an admissible coloring of G with the color set F. It is shall call a coloring admissible, if $C(v_i)=C(v_j)$ for all adjacent v_i and v_j (that is, for those vertex connected by an edge). It is call an admissible coloring minimizing $\{C(v)\}$ an optimal coloring.

Naturally the size of the color set is greatly technology and legislation dependent. In most European countries, F = {1, 2… 13} for DSSS technologies, of which the subset F'= {1, 6, 11} corresponds to the non-overlapping channels.

Adjacency matrix: Suppose G is a graph with m vertex and suppose the vertex have been ordered, say, $v_i, v_j, \ldots, v_m$. As shows Fig. 3 graph and its matrix adjacent. Then the adjacency matrix $A(G) = [a_{ij}]$ of the graph G is the m × m matrix defined by:

$$a_{ij} = \begin{cases} 1, v_i v_j \in E_G \\ \\ 0, v_i v_j \notin E_G \end{cases}$$



(a)

	v1	v2	v3	v4
v1	0	1	1	0
v2	1	0	0	1
v3	1	0	0	1
v4	0	1	1	0

(b)

Fig. 3: Graph G with the matrix adjacent

The adjacency matrix A of a graph G does depend on the ordering of the vertex of G, that is, a different ordering of the vertex yields a different adjacency matrix. However, any two such adjacency matrices are closely related in that one can be obtained from the other by simply interchanging row and columns. On the other hand, the adjacency matrix does not depend on the order in which the edges (pairs of vertex) are input into the computer.

Proposed vertex merge algorithm: The problem of approximate vertex coloring is a much studied one and the number of available algorithms is vast. After considerable review effort it is decided to create a new algorithm which it is call the Vertex Merge algorithm (VMA). The algorithm is fundamentally deterministic, as opposed to many randomized algorithms proposed. This is necessary as the access points must naturally agree on the channels allocated.

VMA used some heuristic method to select a vertex to be colored, which it then colors using the first color consistent with the coloring problem statement. The heuristic used by the VMA is to find the subset of vertex with highest "degree", that is, the vertex with largest number of differently edge neighbors. If this subset contains only one vertex, it is chosen to be colored. If more than one vertex remains in the set, the selection is then made in the order of decreasing number of uncolored neighbors

Algorithm: The following is a step by step VMA:

- Arrange the vertex by decreasing order of degrees
- Choose the first uncolored vertex from the set
- Color the chosen vertex with the least possible color
- Merge the vertex with the first non-neighbor vertex
- Color the chosen vertex with the same color. If there is no more non-neighbor vertex, return to step 2
- If the entire vertex is colored, stop. Otherwise, return to Step 2

We demonstrate the steps of the algorithm with a small example. The input graph is shown below in Fig. 4 with $n = 6$ vertices labeled $V = \{1, 2, 3, 4, 5, 6\}$. The algorithm required3 coloring of the vertices using the set of colors {1, 2, 3} represented by red, green and blue respectively:

- Arrange the vertex by decreasing order of degrees. Vertex with highest degree is v_1 and v_5 then v_2, v_3, v_4, v_6 each with 2 degree. Then the sequence is $\{v_1, v_5, v_2, v_3, v_4, v_6\}$
- Choose the first uncolored vertex from the set. This causes vertex v_1 to be colored with color 1 (Fig.5)

