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An Approach for Non-Conflict Time Scheduling in Packet Radio Networks with TDMA

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Introduction

In packet radio networks with time division multiply access (TDMA), each one of the nodes is transmitting in determined time intervals, called time slots [1]. The non-conflict functioning of the radio network requires that the neighbouring nodes must not interfere in the environment during one and the same time slot [1, 2]. Some approaches for non-conflict scheduling are described in the references, which use neural networks [1]. The main shortcoming of these approaches is the lack of a guarantee for convergency, while the approach suggested is always convergent. No proof is necessary for this confirmation since it is obvious – the convergence is guaranteed by the increase of time slots number when necessary.

The formalization of the procedures defining the slots number and the construction of a non-conflict schedule is very important in networks with a large number of nodes.

Approach description

A necessary condition is to have the topology of the packet radio network with time division multiply access, which gives information about the neighbouring nodes. A list with the following structure is filled for every node – the node number, the "neighbouring" and "non-neighboring" field, the field "neighbouring" containing the numbers of all the nodes, with which it is directly connected, while the "non-neighboring" field – all the remaining ones. The next stage is connected with the determining of the number of "time slots" – *m*, their initial defining being not final. During the process of schedule construction the increase of *m* may be implied. In order to define *m*, the node with a "neighbouring" field which consists of the maximum number of members, is searched for in the lists. S_{max} denotes the maximal number of "neighbouring" nodes and then *m* is defined by the formula $m = S_{max}+1$. It is assumed that *i* is the one, which possesses the maximal number of "neighbouring" nodes. The strategy selected is to represent node i and its neighbouring nodes as basic in every of the defined slots, m in number (each slot is assigned a node). For each one of the time slots a list is defined comprising of: the time slot number, field "represented" and field "obligatory absent". The "represented" field contains initially only one number per a node (node i or any of its neighbouring). The field "obligatory absent" includes at first only the neighbouring nodes of the node represented in the given slot.

Node i and its neighbours only are located in the time slots at this stage, the rest of the nodes, non-neighbouring to node i, with numbers found in the "non-neigbouring" field of node i list, remain to be distributed. It is assumed that the location can start from the non-neigbouring to node i, which possesses the highest number and from a slot with number one. It is also possible to start from the lowest number of a non-neigbouring node, as well as from a slot with number m or from the highest number of a non-neigbouring node and a slot with number m, or from the lowest number of a non-neigbouring node and a slot with number one, but this will not lead to any advantage, just to another schedule.

The procedure checks at first whether the non-neigbouring node with the highest number j is not in the "obligatory absent" field of slot No 1 (surely it is not present for the first iteration). Hence, node j can be represented in slot No 1, the list of which gets a new form – in the field "represented", nodes i and j are already present, while in the "obligatory absent" field besides the numbers of the neighbouring to node i, the numbers of the neighbouring to node j are also present. The same procedure is executed with the next number of the non-neighbouring to node i, node k ($k<j$) and slot No 2. Naturally the list of slot No 2 is altered in an analogous way to this of slot No 1. After the slots are over under the condition that there are still non-neighbouring nodes to node i, that are not distributed, it is started from slot No 1. There is a real possibility some of the non-neigbouring to node j nodes to be inappropriate for representation in the initially defined m slots. In order to ensure convergency of the procedure, the number of the slots is increased until all the nodes in the network can be represented.

The approach is formally described as follows:

1. S_i denotes the set of nodes neighbouring to node i.

2. N_i denotes the set of nodes non-neigbouring to node i.

3. W denotes the set of all the nodes in the network, having in mind that $W=S_i+N_i$ for every node; i.e. for $i=1$ upto n.

4. For $i=1$ upto n this set S_i is looked for, which contains the maximum number of members and is denoted by S_{max}.

5. The number of the time slots is defined according to the formula: $m=S_{max}+1$.

6. The represented and obligatory absent nodes are defined for each one of the time slots from P_1 upto P_m.

7. The node with the highest number among the set of the undistributed in the time slots nodes is selected and it is checked in which one of the time slots it can be represented, starting from P_1. It should be accounted, that the addition of a new node to a given time slot causes a change in the obligatory absent field of this slot. This iteration continues upto the last one, i.e., upto the lowest number of nodes. It is possible some nodes to remain undistributed in the slots so defined.

