Saving Energy and Maximizing Connectivity by Adapting Transmission Range in 802.11g MANETs

Fatiha Djemili Tolba, Damien Magoni and Pascal Lorenz

Original scientific paper

Abstract— **Node lifetime is an important metric for communication in networks. However, node lifetime is still severely restricted by the limitations of power supply. In this paper we propose a new algorithm *Save Energy and Maximize Connectivity* (SEMC) that economizes the energy and keeps connectivity between the nodes. By varying the transmission range and respecting the behavior of node (mobility), the energy consumption will be considerably reduced and the connectivity can be continually preserved. The advantage of SEMC indeed that it is generic and it can be used by all MANET routing algorithms such as AODV and DYMO. Results obtained by SEMC are compared with those produced by IEEE 802.11g.**

We implement the SEMC algorithm using the NS-2 simulator and perform an extensive experimental evaluation of several important performance measures with a focus on energy consumption and connectivity. Our findings indeed demonstrate that SEMC achieves significant improvements in node's lifetime and communication in the network.

Index terms—**Mobile ad hoc networks, IEEE 802.11g, transmission range, energy, connectivity.**

I. INTRODUCTION

Ad hoc wireless networks have recently attracted enormous research attention due to their wide-range of potential applications. While ad hoc network can, in general, be describes as an autonomous system of mobiles nodes connected by wireless links. The nodes can act as both hosts and routers since they can generate as well as forward packets. These nodes are also free to move and organize themselves into a network. Ad hoc wireless network does not require any fixed infrastructure (i.e. a wired or a fixed wireless base station). The principal characteristics of this type of network are the dynamic topology and the limited energy of mobiles nodes. The interest in such network architecture is focused on battlefield, voice and video communications such as conferences, hospitals and military applications, and also for disaster relief situations (rescue).

Ad hoc wireless network is usually modeled by a unit graph, where two nodes are connected if and only if they are in the same transmission range. This last range determines the range over which the signal can be coherently received, and is therefore crucial in determining the performance of the network such as energy consumption, connectivity and delay. One of major concerns in ad hoc network is the fact that the energy at each node is limited because the only source of this energy is a battery implemented in it. If the battery is discharged the node can not receive or send any packet. So, it is necessary to control the transmission range for both minimizing energy consumption and extending battery life.

To seek the best value of transmission range that preserves connectivity and conserves energy is an important problem for network functionality. This is due to the fact that there are two opposite tendencies in the increase of transmission range. On one hand, increasing the value of transmission range increases the transmission power, so that a strong consumption of energy in each node is produced. On the other hand, increasing the value of transmission range preserves the connectivity (increases of number of neighbors). However, the decrease in transmission range causes a preserve of energy and a decrease of interferences but can adversely impact the connectivity of the network by reducing the number of active links and, potentially, partitioning the network [1], [2]. For this, a value should be found which makes the compromise between the connectivity and the consumption of energy.

In the literature, a lot of attention has been devoted to transmission range and power control. Some have focused in seeking of optimal transmission range using the same transmit power in order to control the connectivity [3], [4], [5], [6] or using different transmission power in order to improve the end-to-end network throughput [7]. Others have focused in seeking of shortest path with a power based metric using various parameters such as energy consumed per packet or the

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Manuscript received October 5, 2006 and revised April 20, 2007.

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energy cost per packet [8], [9]. Another possible approach is based on the change of the MAC layer; the main idea is to use different transmission power according to the packet data type [10], [11].

In this paper, we propose a new algorithm SEMC for controlling the transmission range in mobile ad hoc networks. This algorithm is the continuity of our work [13] in the same theme. The first goal of SEMC is to economize the energy where nodes are likely to operate on limited battery life. The second is the preserved the connectivity between the nodes knowing that the connectivity plays an important role in route discovery. This algorithm is generic and completely distributed so it can be used in many cases. Note that our algorithm SEMC is proposed for ad hoc networks not for the sensor networks. Furthermore, SEMC is implemented in the second layer of the OSI what to mean that SEMC is independent of routing algorithms.

The rest of this paper is organized as follows. Section 2 reviews the previous work in this area. In section 3, we introduce the protocol IEEE 802.11x in general, and describe 802.11g in some detail noting that it is our reference model. We then proceed, to section 4, by describing our idea, including our proposed algorithm SEMC. In section 5, extensive numerical results are presented and we demonstrate that the proposed algorithm is better in terms of energy conservation and connectivity preservation. Conclusions are drawn are described in section 6.