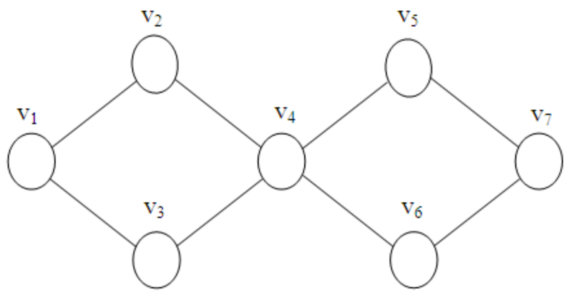


Fig. 4: Example graph

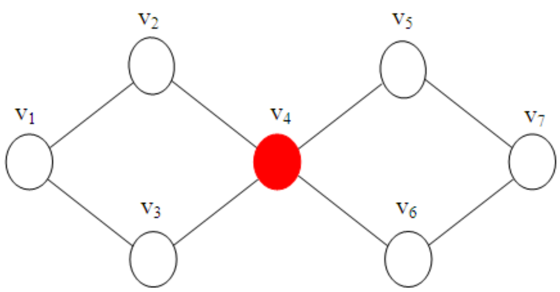


Fig. 5: Example graph with second step VMA

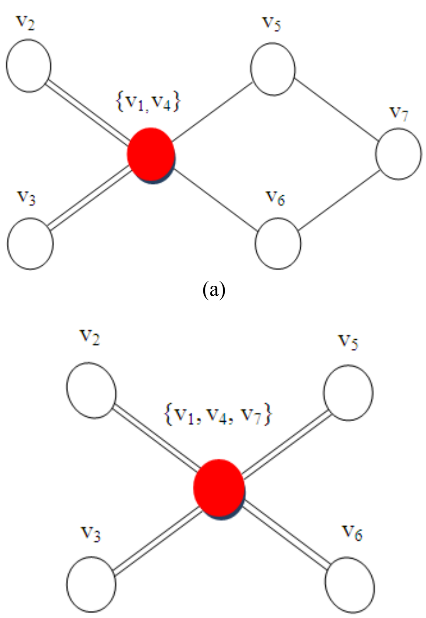


Fig. 6(a-b): Example graph with third step VMA

- Merge with the first non-neighbor vertex, in this case the vertex are not neighbor with v_1 are v_4. Thus that the v_1 merger into v_4. Then v_1 same color with v_4 (Fig.6)

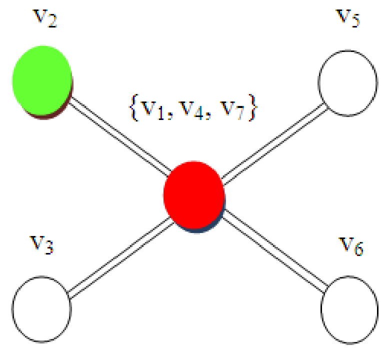


Fig. 7: Example graph with fourth step VMA

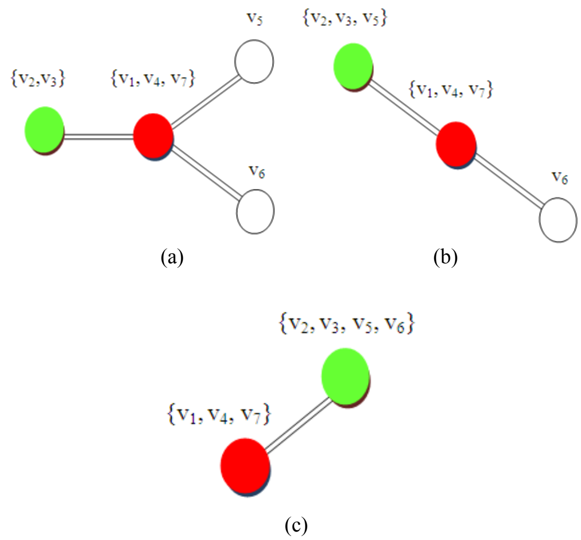


Fig. 8 (a-c): Example graph with fifth step VMA

If there is no more non-neighbor vertex, choose first uncolored vertex from the set:

- Now sequence uncolored vertex which have the highest degree is $\{v_5, v_2, v_3, v_6\}$
- Choose the first uncolored vertex from the set. This causes vertex v_5 to be colored with color 2 (Fig. 7)
- Merge with the first non-neighbor vertex, in this case the vertex are not neighbor with v_5 are v_2, so that the v_5 merger into v_2. Then v_2 same color with v_5 (Fig. 8)

If there is no more non-neighbor vertex, choose first uncolored vertex from the set:

- Now sequence uncolored vertex which have the highest degree is $\{v_3, v_6\}$
- Choose the first uncolored vertex from the set. This causes vertex v_3 to be colored with color 3 (Fig. 9).