8. If some undistributed nodes are present, new time slots are added until the entire finishing of all the nodes in the network. It is obvious that the process is always convergent.

An example realization of the approach

The formal approach for constructing a non-conflict schedule is illustrated by a twelve-nodes packet radio network with time division multiply access. Fig. 1 shows the network topology.

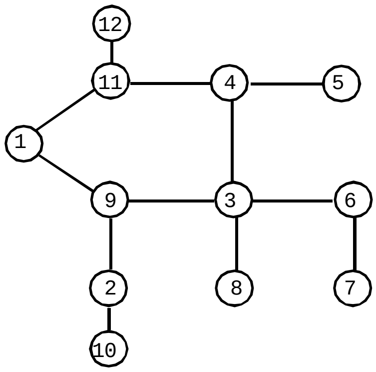

Fig. 1

For each one of the nodes a list is made with the following structure: on one side the nodes, that are neighbouring to the given node are included, on the other – the rest of them. The list is formed as Table 1.

Table1

Node No	Neighbouring	Non-Neighbouring
1	9, 11	2, 3, 4, 5, 6, 7, 8, 10, 12
2	9, 10	1, 3, 4, 5, 6, 7, 8, 11, 12
3	4, 6, 8, 9	1, 2, 5, 7, 10, 11, 12
4	3, 5, 11	1, 2, 6, 7, 8, 9, 10, 12
5	4	1, 2, 3, 6, 7, 8, 9, 10, 11, 12
6	3, 7	1, 2, 4, 5, 8, 9, 10, 11, 12
7	6	1, 2, 3, 4, 5, 8, 9, 10, 11, 12
8	3	1, 2, 4, 5, 6, 7, 9, 10, 11, 12
9	1, 2, 3	4,5,6,7,8,10,11,12
10	2	1, 3, 4, 5, 6, 7, 8, 9, 11, 12
11	1, 4, 12	2, 3, 5, 6, 7, 8, 9, 10
12	11	1, 2, 3, 4, 5, 6, 7, 8, 9, 10

The strategy for initial determining of the time slots in the schedule is as follows: this node is searched for, in the neighbouring field of which there are maximum members. For the example considered this is node 3, its neighbouring field in the list containing four nodes (4, 6, 8 and 9). The number of the time slots is determined from that, as $m = S_{max} + 1$, i.e. for the case $m = 5$. The node 3 and its neighbours with numbers 4, 6, 8 and 9 are represented in every one of the so defined slots according to the strategy selected.

In slot No 1 node 3 is represented and towards it a list is attached of the nodes, represented in it and of those that cannot be obligatorily represented in this slot. This approach is applied for each one of the slots. The result is given in Table 2.

Table 2

Slot No	Represnted	Obligatory absent
1	3	4, 6, 8, 9
2	4	3, 5, 11
3	6	3, 7
4	8	3
5	9	1, 2, 3

At this stage the distribution of only five from the twelve nodes in the network is realized. The nodes remaining for distribution are obtained from the list of node 3 – these are the nodes of the "non-neighbouring" field, namely 1, 2, 5, 7, 10, 11, 12.

The approach which begins the distribution from the node with the highest number is accepted (for this case it is 12) and slot No 1. The procedure checks at first whether node 12 is not present in the "obligatory absent" field of slot No 1 (it is obvious that for the first iteration this check is unnecessary).

In the case discussed node 12 is not present in the "obligatory absent" field for slot No 1 and besides this it is non-neighbouring to node 3, represented in slot No 1, which is checked by the procedure - in the field "non-neighbouring" from the list of node 3, node 12 must be present.

The same procedure is applied for node 11 and slot No 2. There is a restriction in this case because it is neighbouring to node 4 (it is not in the "non-neighbouring" field from the list of node 4, represented in slot No 2).