I. RELATED WORK

In the last decade a lot of researchers have contributed in the controlling of energy in ad hoc wireless networks. Consequently, several algorithms using transmission range have been proposed. An overview of these algorithms is presented below.

In [3], the authors seek to find the minimum uniform transmission range that ensures network connectivity by proposing three algorithms: Prim's MST (Minimum Spanning Tree), Prim's MST with Fibonacci heap implementation and the area-binary. However, in these algorithms either each node has all information about the network or a specific node has the information about the MST and diffuses it. Whereas, it is more interesting that each node has local information about its neighbors.

In [4] Althaus et al. study the problem of transmission range with a goal to minimize the power computation to ensure network connectivity. The authors give a minimum spanning tree (MST) based 2-approximation algorithm for Min-Power Symmetric Connectivity with Asymmetric Power Requirements. In the same problem Santi [5] proves that the Critical Transmission Range (CRT) in the mobile case is at least as large as the CRT in case of uniformly distributed points.

Narayanaswamy et al. [6] proposed a distributed protocol for power control and provided a conceptualization of this control. This algorithm aims to find the smallest common power (COMmon POWer) level at which the network is connected. In the same category, Elbatt et al. [7] proposed to use the notion of power management and they studied the impact of the use of different transmission powers on the average power consumption and end-to-end network by limiting the degree of a node in a clustering algorithm. However, the simulation results are given only for a slow speed of nodes (1 to 5 m/s) and for a fixed density network.

The power control in the routing algorithm for ad hoc networks is used by Kawadia and Kumar [8]. Each node runs several routing layer agents that correspond to different power levels. In this protocol each node along the packet route determines the lowest power routing table in which the destination is reachable. However, this protocol is more suitable for a network with low mobility and the results of the simulations are given only for a single model where the number of nodes in the network is invariable. In [9] Spyropoulos and Raghavendra proposed an energy-efficient algorithm for routing and scheduling in an ad hoc network with nodes using directional antennas. The first step of this algorithm consists of finding the shortest cost paths, using the metric “minimize energy consumed per packet”. The next step finds the maximum amount of time that each link can be up, using the metric “maximize network lifetime”. In the last step, scheduled nodes’ transmissions are found by executing a series of maximum weight matching. However, since each node is assumed to have a single beam directional antenna, the sender and the receiver must redirect their antenna beam towards each other before transmission and reception can take place [2].

The idea to change the MAC layer is presented in [10]. The authors have proposed a power control scheme where the principle is to use two power levels to transmit each data packet: the maximum transmit power for RTS-CTS and the minimum transmit power for DATA-ACT. This work has been implemented using omni-directional antennas. Therefore, the scenario is completely changed when we use directional antennas to transmit and receive signals. Interestingly, Saha et al. [11] propose to use two levels of transmission power using an antenna operating in omni-directional and directional mode. Their work helps to conserve the transmission power when the directional transmission is used.

II. IEEE 802.11 PROTOCOL

IEEE 802.11, the *Wifi* standard, denotes a set of *Wireless Lan* (WLAN) standards developed by working group 11 of the *IEEE* LAN/MAN Standards Committee (*IEEE 802.11*). The term 802.11x is also used to denote this set of standards and is not to be mistaken for any one of its elements. The 802.11 family currently includes six over-the-air *modulation* techniques that all use the same protocol. The most popular (and prolific) techniques are those defined by b, a, and g amendments to the original standard. Security was originally included and was later enhanced via the 802.11i amendment and improvement of quality of service is assured via 802.11e. Other standards in the family (c, d, f, h, j, n) are service enhancements and extensions or corrections to previous specifications. 802.11b was the first widely accepted wireless networking standard, followed by 802.11a and 802.11g.

A. *IEEE 802.11g*

The standard IEEE 802.11g works in the 2.4 GHz band (like 802.11b) but operates at a maximum raw data rate of 54 Mbit/s, or about 24.7 Mbit/s net throughput like 802.11a. The 802.11g hardware can work with 802.11b hardware. Details of making b and g work well together occupied much of the lingering technical process. In older networks, however, the presence of an 802.11b participant significantly reduces the speed of an 802.11g network. The modulation scheme used in 802.11g is *orthogonal frequency-division multiplexing* (OFDM) for the data rates of 6, 9, 12, 18, 24, 36, 48, and 54 Mbit/s, and reverts to (like the 802.11b standard) CCK for 5.5 and 11 Mbit/s and DBPSK/DQPSK for 1 and 2 Mbit/s. Even though 802.11g operates in the same frequency band as 802.11b, it can achieve higher data rates because of its similarity to 802.11a. However, 802.11g suffers from the same interference as 802.11b in the already crowded 2.4 GHz range.

