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To cite this version:

Anis Laouti, Paul Mühlethaler, Abdellah Najid, Epiphane Plakoo. Simulation Results of the OLSR Routing Protocol for Wireless Network. [Research Report] RR-4414, INRIA. 2002. inria-00072174

HAL Id: inria-00072174
https://hal.inria.fr/inria-00072174

Submitted on 23 May 2006

INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

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No 4414

Mars 2002

THÈME 1

Rapport
de recherche

ISSN 0249-6399 ISRN INRIA/RR--4414--FR+ENG

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Thème 1 — Réseaux et systèmes
Projet HIPERCOM

Rapport de recherche n ° 4414 — Mars 2002 — 24 pages

Abstract: In this research report, we present simulation results for the Optimized Link State Routing protocol: "OLSR". "OLSR" is a routing protocol currently submitted at the IETF in the Mobile Ad-hoc NETwork workgroup. "OLSR" is a proactive protocol, thus it periodically sends "control" packets to build and up-date the topolgy. The aim of this article is to study the performance of the OLSR protocol. Although most of the results that we show remain valid for any kind of above medium access control and physical layer, the simulation results were obtained with an IEEE 802.11 medium access control and physical layer. The key parameters that we evaluate in this article, include: the overhead incurred by the routing protocol, the percentage of packets lost in the control packets and the lack of routes due to control packet loss. We also study the benefit of a genuine optimization of the "OLSR" protocol: the multipoint relay optimization. We test the "OLSR" capability to support mobility.

Key-words: Adhoc Network, Routing protocol, Wireless Local Area Network, IEEE 802.11 standard, performance evaluation, hidden nodes, spatial reuse.

(Résumé : tsvp)

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Résultats de Simulation pour le Protocole de Routage OLSR pour Réseau sans Fil

Résumé : Dans ce rapport de recherche, nous proposons de présenter des résultats de simulation pour le protocole de routage pour réseau mobile : “OLSR” pour Optimized Link State Routing protocol. “OLSR” est actuellement présenté à l’IETF dans le groupe de travail Mobile Ad-hoc NETwork (MANET). OLSR est un protocol proactif donc il envoie périodiquement des paquets de “contrôle” pour construire et mettre à jour la topologie du réseau. Bien que la plupart des résultats que nous montrons restent valides pour n’importe quelle sorte de couche d’accès et de niveau physique, les résultats présentés sont obtenus avec une couche MAC et physique IEEE 802.11. Parmi les paramètres clef que nous évaluerons dans cet article, nous trouvons: la charge induite par le traffic de contrôle pour le routage, le pourcentage de perte de paquets de contrôle, les défauts de route dus au perte de paquets de contrôle. Nous étudierons aussi l’optimisation particulière d’OLSR des relais multipoint. Nous testerons aussi les performances d’OLSR dans des scnarios avec mobilité.

Mots-clé : Réseau Adhoc, Protcole de Routage, Réseau Local sans fil, Standard IEEE 802.11, éavluation de performance, Noeuds cachés, Réutilisation spatiale.

1 Introduction

The wide diffusion of wireless local area network (WLAN) technologies e.g. IEEE 802.11 [6], HiPERLAN [5], Bluetooth has opened up a new technical area: mobile adhoc networking. In fact, wireless technology removes the burden of cables and allows to build network on demand see figure 1. When the network covers large areas one needs relaying packets to insure the network connectivity. Thus we are facing routing issues. These problems have received a strong interest from the academic world. At the Internet Engeneering Task Force (IETF) a new working group MANET (Mobile Adhoc NETwork) was set up in 1997 to study routing in mobile ad-hoc networks.

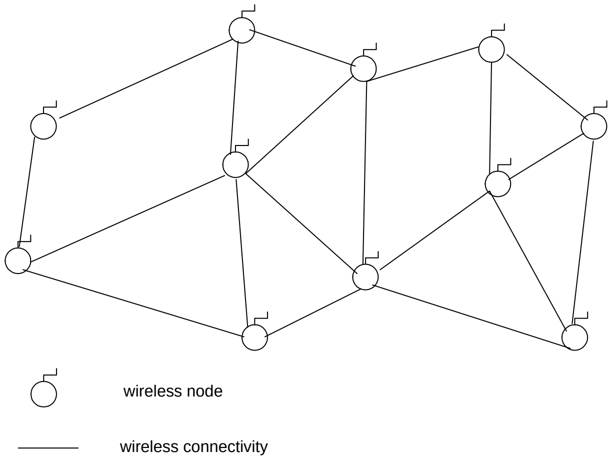

Figure 1: An adhoc network which needs routing to ensure a proper connectivity.

Moreover the emergence of widely accepted wireless standards such as the IEEE 802.11 is strongly in favor of using this standard as MAC and physical layer below a routing protocol. That is precisely what we are doing in this article. This paper is organized as follows; the next section describes what an adhoc network is and the two main kinds of routing schemes for a mobile adhoc network : on demand routing protocols and proactive protocols. Section 3 first describes the mode of operation of "OLSR". Section 4 provides a brief overview of the IEEE 802.11 access technique and briefly describes the simulation model. Section 5 presents simulation results. The first subsection is devoted to simulations on small or average size networks. A second subsection is devoted to large networks with a large number of nodes. In each of these sections we study the overhead incurred by the control packet of the routing protocol, the average route availability in the routing tables. Simple topologies and traffic loads are described. Both static scenarios and scenarios with mobility are investigated. We interest in greater depth for the genuine optimization of OLSR Multipoint relay optimization.

2 Adhoc network and routing protocol

2.1 Adhoc network

An adhoc network is a network which is spontaneously generated by nodes within a given area. These nodes are expected to be connected and it is usually admitted that collaboration is required, which therefore means that every nodes must in principle handle traffic even if it is not its recipient. Adhoc networking leads to numerous problems. The issues that are mostly encountered are: routing, configuration, administration, and security.