The procedure discovers whether node 11 can be represented in slot No 3. In the field "obligatory absent" of slot No 3, node 11 is not present, so it should be checked in the list of node 6 if node 11 is available in the "non-neighbouring" field. It is there, hence node 11 can be represented in slot No 3.

The next node is No 10, for which the procedure checks whether it can be represented in slot No 4. Node 10 is not present in the "obligatory absent" field of slot No 4 on one side, and on the other – it is non-neighbouring to node 8, apriori represented in slot No 4, which enables its representation in the same slot.

The same procedure is applied for node 7 and slot No 5. The check shows that node 7 is not in the "obligatory absent" field in the list for slot No 5 and the next check is whether it is not neighbouring to the apriori represented node 9 in slot No 5. The check proves that it is not neighbouring to node 9, because it is present in the "non-neighbouring" field in the list of node 9, which enables the representation of node 7 in slot No 5.

The initially defined slots have finished, three nodes have remained undistributed – 5, 2 and 1.

The increase in the slots number is still not necessary since the procedure has not been applied for all the nodes and all the primarily determined slots. The lists of the slots are modified and they obtain the form, shown in Table 3.

Table 3

Slot No	Represnted	Obligatory absent
1	3, 12	4, 6, 8, 9, 11
2	4	3, 5, 11
3	6, 11	3, 7, 1, 4, 12
4	8, 10	3, 2
5	9, 7	1, 2, 3, 6

The modification consists in the expansion of the lists with numbers of the newly represented nodes, adding the numbers of the neighbouring nodes to the newly represented in the "obligatory absent" field. For this purpose the "neighbouring" fields from the nodes lists are used.

According to the strategy chosen the procedure is applied at first for node 5 and slot No 1. The check in the “obligatory absent” field shows that node No 5 is not from the enumerated ones and therefore it can be represented in slot No 1.

The same procedure is applied for node 2 and slot No 2 and the result is that node 2 can be represented in slot No 2 because it is unavailable in the “obligatory absent” field.

The last node not distributed is with No 1 and the slot, in which the distribution procedure is trying to represent it is with No 3. Information is obtained from the list of slot No 3 about the fact, that node 1 is in the “obligatory absent” field, which forbids its representation in this slot. The procedure chooses the next slot No 4, from the list of which it can be seen that node 1 can be represented in this slot for it is not found in the “obligatory absent” field.

The final form of the schedule is given in Table 4.

The non-conflict scheduling for a twelve-nodes packet radio network with time division multiply access is shown in Fig. 2.

Number of the represented node

Slot	1	2	3	4	5	6	7	8	9	10	11	12
P1			1		1							1
P2		1		1								
P3						1					1	
P4		1						1		1		
P5							1		1			

Fig. 2

The nodes numbers are written on the abscissa axis, while the ordinate contains the numbers of the time slots, indicating by one the representation of the given node in a corresponding slot.

Table 4

Slot No	Represented	Obligatory absent
1	3, 12, 5	4, 6, 8, 9, 11, 4
2	4, 2	3, 5, 11, 9, 10
3	6, 11	3, 7, 1, 4, 12
4	8, 10, 1	3, 2, 9, 11
5	9, 7	1, 2, 3, 6

Conclusion

The approach has achieved two purposes – automatic determination of the time slots number in the process of schedule construction and obtaining a non-conflict schedule. The lists formation for the separate nodes is the primary information, entered at the beginning of the process, using a radio network topology for the purpose. This could be a labour-consuming process for networks with a great number of nodes, which is a shortcoming of the approach, but having in mind that the design of a non-conflict schedule for such networks is difficult enough, and in most of the cases – impossible, it could be neglected.

The advantage of the formal approach described is that it is always convergent, which is achieved with the increase of the time slots number.

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Подход для определения бесконфликтного расписания в пакетных сетях с коллективным доступом и времеделением

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(Резюме)

Предложен формализованный подход для определения бесконфликтного расписания в пакетных сетях с коллективным доступом и времеделением. Показано значение подхода в сетях с большим числом узлей. Подход иллюстрован при помощи примера радиосети с двенадцатими узлями.