Transmission power is the amount of power used by a radio transceiver to send the signal out. Transmission power is generally measured in milli watts, which you can convert to dBm. In our work, we took CISCO aironet 802.11g wireless card bus adapter as a reference model. Their received powers are resumed as in the above table.

TABLE I
RECEIVE POWER IN 802.11G

Throughput	Receive power
1 Mbit/s	-94 dBm
2 Mbit/s	-93 dBm
5.5 Mbit/s	-92 dBm
6 Mbit/s	-86 dBm
9 Mbit/s	-86 dBm
11 Mbit/s	-90 dBm
12 Mbit/s	-86 dBm
18 Mbit/s	-86 dBm
24 Mbit/s	-84 dBm
36 Mbit/s	-80 dBm
48 Mbit/s	-75 dBm
54 Mbit/s	-71 dBm

III. OUR CONTRIBUTIONS

In this section, we introduce our contribution in which we give the basic idea. After this, we discuss the details of the algorithm.

A. *Basic idea*

The main objective of the algorithm SEMC is to propose a generic solution that can be used by various routing algorithms such as AODV, DYMO, etc. SEMC aims to preserve the energy that prolongs the lifetime of a node and also the lifetime of the network as a whole. In addition, SEMC aims to maintain the connectivity of mobile nodes that improves the communication in network. The fundamental idea is to provide at each node the possibility to use the value of transmission range that adjusts it on the distance between itself and other nodes.

The SEMC is completely distributed and it takes into account some features such as transmission range, connectivity and position of the node (mobility). In the following, we explain the choice of each feature.

Transmission range plays an important role in the communication between two nodes as mentioned previously. However, in the mobility model the nodes are free to move within or outside the transmission range that render the precise computation of its values difficult. Moreover, a larger value of transmission range requires a higher transmission power that increases the consumption of the battery energy On the other hand the transmission range influences the connectivity of the node and consequently the quality of routing [13]. In order to prolong the life span of the node and to preserve the other performance parameters of the network such as the quality of signal, the connectivity and the delivery of packets, it is necessary to find a value for the transmission range that optimizes the connectivity and energy consumption parameters. For these reasons the transmission range is the most important factor to tune properly.

Connectivity: an evaluation of the number of neighbors is an indicator of the connectivity in wireless networks. The connectivity is essential in ad hoc wireless networks in order to guarantee the possibility for source node to reach any other node in the network via multiple hops. In other words, connectivity is an important mechanism in the route discovery process.

Position of the nodes: while we work in an environment where the nodes are mobile, we must update the coordinates of nodes at each time step. Note that the mobility can be described in terms of *speed*. In SEMC algorithm, the value of time step depends on the speed of the node.

In order to find the position of the node we opt for the following method: Each node broadcasts its address which is registered by all its neighbors. It is assumed that a node receiving a broadcast from another node can estimate their mutual distance from the power level of the signal received. The Global Position System (GPS) is another solution to know the position; however, it consumes more of energy.

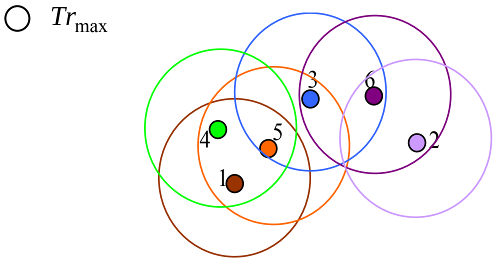


Fig. 1. Network topology.

Fig. 1 shows an example of an arbitrary topology of ad hoc wireless network. Each point of the area presents a mobile node and the colored circle presents the transmission range of each node. Initially, the transmission range (Tr_{max}) equals to

IEEE 802.11g. Indeed, using this range the node has a maximum number of neighbors and consequently the node has a better connectivity in the network.

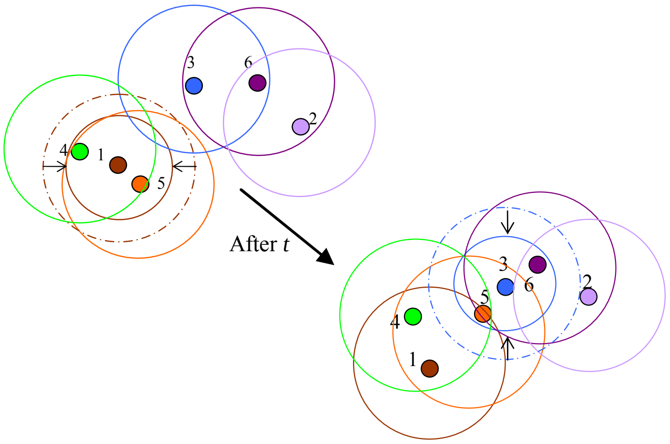


Fig. 2. Variation of transmission range according to the node connectivity.