Configuration and routing are the two main problems since they are mandatory to ensure the network connectivity. The configuration issue is generally ignored and static addresses are used. Routing is then the major problem since routing is necessary to ensure the network connectivity. Another reason which probably explains the interest raised by the routing issue is the existing state of art in routing for wired networks. The routing issue is also a suitable matter for academic studies.

2.2 Routing protocol in adhoc network

Routing is rather an old subject. In cable network, the existing literature usually defines two classes of routing protocols: distance vector routing protocols and link state routing protocol.

In a“distance vector” routing protocol, a node sends to its neighbor nodes a table which indicates the nodes that it can reach and for each node within reach the distance to this node. It can be shown that in normal operation this scheme will converge and will provide the shortest path routing to any given destination. In a “link state” routing protocol, a node broadcasts over the network the list of its neighbors. Thus in normal operation all the nodes have the neighborhood of all the nodes. Therefore a straigthforward algorithm can compute the whole network topology, we have all the routes and thus of course the shortest path to all the destinations.

Routing in a wireless networks leads to similar problems as for a wired network. However the wireless media are inherently less efficient than wired media in terms of bandwidth. Moreover a wireless router which only uses one interface (usually assumed) can not send traffic to two neighbors simultaneously, unlike a wired router. The scarce ressources of the wireless media probably explain why other types of routing protocols have been designed to optimize bandwidth requirements. This reason probably explains why in a mobile adhoc network a new kind of protocol has been introduced: reactive protocols. These protocols only build a route when an application requires it. Therefore in wireless routing protocols one usually distinguishes between

- reactive routing protocols,
- proactive routing protocols.

In reactive routing protocols a route to a destination is created only on demand. This means that when a node must send its packet to a destination, a routing request is sent in the network, this request aims to obtain a route to the destination. The protocols belonging to this class, include "AODV","DSR" and "TORA"[9, 10, 11], which have been proposed to the IETF MANET workgroup. On the other hand, proactive protocols periodically send control packets to maintain the knowledge of the network topology. Among protocols of this class proposed to the IETF, one can find "OLSR" , "FSR" and "TBRPF"[3, 13, 12].

3 Description of the OLSR protocol

3.1 The OLSR protocol

The "OLSR" Optimized Link State Routing protocol [3] is a proactive routing protocol and it is also a link state protocol. "OLSR" uses two kinds of control packets: "hello" packets and "TC" packets (TC for Topology Control).

"hello" packets are used to build the neighborhood of a node and at the same time "hello" packets are used to compute the "multipoint" relays of a node (the concept of multipoint relay will be explianed latter) "hello" packets are sent in broadcast at one hop. "TC" packets are broadcast in the whole network. "TC" packets broacast by a node contain the list of its neighbors. Actually this list does not contain all its neighbors but a subset, which will be explained latter. A "hello" sent by a packet contains the list of neighbor. OLSR uses periodic broadcast of hello packets to sense the neighbourhood of a node and to verify the symmetry of radio links. Hello packets sent by a node contain the status of its links with the other nodes in its neighbourhood. This status can be :asymmetric,symmetric,or multipoint relay.

During the initialisation phase, when a node A receives a hello packet from a neighbour, say node B, this station sets in its neighbour table station A with a status "Asymmetric". Then, when node B send its next hello packet, B will send in its hello packet that A is its neighbour table with status "Asymmetric". At the reception of the hello packet from B, A will put in its neighbour table B with the status "Symmetric". A will then send a hello packet in which B will appear with the status "Symmetric" and B will update the status of A in its neighbour table and will register it as "Asymmetric". See figure 2.

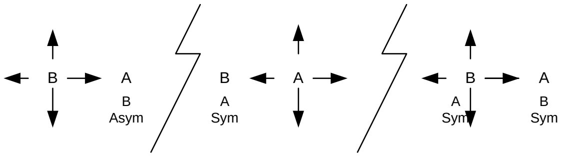

Figure 2: Neighborhood control: exchange of "hello packets" .

Multipoint relay is a special status that will permit optimisation of broadcast. Let us consider figure 3. In this figure, we have shown a node with its neighbors and its two hop neighbors. A two hop neighbors of a node is a neighbor of its neighbors which is not already a neigbor. To obtain a complete broadacast, its is sufficient that the packet be repeated by a convenient subset of its neighbor. This subset must be computed in such a way that all the two hop neighbor receive the packet. If this requirement is achieved, it can be shown by induction that a complete broadcast is obtained. Actually, this technique provides a way to locally compute a spanning tree. For a given node the computation of the subset of its neighbor that satisfies the two hop coverage is an NP hard problem. However one can find simple heuristics, a very natural heuristic is derived from the greedy algorithm and selects at each step the neighbor which covers the maximum number of two hop neighbors.

The "TC" packets are sent periodically by a node. This packet contains the list of its multipoint relay i.e. the subset of nodes which make it possible to cover all its two hop nodes. The "TC" packets are sent in broadcast and with the multipoint relay rule only the multipoint relay nodes will retransmit the packet. A sequence number is used to avoid loops due to infinite retransmission of the packet. Another field is used to allow to know which of two "TC" packets is the more uptodate. Although a node does not send all its neighborhood in the "TC" packet, it can be shown that this information is sufficient to build a topology of the network givin the shortest path, This was shown for the first time in [2].

