

Using Mobility to Enhance Routing Process in MIS System

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Abstract—This paper introduces the original Mobile Intelligent System (MIS) in an embedded Field-Programmable Gate Array (FPGA) architecture. This would allow the construction of autonomous mobile network units which can move in environments that are unknown, inaccessible or hostile for human beings, in order to collect data by various sensors and route it to a distant processing unit.

To have a better performing routing process, we propose a new mobility measure. Each node measures its own mobility in the network, based on its neighbors' information. This measure has no unit and is calculated by quantification in regular time intervals.

Index Terms—Information systems embedded application, intelligent sensors, wireless sensor network, ad hoc networks, OLSR protocol, multipoint relays, node mobility and mobility quantification

I. INTRODUCTION

Sensors have become an essential element in all systems where information resulting from the external environment is to make evaluations and act. To have an exact and complete grasp of the subject requires the deployment of several sensors and, possibly, the combination of all retrieved information to better adjust each parameter's sensor.

A sensor network is composed of a large number of units called nodes. Each node mainly consists of one or several sensors, a processing unit and a communication module, etc. These nodes communicate between each other according to the network topology and the existence or not of an infrastructure (access points) to forward the information to a control unit outside the measure zone. With these features available, we can imagine an adaptive complex system built on several sensors in a wireless communication system. An original system has been designed and realized: MIS (Mobile Intelligent System) project, which allows integrating three main functions: information' acquisition, processing and routing around an embedded architecture such as FPGA (Field-Programmable Gate Array).

Mobility impacts conditions where routing protocols should operate, the context that nodes can use to communicate, and the problems that protocols should solve.

In this paper, we introduce the architecture of the MIS and present a new quantitative measure of mobility reflecting the mobility degree in each MIS. Using OLSR routing protocol, this mobility measure will be exploited by the MIS during the route discovery process to enhance it and adapt it in the presence of high mobility.

This paper is organized as follows: The first section consists of a general introduction. The second one focuses on the functional architecture and the experimental MIS platform and its units. Section 3 shows the importance of mobility in designing ad hoc routing protocols. Section 4 introduces and discusses our network mobility measure. Section 5 presents some experiments of the behaviour of network mobility in different Mobile Ad hoc Networks (MANET) configurations. In Section 6, we present an application of our proposed mobility measure. The last section concludes and presents some future works.

II. MIS PLATFORM

In this section, we present the MIS project and its experimental platform system previously introduced in [1-5].

A. MIS Presentation

MIS (Mobile Intelligent System) is a platform of intelligent wireless sensor prototyping elaborated within the Wireless Sensor Networks (WSN) group of the Laboratory Electronic and Communication (LEC) for topological applications of communicating objects' networks. This platform is based on various sensors (CO, resistive tape recorder, etc.), a routing and treatment unit, a module of wireless radio communication using standard BLUETOOTH or WIFI and a routing and treatment unit based on a microprocessor (IP software).

B. MIS Applications

One of the main applications is to construct autonomous mobile networks capable of moving in environments which are unknown, inaccessible or hostile for human beings or in risky areas (fire, radiation, earthquake, etc.) in order to optimize human assistance. The aim is to provide ground information to establish a strategy of evolution according to the set target. For example, victims can be located during rescue operations thanks to small mobiles capable of infiltrating through rubble or exploring the watery funds. Another equally important application is military exploitation. In this context, the use of sensor networks allows the surveillance of the perimeters, to assist air or ground attacks and to lead espionage operations. To this end, no element should be indispensable for the functioning of the network. Such an ad hoc architecture can maintain the network in activity after the loss of one or several elements and requires a routing module.

C. MIS Architecture

The functional architecture and the experimental platform MIS is built on the development kit ALTERA Cyclone (System One Programmable Chip). It is essentially

composed of four units (figure 1): an acquisition unit, a treatment unit, a routing unit and a communication unit.

The detailed architecture of the designed and produced beacon is given below (fig.2-3). It is articulated around the Nios II processor. Several interfaces are used to connect the peripherals to the processor (SPI, UART, Bus Avalon, PIO, etc.).