After some time, the Fig. 2 shows that the node number 1 changes its transmission range in order to keep the same number of neighbors. In the same way, the node number 3 changes its transmission range after a time *t*. By reducing the transmission range these nodes (1 and 3) preserve the same number of neighbors and also the connectivity. In addition, transmitting at low power reduces the energy consumption. Note here that a smaller value of transmission range consumes less energy.

B. Description of the proposed algorithm

First, we note that our work is focused on level 2 (Data link layer) of the OSI layers. In the following we describe the proposed algorithm SEMC for wireless ad hoc networks. Before proceeding with the presentation of the various steps of the algorithm we describe the system model.

We consider a network topology which is represented by a graph $G = (V, E)$ where V is the set of mobile nodes ($|V| = m$) and $e = (u, v) \in E$ will model wireless link between a pair of nodes u and v only if they are within the wireless range of each other.

The algorithm consists of seven steps (see Fig. 3) as described below:

Step 1

Each node broadcasts a data packet with some information about its address, position and time stamp. Initially the transmission range *Tr* takes the value of 802.11g for a throughput of 54Mbps.

Step 2

Each node receives this packet, calculates the distance *d*, as:

$$d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \qquad (1)$$

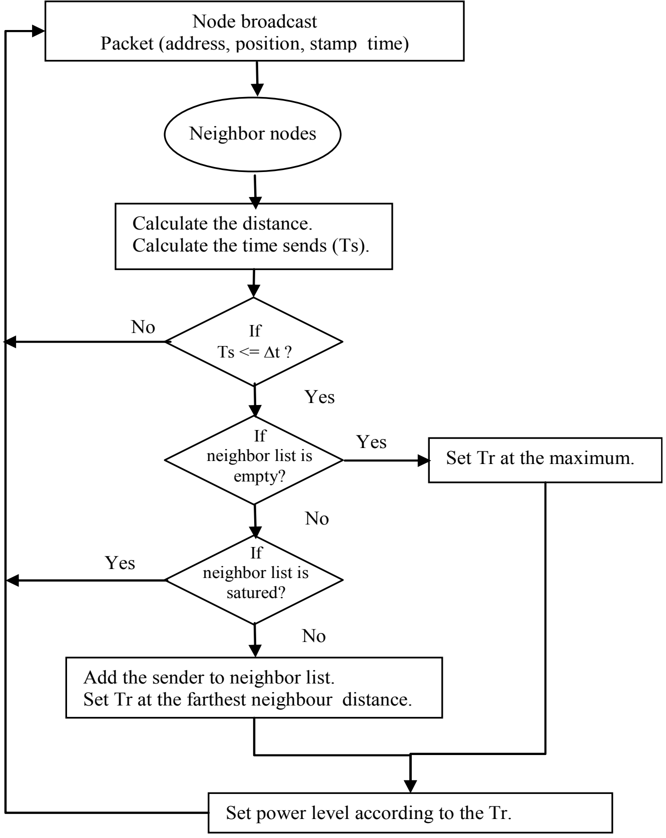
Where (x_1, y_1) and (x_2, y_2) are the coordinates of the sender and receiver nodes respectively.

Step3

Recalculate the distance d_1 taking into account the speed of the node $s_{\max}$ for the time period Δt in order to envisage the future position of the node.

$$d_1 = d + 2 * s_{\max} * \Delta t \qquad (2)$$

Fig. 3. Proposed algorithm.



Note here that each node fixes the value of Δt according to its speed. A node transmits its information only if it moves with a significant speed. In this case, the speed and the position change and consequently the transmission information changes and this merits the broadcast, else the node saves its old information.

$$\Delta t = \frac{\Delta t}{speed} * k \qquad (3)$$

Where k is a constant reference speed equal to 1m/s.

Step4

Calculate the necessary time for the packet arrived at the receiver.

$$t = t_{current} - t_{stamp} \qquad (4)$$

Where $t_{current}$ and t_{stamp} are the current time and the time stamp.