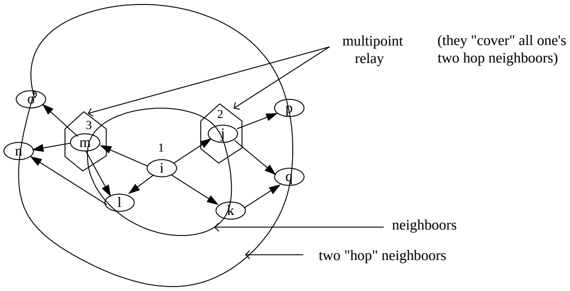

Figure 3: Two hop neighbors and "multipoint relay" of a node

In OLSR we use the figures that are given in the table below

period or time to live	time(s)
hello period=p_{hello}	2
hello time to live= TTL$_{hello}$	6
TC period=p_{TC}	6
TC time to live=TTL$_{TC}$	20

Table 3: Constants used in OLSR

4 The IEEE 802.11 standard and the simulation model

4.1 The IEEE standard

4.1.1 IEEE 802.11 physical layer

We use the IEEE 802.11 direct sequence (DS) system. This physical layer can offer a throughput of 1 or 2 and 5.5 or 11 Mbit/s with the IEEE 802.11b standard. We have used the following assumptions: the broadcast packets are sent at 1 Mbps, the point to point packets are sent at 11 Mbps. Our simulation take into account the exact overhead caused by the physical layer. For further detail refer to [6] and [4]

4.1.2 The IEEE 802.11 MAC scheme

The MAC scheme of the IEEE 802.11 [6] is primarily based on a CSMA (Carrier Sense Multiple Access) scheme. The main principle of this access technique is a preventive listening of the channel to be sure that no other transmission is on the way before transmitting its packet. If the sensing of the channel indicates an ongoing transmission then the node waiting to start its transmission draws a random back-off delay. At the end of the outgoing transmission this back-off will be decremented whenever the channel is free (no carrier sensed). The node starts its transmission when its back-off delay reaches 0. This mechanism is presented in figure 2.

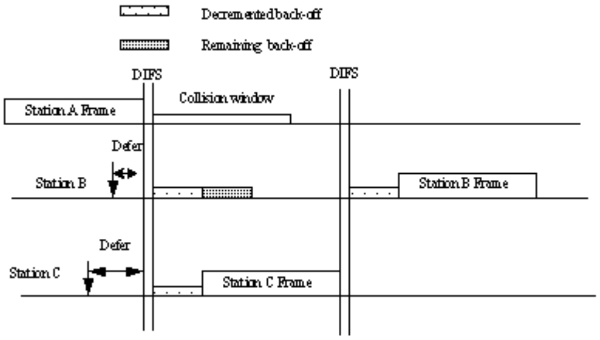

Figure 4: The IEEE 802.11 backoff mechanism

With radio signals, it is not possible to directly detect collisions in a radio network. The IEEE 802.11 standard uses an acknowledgement for a point to point packet, broadcast packets are not acknowledged. When point to point packets are not acknowledged they are retransmitted but the backoff window is increased with each unsuccessful transmission.

4.2 The simulation model

We use the same simulation model as that used in [4].

4.2.1 Physical layer model

The main assumption of our physical layer model is that we have a linear superposition of signals sent by potential transmitters. This model naturally leads to the introduction of a transmission matrix $cs_{i,j}$ which gives the strength of the signal sent by node j to node i. The signal strength $Pow(i)$ received by node i is therefore $Pow(i) = \sum_{j=1}^{n} a_j cs_{i,j}$ where $a_j = 1$ if node j is transmitting, or $a_j = 0$ otherwise. Simple propagation laws of radio signals usually have the following expression $cs_{i,j} = \frac{P_j}{r_{i,j}^{\alpha}}$ where P_j denotes the power sent by node j, r_{ij} denotes the distance between node i and node j and α denotes the signal decay, usually $2 \leq \alpha \leq 6$. Of course this is an approximate model. However it should be noted that the only important assumption is the linearity of the model. We can actually use this linear model with all existing propagation models or pre-computed figures. All we will need is the transmission matrix $cs_{i,j}$.

We need to introduce the carrier sensing parameter. This parameter is a threshold above which the channel is assumed to be busy. In a CSMA protocol this threshold makes it possible to decide whether the channel is idle or busy. We will call this parameter the $carriersenselevel$.

We need then to precise conditions to ensure the correct reception of packets. We will assume that a packet sent by node i to node j in the transmission interval $[t_b, t_e]$ is correctly received by node j if

- $\forall t \in [t_b, t_e] \quad cs_{i,j}(t) \geq datalevel$
- $\forall t \in [t_b, t_e] \quad \frac{cs_{i,j}(t)}{\sum_{k \neq j} a_k(t) cs_{i,k}(t)} \geq capturelevel$

We have introduced two parameters : the $''datalevel''$ and the $''capturelevel''$. The $''datalevel''$ corresponds to the signal strength necessary to successfully transmit a signal. The $''capturelevel''$ corresponds to the minimum value of a signal to noise ratio to successfully decode a transmission.

4.2.2 Medium access scheme simulation model

This model is very close to real operations.However, it contains two simple approximations which simplify the acknowledgement and the RTS/CTS schemes. A complete description of the this model can be found in [4].

4.2.3 Simulation tool

The OPNET simulation tool is one of the most widespread tools. This tool provides a scheduler, an easy way to code state automatons and a very powerful graphic interface to present simulation results. OPNET also contains a lot of codes dedicated to simulating radio links, access protocols and various protocol layers. We tried to use these codes but they resulted in simulations of long duration. Since the speed of our simulation was of prime importance to us, we decided not to use any of these facilities.

5 Simulation results of OLSR

We will divide this part into three subsections. The first subsection describes the simulation parameters used and defines the scenarios. The second subsection is devoted to simulation results for a small or average size network. These ad-hoc networks use from 10 to 30 nodes. This type of network size corresponds to the utilization of the PRIMA project [1]. The third subsection is devoted to large networks. In this section we test a networks with more than 100 nodes. The idea is to check if the OLSR technology can cope with large networks. For both large small and average networks we will test the overhead generated by the routing algorithms, the percentage of packet loss in the control packets and the incurred default of route. We will also check if "OLSR" can support mobile nodes.

5.1 Simulation parameters and scenarios

5.1.1 Values of the physical parameters

We chose a signal decay $\alpha = 2$ and $capturelevel = 10$. The $datalevel = 4.10^{-4}$ is computed such that the transmission range is exactly 50 m. The $carriersenselevel = 10^{-4}$ leads to a carrier sense range of 100 m.