The system is also composed of different sensors allowing data acquisition and the generation of numerical signals. These signals are treated by target card ALTERA cyclone. After treatment, control signals are routed towards a central station using a routing protocol.

The routing protocol can be implemented on MIS in two different ways, either directly into software or in a hybrid way: the software part of MIS is in C language and material acceleration is implemented using hardware description language VHDL (optimizations to be made to meet the criterion of consumption and execution speed). This implementation has been finalized and made possible by adding an operating system of the μ Clinux type. The big advantage of μ Clinux in comparison with other systems is the compatibility of API's programming with the Linux standard systems. It also has all TCP/IP network functions, available on the Linux kernel and supported by the ALTERA card. Furthermore, it does not consume a lot of memory.

In the next subsections, we shall mainly describe our contribution: “*Using Mobility to Enhance the Routing process in the MIS System*”, subject of this paper.

III. IMPORTANCE OF MOBILITY IN PROTOCOL DESIGN

The behavior and characteristics of a network's wireless links is very different when it comes to mobility, which makes the design of communication protocols operating in the presence of mobility more challenging. Mobility also changes the neighborhood in which a given node must share the communication bandwidth available with others. As nodes move, the paths established from sources to destinations can be broken, which leads to the creation of new paths and the reallocation of resources along such paths to meet the application requirements. However, while mobility makes the implementation of several functions and services more challenging, it allows some useful functionality. For example, thanks to mobility, a node can know its location and can therefore exploit location-dependent services. Similarly, mobility introduces a fundamental change in our perception of networking. While the end-to-end connectivity assumption is justified in wired networks, the cost, energy consumption and form factors of computing devices have enabled embedded computing and networking devices that can be used in environments where end-to-end connectivity may at best be intermittent.

IV. THE PROPOSED MOBILITY MEASURE

A node in a wireless network can be found in three states in relation with its neighbour: node moving/ its neighbour static, node static/its neighbour moving, and finally node moving/ its neighbour moving. Consequently, these three possible states result in a change in the link status of the node with its neighbour. Hence, as the node moves in the network, the link status changes over time.

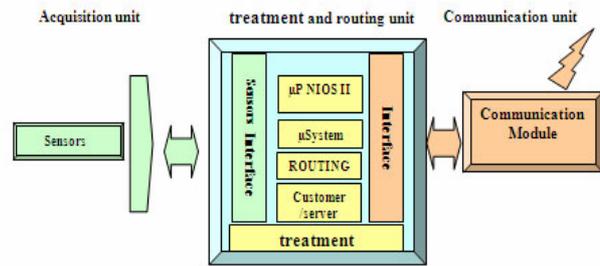


Figure 1. MIS architecture

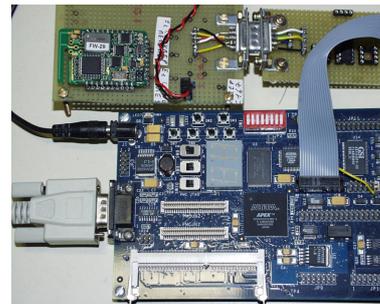


Figure 2. Wireless unit interfaced with the processing unit

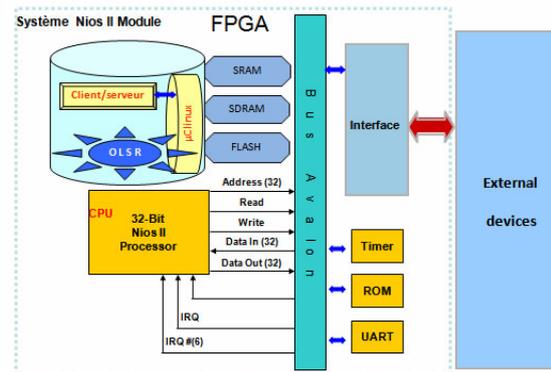


Figure 3. Synoptic of the System SoPC NIOS II for the acquisition and the routing of temperature