Step 5
Compare the time t with the period time Δt,
If $t \leq \Delta t$ so,
test the list of neighbors $list_{neighbours}$.
If $list_{neighbours} \leq neighbours_{\min}$ so,
Add the sender to the list of neighbors.

Step 6
If the list of neighbors is empty so set transmission range to maximum $Tr_{\max}$. Else set transmission range to the farthest neighbors distance.

Step 7
In the final step, set power level Pow corresponding to the current transmission range.

$$Pow = T_x - m\arg in - rx_{thr} \tag{5}$$

$$T_x = attenuation + m\arg in + rx_{thr} \tag{6}$$

$$\begin{aligned} attenuation &= 20*\log\left(4\cos(-1)/3*10^8\right)+ \\ &20*\log(2.4897*10^9)+20*\log 10*Tr \end{aligned} \tag{7}$$

Where:

$m\arg in$ is a fixed margin chosen in order to avoid the undervaluation.

rx_{thr} is the reception threshold (-70 dbm).

Note here that the update of data is being carried out each time period.

In the previous steps, we show at first that the power level is based on the distance between the receiver and the sender. The fact that the node changes its transmission range according to its needs (distance) means that the life span of battery can be prolonged.
The realization of this last fact is at the heart of our work. On the other hand, we find that a fixed connectivity value for all nodes allows building a connected graph and limits the nodes in terms of number of messages sent to the neighbours which consume a lot of energy. This facilitates the communication between the nodes.

IV. SIMULATION

A. Performance evaluation

We illustrate some results from simulations of our algorithm SEMC and we compare its performances with those of IEEE 802.11g. In order to address these performances, we choose four metrics that are:

a) The energy used.
b) The connectivity factor.
c) The average number of neighbors.
d) The average number of hops.

We present this analysis and evaluate the SEMC according to some rules describe in [12].

1) Energy used

The energy can be stated as:

$$E = Pow * T \tag{8}$$

The energy E_{Tx} to transmit a packet and E_{Rx} to receive a packet can be stated as:

$$E_{Tx} = Pow_{Tx} * t \tag{9}$$

$$E_{Rx} = Pow_{Rx} * t \tag{10}$$

So, the total energy consumption can thus be expressed as:

$$E_{tot} = \sum_{i=0}^{T} E_{Tx} + \sum_{i=0}^{T} E_{Rx} \tag{11}$$

$$= \sum_{i=0}^{T} \left(Pow_{Tx} * t\right) + \sum_{i=0}^{T} \left(Pow_{Rx} * t\right) \tag{12}$$

2) Probability that node remain paused

The long-run proportion of time spent paused P_{pause} can be stated as:

$$P_{pause} = \frac{E(P)}{E(P)+E(T)} \tag{13}$$

Where $E(P)$ denote the expected length of a pause, and $E(T)$ denote the expected time elapsed between two pauses.

$$E(T) = E(L/\ S) \tag{14}$$

$$= E(L)E(1/\ S) \tag{15}$$

Where L is the length of an excursion, and S is the speed of the node on that excursion. Note that S is chosen from a uniform distribution on $(v_0,\ v_1)$ at the beginning of each excursion. Then $T=L/S$

Where $E(1/S)$ computed as:

$$E(1/\ S) = \frac{\log(v_0/\ v_1)}{v1 - v_0} \tag{16}$$

Where the numerical value of *E(L) is 521,405*
Therefore,

$$E(T) = 521{,}405\frac{\log(v_0/\ v_1)}{v_1 - v_0} \tag{17}$$

Note that these results of experiments are given for different node densities in the network and for different speeds of nodes. In Fig. 4 we confirm that our algorithm SEMC saves more energy than IEEE 802.11g because the ratio, in most cases, does not exceed 0.5. In the case of 40 and 80 nodes the ratio goes up to 0.25. This result proves that the energy used by IEEE 802.11g is more than our algorithm while maintaining good connectivity.

B. Simulation parameters

We evaluate the performance of our algorithm SECM by simulation using the Network Simulator (NS-2). We consider a network with a varied number of nodes. The topology used is random where the nodes are uniformly distributed and are moved by using the random waypoint mobility model [12]. The nodes move in all possible directions with a varying speed and they can attain 80m/s. This can represent the speed of movement of any terrestrial vehicle. For each time step Δt a number of nodes within the same transmission range (neighbors) are generated according to the two-dimensional position.

We set our simulation parameters as follows:

TABLE II
PARAMETERS USED IN SIMULATIONS.