5.1.2 Access techniques

We use the IEEE 802.11 access technique and we don't use the RTS/CTS technique. The broadcast packets are sent at 1 Mbit/s as the point to point packets are sent at 11 Mbit/s.

5.1.3 Network topologies

The various topologies that we consider are listed below:

- a near perfect connectivity
- nodes nearly on a grid
- nodes on a large strip.

In figure 5, we show a scenario with a nearly perfect connectivity. Nearly all the nodes are within one hop range from the other nodes; only a few nodes at the peripheral of the network are not at one hop from all the nodes in the network.

In figure 6, we shown a scenario where the nodes are nearly on a grid with a square unit of $40m$ x $40m$. For 10 nodes we have 1 node left which we put randomly in the square of the 9 nodes. For 20 nodes we have 4 nodes left which we put randomly in the square of the 16 nodes. For 30 nodes we have 5 nodes left which we put randomly in the square of the 25 nodes.

In figure 7, we show a scenario of 10 nodes in large strip. We also propose scenarios with 20 and 30 nodes obtained by nearly superposing two or three sets of the previous 10 nodes.

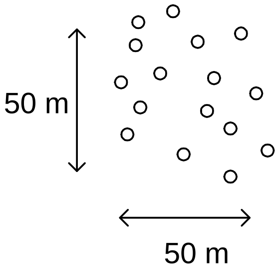

Figure 5: Near perfect connectivity

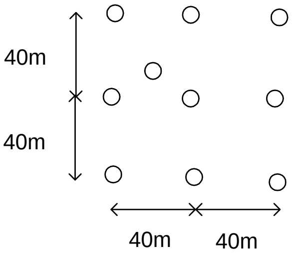

Figure 6: Nodes nearly on a grid

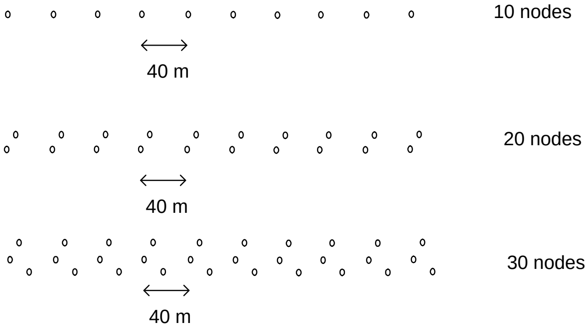

Figure 7: Large strip

In the following we sometimes compare the simulation results with simple analytical evaluation. For this purpose we introduce the following parameters

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[1] This work has been partially funded by the RNRT PRIMA project.

Network parameter	
n	number of nodes
e	number of edges
d	average degree of a node
L	average length of a route

Protocol parameter	
p_{hello}	hello period
p_{TC}	TC period
δ	average size of of TC packet
R	average number of retransmission per broadcast
$r = R/n$	average number of retransmission per broadcast

By definition we call a network small or average when this network has less than 50 nodes. A large network will have 50 nodes or more.

5.1.4 Traffic scenarios

During the firt 30 seconds, we only have control traffic. At 30 seconds the topology is completely stabilized; actually the topology is stabilized much earlier but for convenience we have kept 30 seconds. We use a simple Poisson traffic. The packets are 8192 bits long. For each packet generated we choose a random destination. With respect to existing applications this scenario is not realistic. However this traffic scenario is well suited to test purposes

5.2 Simulation results for small or average networks

5.2.1 Control overhead

First evaluations

We study for various configurations the routing overhead in bits per second. In figure 8, we show the overhead introduced by the hello for various scenarios. In this figure we have: a near perfect connectivity with 10 nodes, nodes nearly on a grid with 20 nodes, and nodes in the strip with 30 nodes.

It is straightforward to compute the overhead incurred by the "hello" packets. This overhead is in octets:

$$\frac{n(4\frac{e}{n} + ov_{hello} + ov_{IP+UDP})}{p_{hello}}.$$

e can be bounded as follows:

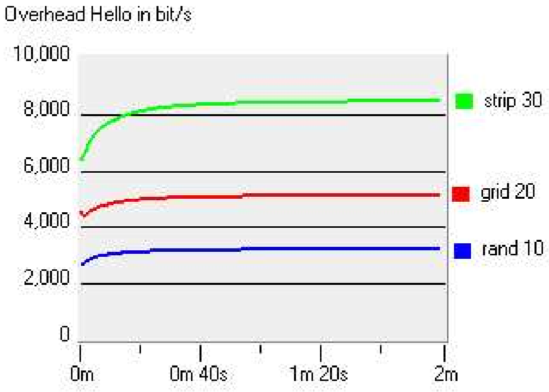

Figure 8: Overhead incurred by the “Hello” frames

$$n-1 \leq e \leq \frac{n(n-1)}{2}.$$

The overhead incurred by the hello is an increasing function of the number of nodes. It is easy to show that the worst case is the completly connected topology, as a matter of fact a node neighborhood contains all the nodes of the network. In this case the overhead inccured by the hello increases by n^2. The better case corresponds to the strip topology in which case the overhead inccurred by the hello increases with n. Simple computations can verify that the results given by the simulation are well in accordance with the analytical approach.

In figure 9, we show in the same conditions, the overhead introduced by the “TC” packets. In this simulation we have used the “MPR” optimization. The situation for the “TC” packets is more complicated since the overhead are broadcaste over all the network and the neighborhood broadcasted depends on the “MPR” strategy. The overhead incurred by the “TC” packets can be easily estimated:

$$\frac{r(\delta + ov_{hello} + ov_{IP+UDP})n^2}{p_{TC}}$$

Simple computations allow us to check the simulation results. For instance, if we assume for the strip with 30 nodes that the TC packets are 50 octets long (2 relays plus overhead) this leads to r around 0.3 which is compatible with the intuitive approach of the strip topology with 30 nodes i.e. two MPRs for six neighbors.