Based on this observation, we define *the node (MIS)* and *the network mobility* in an ad hoc environment. *Mobility* is quantified locally. It is independent from the location of a given node. We represent this local and relative quantification by its neighbour's change rate. *The node mobility* at a given time t for node A in the ad hoc network is defined as the change in its neighbour compared to the previous state at time $t - \Delta t$. Thus, nodes that join or/and leave the neighbour of node A will impact the evaluation of its *mobility*. As explained before, we define the *mobility* of node A at time t by the following formula:

$$M_A^\lambda(t) = \lambda \frac{NodesOut(t)}{Nodes(t - \Delta t)} + (1 - \lambda) \frac{NodesIn(t)}{Nodes(t)} \quad (1)$$

Where,

NodesIn(t) : The number of nodes that joined the range of node A during the interval $[t - \Delta t ; t]$.

NodesOut(t) : The number of nodes that left the range of Node A during the interval $[t - \Delta t ; t]$.

Nodes(t) : The number of nodes in the range of node A at time t .

λ : a 0 to 1 positive value defined in advance to promote incoming/outgoing nodes depending on situations (attacks, rescue operation, etc.).

The choice of the value ($\lambda = 1/2$) will ponder equally the NodesIn(t) and NodesOut(t) nodes during Δt and keep the *mobility* node value in the interval [0,1]. In other words, let us take node A that has 11 neighbors at $t - \Delta t$ (Figure 4(a)). During the Δt time interval, its neighbour has changed its position as shown in (Figure. 4(b)): two nodes (red color) have left the range of node A , and three nodes (green color) have joined its neighbour. Consequently, the state (neighbors) of the node will change after Δt (Figure 4(c)). At the end of each time interval, the node will be able to evaluate the change in its neighbour represented by this relative *mobility* which, in this example, is equal to 21%:

$$M_A = 0.5 \frac{2}{11} + (1 - 0.5) \frac{3}{12} \approx 21\% \quad (\text{with } \lambda = 1/2).$$

The node *mobility* quantification has no unit, varies between 0 and 1, and does not suppose any mobility model [6] for evaluation. Each node in the MANET can make an autonomous and automatic evaluation of its mobility at regular time intervals. This evaluation can be periodically done while exchanging Hello messages (a characteristic that we find in the proactive protocol family).

Moreover the calculation and recalculation of *node mobility* is fast and does not consume many resources (CPU and memory).

After measuring the node mobility, we can define the *network mobility* measure in regular time intervals as the average of the involved nodes mobility:

$$Mob(t) = \frac{1}{N} \sum_{i=0}^{N-1} M_i(t) \quad (2)$$

Where N is the number of nodes in the network.

In addition, we can define the time average of this network mobility as the average of the simulation period (T):

$$M = \frac{\Delta t}{T} \sum_k Mob(t) \quad (3)$$

Where $k \in \{0, \Delta t, 2 \Delta t, \dots, T\}$. T is the time of simulation.

V. VALIDATING OUR MOILITY MEASURE

In this section, we present the behavior of the *network mobility* relating to some characteristics of the ad hoc network for the default case ($\lambda = 1/2$). The default case corresponds to an environment where NodesIn(t) and NodesOut(t) are equally pondered.

As *mobility* is a main constraint with a direct impact on the performance of MANETs (Mobile Ad hoc NETWORKs), it is necessary to study its behaviour in different scenarios by changing several properties of the ad hoc network: number of nodes, network dimension, transmission range and speed of nodes.