Parameters	Values
Number of nodes	10, 20, 40 and 80
Area	1000 x 1000 m
Minimum reception power	-70 dBm
Maximum transmission power	18 dBm
Minimum connectivity	2 – 16
Pause time	0,10, 50,100,200 and 400 s
Maximum speed of the nodes	5 – 80 m/s

C. Simulation results

By increasing the number of nodes in the network, we show that SEMC still performs better than IEEE 802.11g in terms of energy used, while maintaining a high level of node connectivity.

We define the following metrics:

- The “energy used” ratio is equal to the energy used by our SEMC algorithm divided by the one used by the IEEE 802.11g protocol,
- The connectivity ratio is equal to the connectivity factor obtained by SEMC divided by the one obtained by IEEE 802.11g. We define the connectivity factor as the inverse of the number of connected components in the network. A connected component is a maximal connected sub-graph. Two vertices are in the same connected component if and only if there exists a path between them.
- The ratio of neighbors is equal to the average number of neighbors obtained by using SEMC divided by the average number of neighbors obtained by using 802.11g.
- The ratio of hops is equal to the average number of hops obtained by using SEMC divided by the one obtained by using IEEE 802.11g. The average number of hops is the average number of hops measured between any pair of nodes in the network.

1) Energy used

In Fig. 4 we observe that the energy used decreased considerably for 10 nodes and it remained almost stable for 20, 40 and 80 nodes although for increased speed. As can be seen, the energy used by 80 nodes is less than the energy used by other numbers of nodes.

In Fig. 5, we see that the ratio of energy slowly decreases as a function of the pause time. Indeed, if the nodes remained in pause state, it saves more energy.

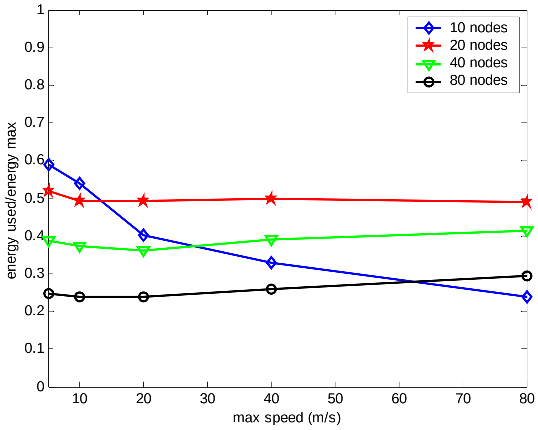


Fig. 4 Energy ratio vs max speed

This result can be explained by the implementation of our algorithm that takes into account the speed of node in the choice of step time. In other words, our algorithm economizes the energy regardless of the speed of nodes or the number of nodes.

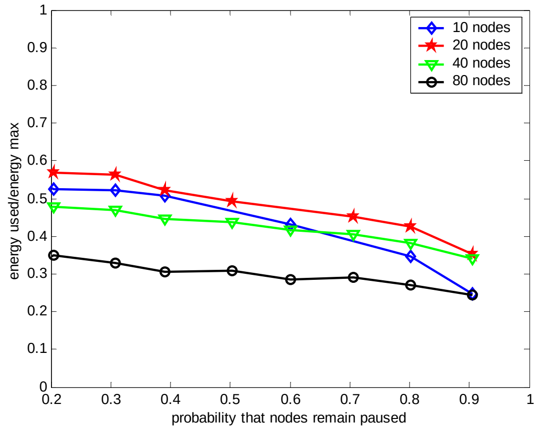


Fig. 5 Energy ratio vs pause probability.

2) Connectivity factor

At first sight, we can say that the communication between the nodes is better (all nodes can communicate between themselves) when the connectivity factor is equal to 1. Consequently, the Fig. 6 shows that the slow increase in the connectivity factor corresponds to the increase in the speed of nodes from 20m/s. That can be explained by the strong mobility of a large set of nodes in the area. This mobility allows nodes to get closer between themselves. So the nodes get together and the connected components’ count increases.

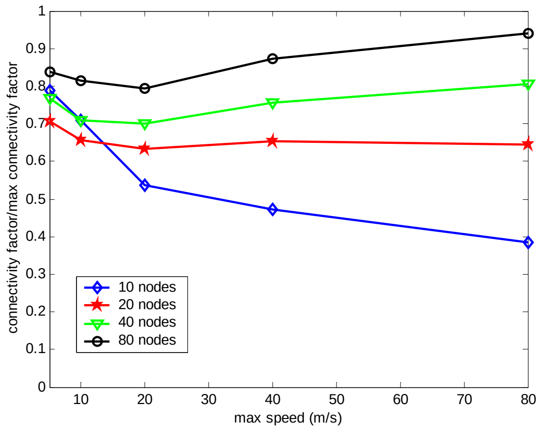


Fig. 6 Connectivity ratio vs max speed.