Effect of the MPR optimization

Of course the overhead incurred by the “TC” packets also depends on the “MPR” optimization. We study the “TC” overhead with “MPR” optimization and without “MPR” optimization i.e. all the neighbors are selected as “MPR”. In figure 10, the results of this

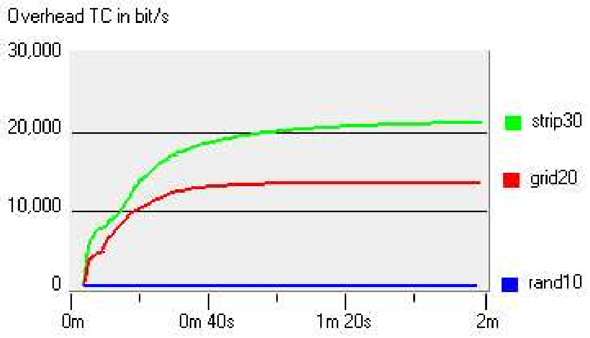

Figure 9: Overhead incurred by the "TC" frames

study are presented. In the case of a random topology with 30 nodes the "MPR" optimization allows an extremely significant reduction in the "TC" overhead. In a dense network, the "MPR" optimization is highly useful. With the topology grid with 20 nodes and a strip with 30 nodes the "MPR" optimization significantly reduces the "TC" overhead. The effect is slightly greater for the strip topology than for the grid. This can be easily understood since in the grid topology every neighbor should be selected as a multipoint relay. Thus the reduction only occurs due to side effects and the random nodes.

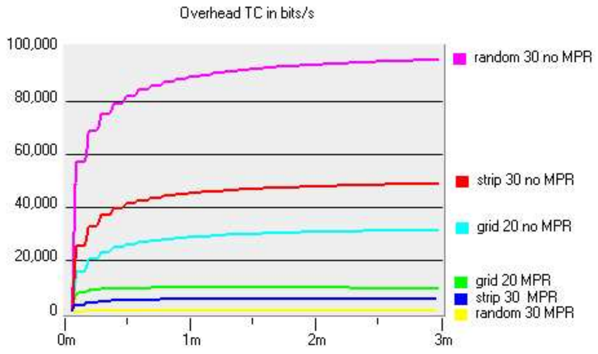

Figure 10: Overhead incurred by the "TC" frames

5.2.2 Loss of data packets

First evaluations

In this part we study the network's behaviour when it is loaded with data packets. We will consider a Poisson traffic with data packet of 8192 bits. For each generated packet in a source node a random destination node is generated. We will study various network loads. We will study a 5%, 10%, 15%, and 20% channel load; this load gives exactly the load of the data packet. Of course this load does not include the multihop effect, if we assume a mean distance of 3 this leads to a network load ranging from 15% to 60%. This covers a slightly loaded network to an overload network for an IEEE 802.11 channel at 11 Mbit/s.

In the simulation program we computed the average number of routes in the routing tables of the network nodes. In figure 11 we give the average route availabilty for a grid network with 20 nodes with a 5% network load (not including multihop effect). We can see that even with a light load network and without mobility we do not have 100% of route availability. This effect is due to the high percentage of collisions for the broadcast traffic. In figure 12 we give the collision rate for this broadcast traffic. This high percentage of collsion for the broadcast traffic is the result of the lack of collision detection on this traffic in the IEEE 802.11 standard. The percentage of collision for this traffic is increased with hidden nodes. We can have a proof of that by studying the same scenario but with a carrier level set up at $2.5.10^{-5}$. With this carrier level every node in the network is within carrier sense reach and there are no hidden nodes. In such conditions we reach a perfect 100% of route availability and we can also observe that the percentage of collisions for the broadcast traffic decreases.

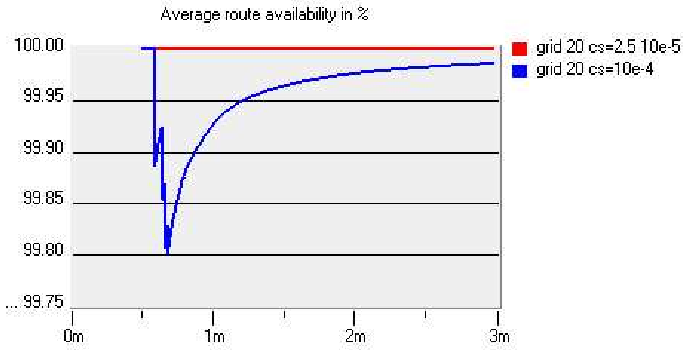

Figure 11: Average route availability in % for a grid topology with 20 nodes

In the following we study the effect of the network load on the average route availabilty. We will study a grid network with a 5%, 10%, 15%, and 20% load. In figure 13 we show the results of our investigation. Figures 14 and 15 we respectively show the number of lost hello packets and TC packets during the lifetime of the simulation. We can notice that the losts

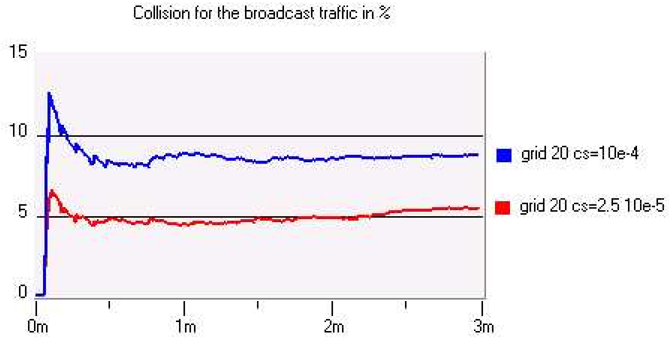

Figure 12: Collision rate in % for the broadcast traffic in a grid topology with 20 nodes

of TC packets increase more quickly than the number of lost of hello packets. This can be explained by the fact that TC packets are relayed.