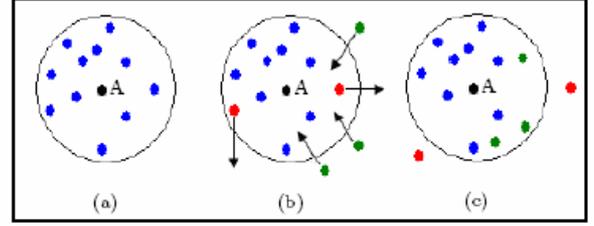


Figure 4. Node mobility quantification in Δt interval

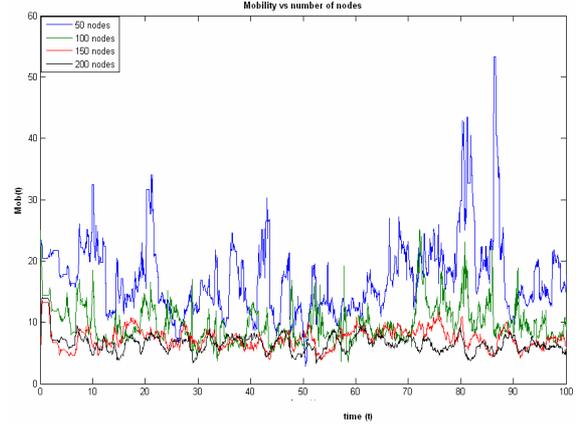


Figure 5. Effect of node numbers on network mobility

We choose the random waypoint mobility model [7] to represent nodes motion in the MANET. This mobility model is the most widely used mobility model, due to its simplicity and capability to synthesize scenarios with varying degrees of mobility. The impact of mobility models [8] [9] is also discussed later in this paper.

In our simulations, we consider a MANET with 1000mX1000m and 100 seconds as a period of simulation. The value of Δt in this mobility quantification work is 0.05 s ($\Delta t = 0.05$ seconds). Moreover, we represent our network mobility M in the following graphs by percentage.

A. The Effects of Node Number

The number of wireless devices is expanding and new multi-user applications are developed to adapt to this increase. This requires the building of larger ad hoc networks with the participation of more and more nodes.

This is why we have decided to simulate the effect of an increase in the number of nodes on the *network mobility* M . In our simulations, we use a square network area of 1000m X 1000m size with different configurations (50, 100, 150 and 200 nodes) and set the transmission range to 100m and the maximum speed to 40m/s (high mobility).

We note from the graphs in Figure 5 that mobility increases (from black to blue) as the number of nodes decreases in the network. More precisely, we can see that the mean and the variance of mobility become important when the node number decreases in the network. This can be explained by the increasing sensitivity of MANET to link state changes when the number of nodes falls down.

B. Impact of Speed

Many simulations concerning the influence of speed on mobility have been made [10]. They show that mobility largely depends on the concerned nodes' speed and direction of movement. In order to confirm this result for our network mobility measure, we consider in our simulations a MANET with 50 nodes. The transmission range is set at 100m. We have taken for simulations the following maximum speed: 0m/s; 20m/s; 40m/s; 60m/s.

Figure 6 shows clearly that an increasing speed automatically implies an increase in the network's mobility. When nodes move at a high speed to a random destination, they have an important change in their neighbours (nodes that join and/or leave their transmission range). In short, the *network mobility M* logically depends on nodes' physical speed.

C. Impact of the Transmission Range

The communication devices available on the market offer a wide range of power levels, which affect the transmission power and connectivity. It is often assumed that the larger the transmission range, the better for data delivery. In this section, we study the impact of the transmission range, on MANET performance. We have found that it affects logically our network mobility's metric. We consider a MANET with 50 nodes in case of high mobility (maximum speed of nodes is 40m/s). In order to show the impact of node's transmission range, we have taken the following values: 50m, 100m, 150m, and 200m.

Figure 7 shows that the network mobility varies inversely with the transmission range.

Otherwise, mobility becomes important if we have nodes with a small transmission range. In the case of a small transmission range, nodes neighbours' that move rapidly in the network have more chance to leave and/or join the transmission range of its neighbour. Consequently, the rate of link state changes and mobility becomes important.

D. Impact of Mobility Models

In the literature, many mobility models have been used to simulate node's motion [6] [11]. In this section we will show the behaviour of our network mobility measure using different mobility models. The simulated mobility models are: mobility waypoint model, Manhattan model and reference point group model.