We observe in Fig. 7 that the ratio of connectivity factor decreases with the increases of the pause time. Therefore, the node can lose its neighbors if it prolongs its pause time.

We conclude that the implementation of SEMC realizes a saving of energy when the connectivity is good. This result also confirms that the prolongation of pause time of nodes, in most cases, can lose some of their neighbors.

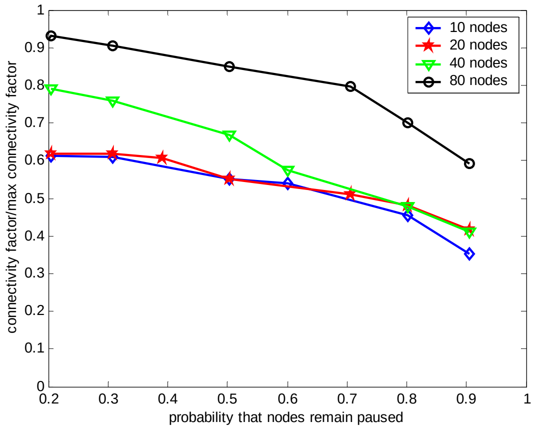


Fig. 7 Connectivity ratio vs pause probability.

3) *Relationship between energy used and connectivity factor*

According to the results presented in Fig. 8, it appears that the curve is uniform that allows deducing that the ratio: energy: connectivity is better in terms of compromise. This can be explained quantitatively by the energy ratio that doesn't exceed 0.60 when the connectivity factor ratio gets more than 0.9.

4) *Average number of neighbors*

Fig. 9 shows the evolution of the ratio of neighbors as a function of the speed of node. We observe that the ratio slowly increases whatever the speed of the nodes in the case of 20, 40 and 80 nodes. However, in the case of 10 nodes, we observe that the ratio of neighbours decreases considerably with the increase of the speed of the nodes. This is explained by the fact that when the network is composed by a low number of nodes that move with high speed, these nodes disperse in the area. Consequently, each node can lose its neighbors and this loss has an influence on the set of neighbors.

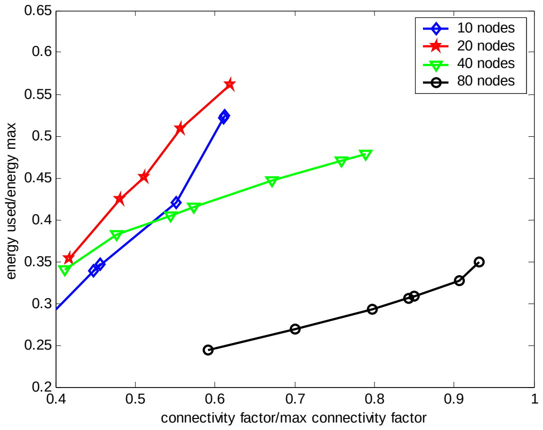


Fig. 8 Energy ratio vs Connectivity ratio.

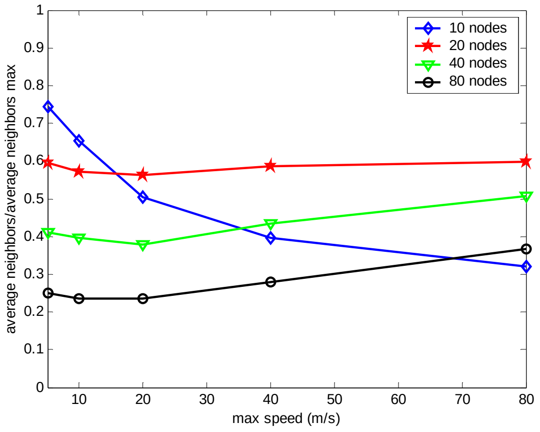


Fig. 9 Average neighbor ratio vs max speed.

Whatever the topology (10-80 nodes), the number of connected components of SEMC is superior to that of IEEE 802.11g (Fig. 6). This means that the amount of connected

Fig. 10 shows a smaller disruption in the number of neighbors according to the increases of pause time of each node.

We conclude that the variation in transmission range enables each node to preserve the same number of neighbors.