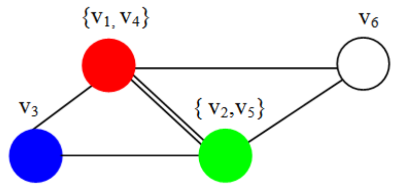


Fig. 9: Example graph with fifth step VMA

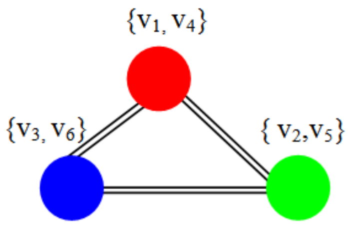


Fig. 10: Example graph with last step VMA

- Merge with the first non-neighbor vertex, in this case the vertex are not neighbor with v_3 are v_6, so that the v_3 merger into v_6. Then v_3 same color with v_6 (Fig. 10)

If all vertex are colored, thus the algorithm terminates and the final coloring is given by $C(v_1, v_4) = 1$, $C(v_2, v_5) = 2$, $C(v_3, v_6) = 3$. Finally, V_G, is colored using the smallest color that is chromatic number is 3.

Of course the number of colors needed to solve the vertex coloring problem for the interference graph is of great interest. This is especially important in the case of DSSS, as the number of colors available is only three, supposing that it is want usage only non-overlapping channels. From the example graph, it is required 3 colors for coloring the graph. It means that required 3 channels for DSSS, which is channel 1, channel 6 and channel 11.

RESULTS

In this section, it is simulation the VMA compare with Dsatur algorithm by input three complex graphs that is graph1 with *n* = 10 vertices labeled *V* = {1, 2, 3, 4, 5, 6, 7, 8, 9, 10}, graph2 with *n* = 14 vertices labeled *V* = {1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14}, and graph3 with *n* = 17 vertices labeled *V* = {1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17}. In the each graph, vertex equal the access point (AP).

Result simulation: Result simulation input three complex graphs will be shows in Table 1.

Table 1: Simulation Result VMA

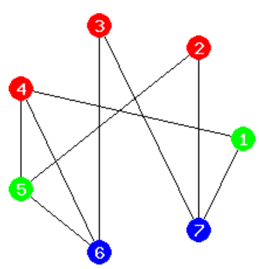
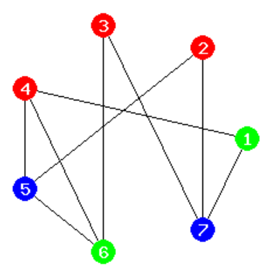
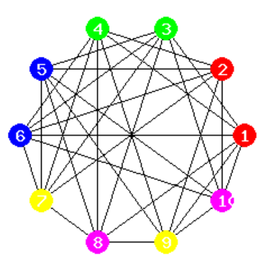
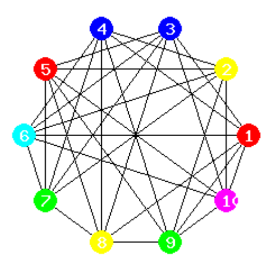
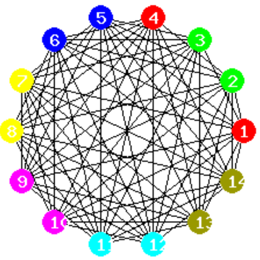
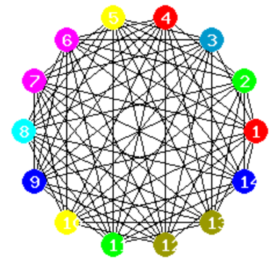
	Output	
Input	VMA	Dsatur
The-graph-1.txt		
		
Number of color	χ(G) = 3 C(2,3,4) = 1, C(1,5) = 2, C(6,7) = 3	χ(G) = 3C (2,3,4) = 1, C(1,6) = 2, C(5,7) = 3
The-graph-2.txt		
		
Number of color	χ(G) = 5	χ(G) = 6

Table 1 continuous

	C(1,2) = 1, C(3,4) = 2. C(5,6) = 3 C(7,9) = 4, C(8,10) = 5	C(1,5) = 1, C(7,9) = 2, C(3,4) = 3, C(2,8) = 4, C(10) = 5, C(6) = 6
The-graph-3.txt		
Number of color	$\chi(G) = 7$ C(1,4) = 1, C(2,3) = 2. C(5,6) = 3 C(7,8) = 4, C(9,10) = 5, C(11,12) = 6, C(13,14) = 7.	$\chi(G) = 8$ C(1,4) = 1, C(2,11) = 2, C(9,14) = 3, C(5,10)=4, C(6,7) = 5, C(8) = 6, C(12,13) = 7, C(3) = 8