We notice that the network mobility behaviour is impacted by the mobility model chosen. For the random waypoint mobility and random Gauss Markov models, the average and variance behaviour of the network mobility are stable all over simulation time. The Manhattan mobility model shows an important variance of mobility. The registered variance can be caused by nodes that are found at *column intersections* [6] [10]. In the reference point group mobility model, the variance is equal to 0, but during the simulation time, the mobility changes dramatically. These variations are produced when the groups are close to each other.

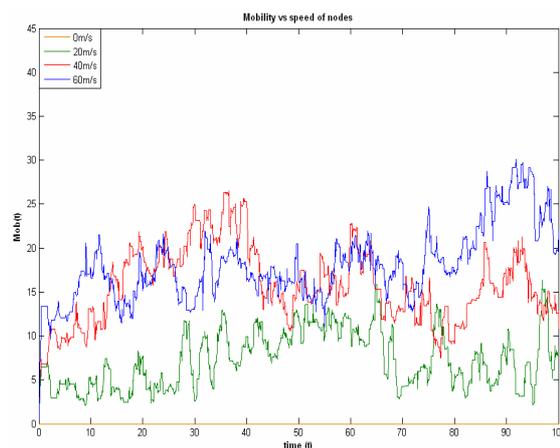


Figure 6. Effect of speed on the network mobility.

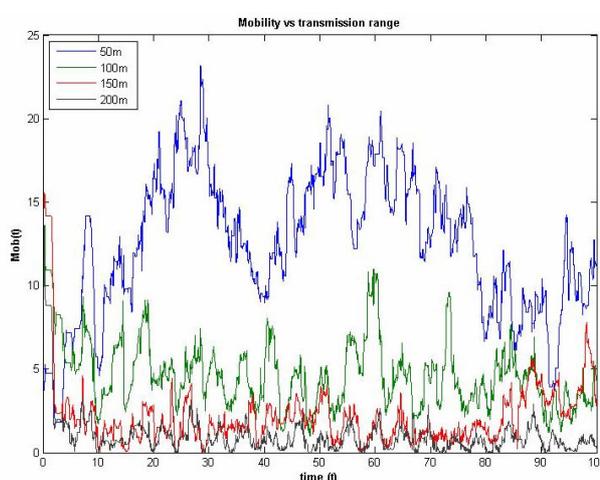


Figure 7. Effect of transmission range on the network mobility measure.

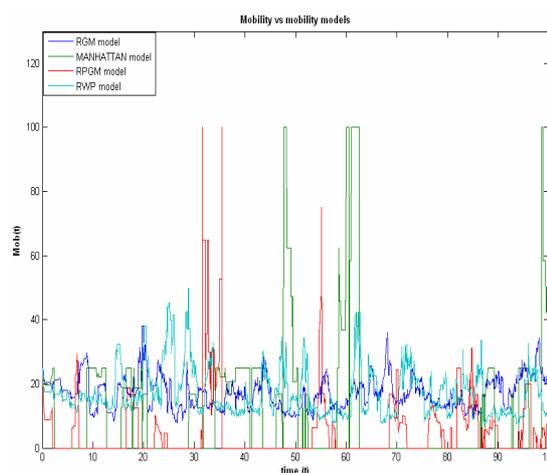


Figure 8. Behavior of the network mobility using different mobility models.

VI. VALIDATING OUR MOBILITY MEASURE

A. Network Scenarios

To generalize the validation of our proposed mobility metric, we have considered two types of network scenarios [8] (entity mobility and group mobility models). In this study, a variety of network scenarios are generated for each type of mobility models as summarized in Tables 1 and 2. For the first type including the RWP and RGM models and to make comparison more challenging, we have considered the worst scenarios by supposing a maximum speed of nodes equal to $V_{max} = 40\text{m/s}$ and a minimum speed equal to $V_{min} = 0\text{m/s}$. For RGM model, speed v and direction θ are updated every $\Delta t = 2.5$ seconds, where $\Delta v_{max} = 0.5$ and $\Delta \theta_{max} = 0.125\pi$.