5) *Average number of hops*

In Fig. 11, we notice that the ratio of hops is high whatever

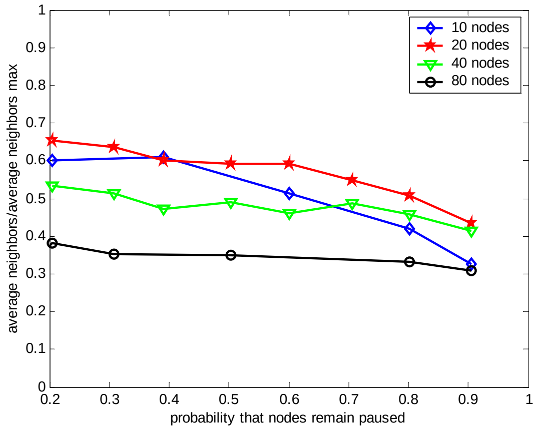


Fig. 10 Average neighbor vs pause probability.

the speed of the nodes in particular for 20, 40 and 80 nodes. In the same way, in Fig. 12 the number of hops remains high with a slow decrease as a function of the pause time of the nodes. This shows that each node increases its transmission range in order to keep the maximum number of neighbours. However, in the case of 10 nodes, the ratio of hops decreases as a function of speed and pause time. This is due to the loss of neighbors. In other words, if the node looses its neighbors, obviously the link between these nodes will also be lost.

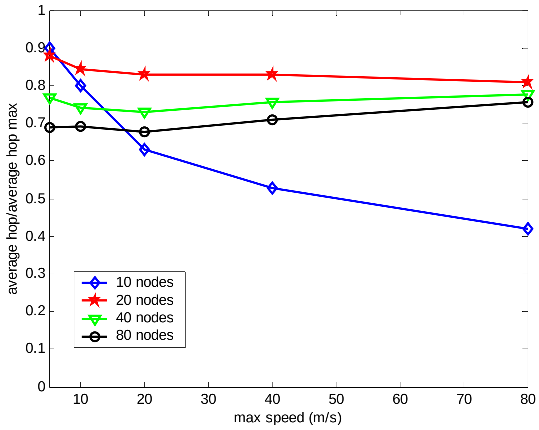


Fig. 11 Average hop ratio vs max speed.

In the four topologies (10-80 nodes), the number of hops measured with SEMC is lower than the one measured with 802.11g. This can be explained by: in SEMC we do not take into account the pairs that have nodes in separate connected components (ie infinite nb of hops between the nodes).

Note that in the best case, SEMC algorithm has good performance results (ie it economizes energy, preserves connectivity and decreases of interferences) by comparison to IEEE 802.11 g and in the worst case, it has the same results than IEEE 802.11 g.

We conclude that the variation of the transmission range enables each node to preserve a sufficient number of neighbors by increasing or decreasing the number of hops. Moreover, we conclude that the connectivity between the nodes can be disrupted by the prolongation of pause time but the energy can be saved.

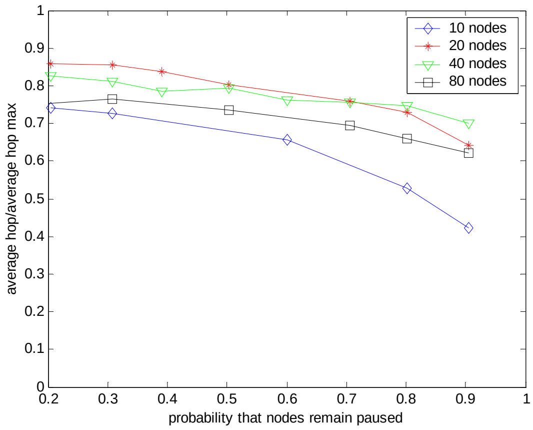


Fig. 12 Average hop vs pause probability.

V. CONCLUSIONS

We have presented a generic algorithm ***Save Energy and Maximize Connectivity* – SEMC -** proposed for ad hoc wireless networks. In this algorithm we have provided two metrics in order to economize the energy and to keep good connectivity in the network. The first metric consists of varying the transmission range in accordance with the distance between itself and its farthest neighbor; therefore, the transmission power will be reduced. The second considers the speed parameter in the choice of time period; therefore, the energy will be saved.

In order to evaluate the algorithm SEMC, a set of simulations are run and its performance is compared to those of IEEE 802.11g using the NS-2.28 simulator. We show that the energy economized by SEMC is considerable. These results are confirmed quantitatively by the ratio of energy that gets around 0.25, not only, an improvement on energy but also on the connectivity that remains good as time goes.

It is necessary to mention that the modifications of the old algorithm SEMC [13] that includes the speed of nodes in the choice of time period improve the results.

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