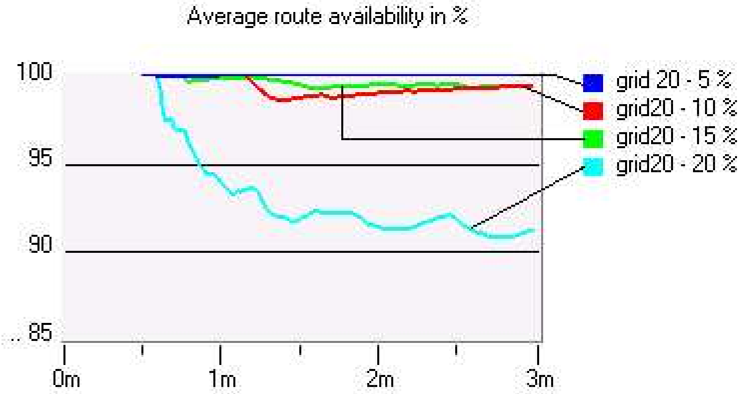

Figure 13: Average route availability in % for a grid topology with 20 nodes and increasing network loads

Effect of the Jitter

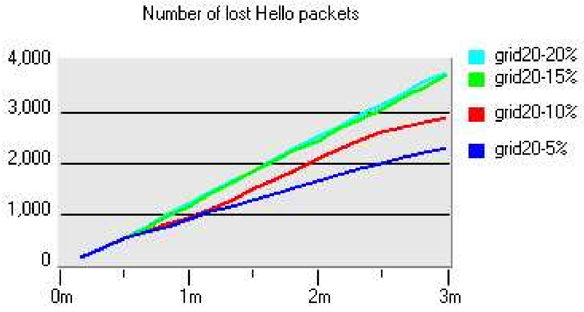

Figure 14: Number of lost hellos for a grid topology with 20 nodes and increasing network loads

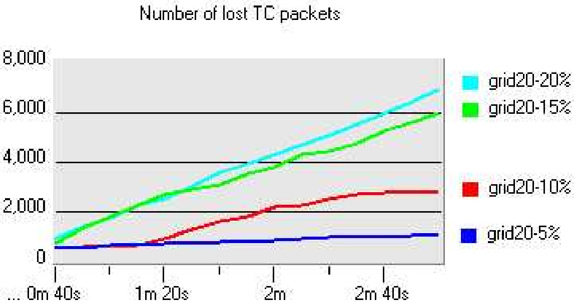

Figure 15: Number of lost TC for a grid topology with 20 nodes and increasing network loads

When a TC packet is relayed it increases the probablity of collision since there is an implicit synchronization due to the relaying of packets. Therefore we have implemented a jitter when the TC packets are relayed. Simulations show that this jitter improves the performance. This can be explained by the reduction in the collision rate for the broadcast traffic as is shown in figure 16.

Effect of the MPR optimization

We study the effect of the multipoint relay optimization of the routing protocol when the load increases. We first study the grid topogy (20 nodes) with a data load of 5% , 10%, 15% and 20%. The simulations show that MPR optimization leads to worse average route availability. Actually this result can be forseen since without the MPR optimization the control traffic contains more redundancy as the collision rate on the broadcast is not significantly increased. This leads to better topology evaluation. The effective throughtput

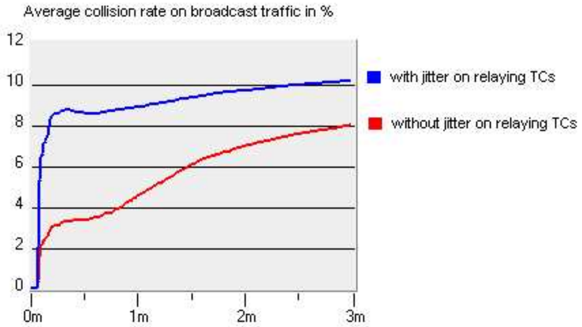

Figure 16: Collision rate for the broadcast traffic in % for the grid 20 at 10% channel load

is slightly better without the MPR optimization at 5% , 10% and 15% input load with a difference in the delivered load ranging from 5% to 10%. But at 20% the maximum network capacity is reached and MPR optimization allows better performances, see figure 17.

We then study the strip topology (30 nodes) with a data load of 5% , 10%, 15% and 20%. The simulations show that the MPR optimization leads to wors eaverage route availabity. The protocol without the MPR optimizaton leads to better performance at 5% , 10% and 15% load. The delivered throughput is between 5% to 10% better without than with the use of the MPR optimization, see figures 18 and 19. But at 20% the MPR optimization allows better performances, see figure 21. This result is obtained although the average route availabity is still better without MPR optimization, see figure20. This can be explained because the additional load produces by the flooding when the MPR optimization is not used leads to more collisions. Thus without MPR optimization the system is loses more packets due to the maximum number of MAC retransmissions reached.

These results with the strip topology are particularily important since these configurations are very difficult for the MPR optimization. In fact the usual redundancy in the flooding is reduced to its maximum with this optimization. It is worth mentioning that even in this very difficult case MPR optimization still offers fair performances at average load and better performances at high load.