DISCUSSION

From the simulation results of the three graphs in the Table 1can be seen that:

A. For input graph1 can be shows that output the simulation given difference result for all algorithms, which are required 6 colors for Dsatur algorithm and 5 colors for VMA. Its means required 6 channels for Dsatur algorithm and 5 channels for VMA. That is:

1. Dsatur algorithm :
   - channel 1 for AP_1 and AP_5
   - channel 4 for AP_7 and AP_9
   - channel 7 for AP_3 and AP_4
   - channel 9 for AP_2 and AP_8
   - channel 11 for AP_{10}
   - channel 13 for AP_6
2. VMA :
   - channel 1 for AP_1 and AP_2
   - channel 4 for AP_3 and AP_4
   - channel 7 for AP_5 and AP_6
   - channel 10 for AP_7 and AP_9
   - channel 13 for AP_8 and AP_{10}

B. For input graph2 can be shows that output the experiment given difference result for all algorithms, which are required 8 colors for Dsatur algorithm and 7 colors for VMA. Its means required 8 channels for Dsatur algorithm and 7 channels for VMA. That is:

1. Dsatur algorithm :
   - channel 1 for AP_1 and AP_4
   - channel 3 for AP_2 and AP_{11}
   - channel 5 for AP_9 and AP_{14}
   - channel 7 for AP_5 and AP_{10}
   - channel 9 for AP_6 and AP_7
   - channel 11 for AP_8
   - channel 12 for AP_{12} and AP_{13}
   - channel 13 for AP_3
2. VMA :
   - channel 1 for AP_1 and AP_4
   - channel 3 for AP_2 and AP_3
   - channel 5 for AP_5 and AP_6
   - channel 7 for AP_7 and AP_8
   - channel 9 for AP_9 and AP_{10}
   - channel 11 for AP_{11} and AP_{12}
   - channel 13 for AP_{13} and AP_{14}

C. For input graph3 can be shows that output the experiment given difference result for all algorithms, which are required 8 colors for Dsatur algorithm and 6 colors for VMA. Its means required 8 channels for Dsatur algorithm and 6 channels for VMA. That is:

1. Dsatur algorithm :
   - channel 1 for AP_1, AP_6 and AP_{13}
   - channel 3 for AP_5, AP_{10} and AP_{15}
   - channel 5 for AP_2, AP_9 and AP_{14}
   - channel 7 for AP_{11} and AP_{17}
   - channel 9 for AP_4 and AP_7
   - channel 11 for AP_3 and AP_8
   - channel 12 for AP_{16}
   - channel 13 for AP_{12}
2. VMA :
   - channel 1 for AP_1, AP_4 and AP_7
   - channel 4 for AP_2, AP_5 and AP_8
   - channel 7 for AP_3, AP_6 and AP_9
   - channel 9 for AP_{10}, AP_{13} and AP_{16}
   - channel 11 for AP_{11}, AP_{14} and AP_{17}
   - channel 13 for AP_{12} and AP_{15}

From the discussion can be shows comparison between Dsatur and VMA in graphic on Fig. 11.

From the Fig. 11 can be shows that number of channel required on VMA less than Dsatur algorithm.

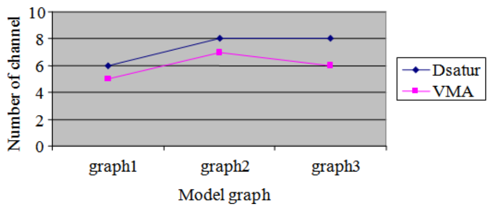


Fig. 11:Comparison between Dsatur algorithm and VMA

CONCLUSION

In this study, it is introduced a new graph model which it is call the Vertex Merge Algorithm (VMA) for channel allocation problems on direct sequence spread spectrum. The problem of minimizing the number of channels required to eliminate interference is a graph coloring problem. Results from the simulation study reveal that the new graph model can provide reduce the channel required on DSSS. It is forms a good basis for developing efficient graph coloring algorithms, because of its aims to reduce the color required and better result compare with Dsatur algorithm.

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