Scenarios with mobility

We have studied the delivered load in a strip with 30 nodes and four moving nodes random mobility 1.5 ms. The 4 moving nodes are moving to the right. The simulations results show that the mobility leads to around 10% degradation of performance in terms of delivered load as we did not have a significant change in the control load. The simulation results show that the mobility has nearly no influence of the overhead generated by the hello packets. It is suprising to see that with mobility there is less overhead due to TC packets. Actually this result can be explained by the increase of the packet loss. In fact the simulation results show that, indeed, there are more TC generated with mobility than

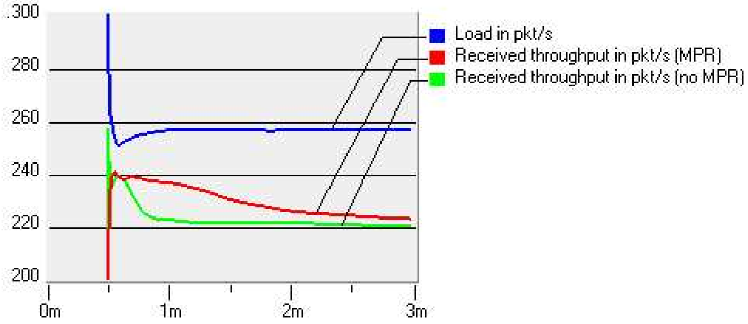

Figure 17: Received packet in pkt/s for a grid 20 topology at 20% with and without the MPR optimization

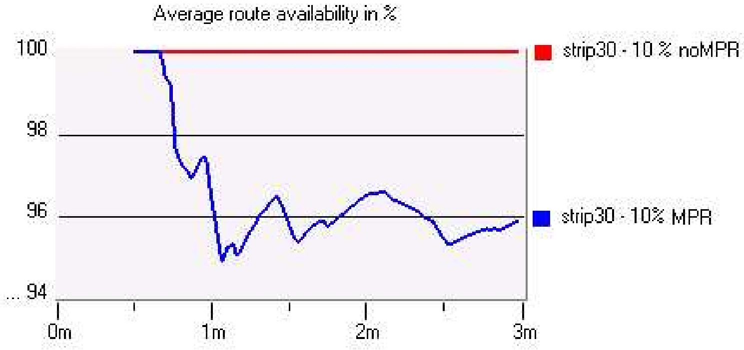

Figure 18: Average route availability in % for a strip topology with 30 nodes at 10% load

without but this effect is counterbalanced by loss in TC packets.The MPR optimization leads to worse performances at 5% and 10% and at 15% and 20% MPR optimization leads to slight improvements of the performances, see figure 22.

The performance with mobility can be improved. In fact while the mobility leads to more failures in the routing An important phenomenon appears when the route change: This is the wrong route effect. When a packet is sent to a neighbor which no longer exists the IEEE 802.11 access scheme tries to send the packet until the maximum retry has been reached yet, the packet can not be acknowledged! This will lead to an additional load which can degrade performances. In figure 23 we have shown the retry number with the strip of 30 nodes with and without mobility. We clearly see that the retry very often number reaches its maximum with mobility, in contrast to what occurs with a static topology. Figure 23 could

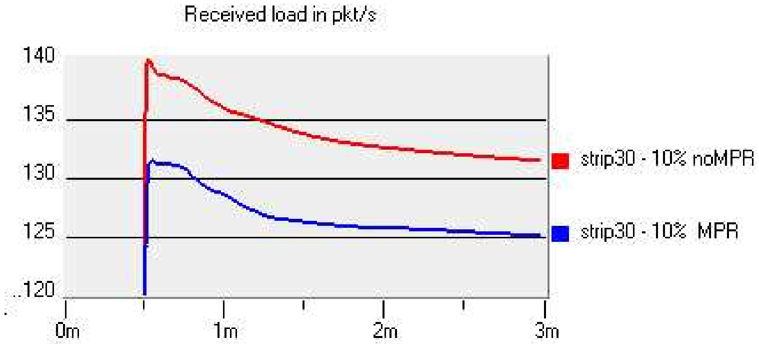

Figure 19: Received packet in pkt/s for a grid 20 topology at 20% with and without the MPR optimization

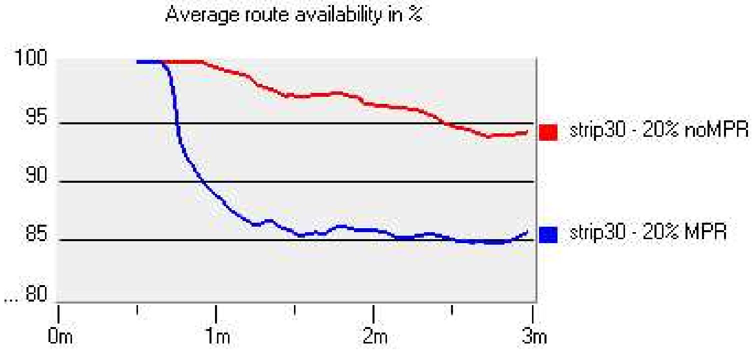

Figure 20: Received load in packet/s for a strip topology with 30 nodes at 20% load

be misleading since it could be thought could understand that the retry always reaches its maximum which is of course not the case. The average value of the retry number is 2 with mobility and 1.15 without mobility. In figure 24 we show the improvement we obtained in the received load if we reduce the maximum MAC retry from 16 to 4.

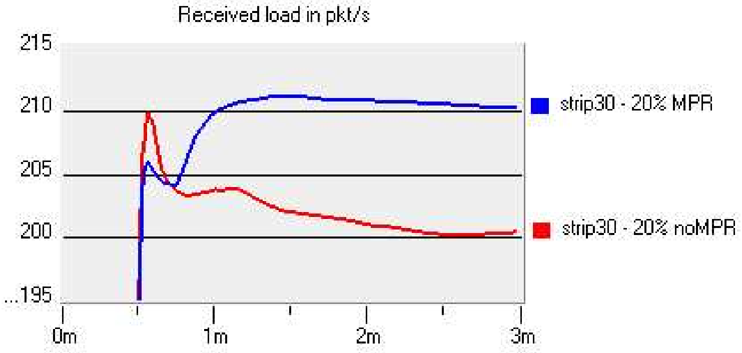

Figure 21: Received load in packet/s for a strip topology with 30 nodes at 20% load

Figure 22: Received load in packets per second in a strip with 30 nodes at 20% of network load and four moving nodes

5.2.3 Packet loss in routing packet

5.3 Large network

We will test a network of 100 active nodes and we will use a grid topology. 81 nodes are placed on the grid and 19 nodes are placed randomly between the nodes in the grid. The distance between two neighboor nodes on a the same lign or column of a grid is $40m$.

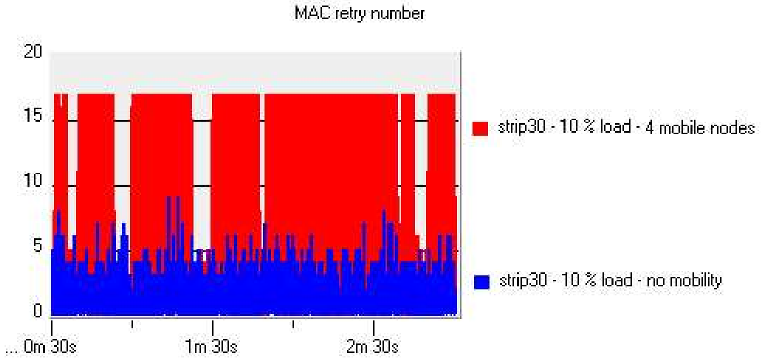

Figure 23: MAC retry number in strip with 30 nodes at 10% load with and without mobility

Figure 24: Received load in a strip with 30 nodes at 10% load with and without mobility and with a maximum MAC retry at 4

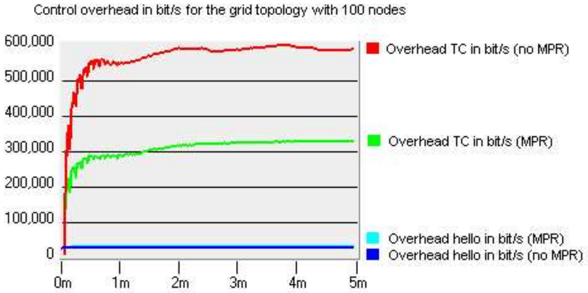

Figure 25: Overhead incurred by the hello in bit/s for the grid 100 topology

5.3.1 Control overhead

We study the overhead in bit/s incurred by the hello and TC packets. The results of the simulation are presented on figure 25. We clearly see that the overhead due to the hello are

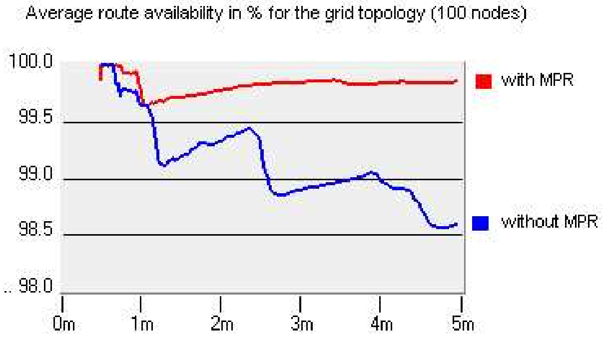

Figure 26: Average route availability in a grid topogy with 100 nodes and 2% of network load

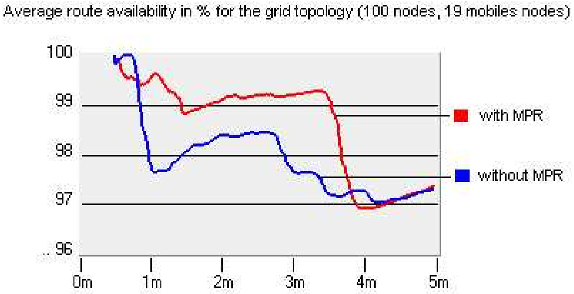

Figure 27: Average route availability in a grid topogy with 100 nodes with 19 mobile nodes and 2% of network load

very significantly smaller in amount than the overhead incurred by the TC packets. We can see that in large network the control overhead can be significant. Of course we have to take into account that this overhead in disseminated in the network and therefore we can take advantage of the reuse effect.

Effect of the MPR optimization

In figure 25 the effect of the MPR optimization on the control overhead is presented. We can observe that the MPR optimization very significantly reduces the TC overhead. This result is quite interesting because with the selected figure nodes on the grid will generally select their four neighbors on the grid as multipoint relays. Therefore the difference between results with and without the multipoint relay optimization are due to side effects and to the 19 randomly placed nodes.

5.3.2 Loss of data packets

With the same topology and with a network load of 2% we are studying the average route availability in the network. In figure 26 we show the results of the simulation. We can observe that we actually have an excellent percentage of route availability. On the same figure we see the MPR optimization leads to sligth improvement of the network throughput. In figure 27 we have the same results but with mobility. The 19 randomly disposed nodes move towards the rigth at a speed of 1 m/s. When a node reaches the border of the simulation area the node changes its direction to the rigth. We can see that the mobility is well handled by OLSR. The average route availability is just very slightly worst than with no mobility.

6 Conclusion

In this paper, we have studied the performance of the "OLSR" routing protocol. We have seen that the overhead incurred by the control traffic of "OLSR" remains small in an IEEE 802.11b network. We have also seen that "MPR" optimization can save a substantial part of the bandwidth. The performances of the "OLSR" in terms of traffic delivered are very good in normal load conditions however the performance degrades when the network is overloaded. We have very carefully study the effect of the MPR optimization on the route availability and delivered throughput. The studied scenarios with the grid and the strip topology show that the MPR optimization still works in the most difficult conditions for this optimization. We have also shown the effect of the hidden node collision. In fact actually hidden node collisions explain the small percentage of route default that we have in small and average size networks. Mobility is well supported by "OLSR" and leads to sligth performance degradation. We have shown that a significant part of this degradation is due to the retry effect of IEEE 802.11; a smaller maximum retry number very significantly reduces the degradation due to the mobility. The "MPR" optimization also improves performance in large networks. The authors are currently leading further studies concerning the optimization of "OLSR" and the IEEE 802.11 layer. More precisely they are studying the optimization of the amount of delivered traffic and "OLSR" optimizations.

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Éditeur
INRIA, Domaine de Voluceau, Rocquencourt, BP 105, 78153 LE CHESNAY Cedex (France)
http://www.inria.fr
ISSN 0249-6399