Table 1 shows the first type of network scenarios that simulate a group of nodes that move randomly in a square region. Each scenario has its proper parameters that distinguish it from other scenarios. For the RWP model, parameters are the region dimensions, the number of nodes N and the *pause time*. For the RGM model, parameters are the region dimension and number of nodes N . For example, scenario *S1* related to the RWP model has 30 nodes that are moving with a pause time equal to 0 seconds in an $800\text{m} \times 800\text{m}$ square region, and scenario *G1* related to the RGM model has 50 nodes moving in $700\text{m} \times 700\text{m}$ square region.

Table 2 illustrates the second type of network scenarios using the RPGM model where nodes move in a $1000\text{m} \times 1000\text{m}$ square region. For the trajectory of the logical center of each group, the RWP model is used. Moreover, for the same reason (i.e. to make comparison more challenging), we assume the worst scenario by supposing the maximum speed of the logical centre is equal to $V_{max} = 40\text{m/s}$, the minimum speed is equal to $V_{min} = 0\text{m/s}$, and a pause time is equal to 0. The update interval $\tau = 1$ is used for the random motion vector. In scenario *P1*, there are 5 groups, where each group contains 10 nodes (total 50 nodes). One of the nodes' reference points is located at the logical centre of each group and the other 9 reference points at the corners of a regular hexagon centred at the logical centre with the length of its side 0.25. The length of the random motion vector has a uniform distribution between 0 and $RM_{max} = 0.25$. All of the 5 nodes' reference points are located at the logical centre of each group. Scenario *P2* ensures more intra-group motion compared to scenario *P1* by having $RM_{max} = 0.5$. As our proposed mobility metric depends on parameter λ , we have also studied its impact on the relationship with the rate of link change. The values of λ considered in this work are: $\lambda = 0.00, 0.25, 0.50, 0.75$, and 1.00 . Finally, to make simulations in the same conditions, the simulation time and communication range for all scenarios are equal to 500 seconds and 100m , respectively. Moreover, to be more precise, let us note that, henceforth, each measure represents an average of 20 measures.

B. Results and Debate

As Node mobility in ad hoc network depends on the change in link status, validating our mobility metric re-

 TABLE I.
ENTITY MOBILITY: NODES MOVE RANDOMLY

Random WayPoint Mobility Model			
<i>Si</i>	<i>Network dimension</i>	<i>N</i>	<i>pause time</i>
S1	800X800	30	0
S2	800X800	40	0
S3	800X800	50	0
S4	600X600	50	0
S5	700X700	50	0
S6	800X800	50	5
S7	800X800	50	10
Random Gauss-Markov Mobility Model			
<i>Gi</i>	<i>Network dimension</i>	<i>N</i>	
G1	700X700	50	
G2	800X800	50	
G3	900X900	50	
G4	800X800	20	
G5	800X800	30	
G6	800X800	40	

 TABLE II.
GROUP MOBILITY: RPGM MODEL IS USED.

<i>Pi</i>	Details
P1	5 groups, 10 nodes/group (total 50 nodes), $RM_{max} = 0.25$ (small intra-group motion),
P2	5 groups, 10 nodes/group (total 50 nodes), $RM_{max} = 0.5$ (small intra-group motion),
P3	10 groups, 5 nodes/group (total 50 nodes), $RM_{max} = 0.25$ (small intra-group motion),
P4	10 groups, 5 nodes/group (total 50 nodes), $RM_{max} = 0.5$ (small intra-group motion),
P5	10 groups, 4 nodes/group (total 40 nodes), $RM_{max} = 0.25$ (small intra-group motion),
P6	4 groups, 10 nodes/group (total 40 nodes), $RM_{max} = 0.25$ (small intra-group motion),

quires a strong linear relationship between this mobility and the link change rate. To this end, we have compared them. The mobility metric in the network being normalized by N (total number of nodes), it is essential to normalize the link change rate measure by $N(N-1)/2$ which represents the maximum number of links in a network with N nodes. Moreover, as the change of the link state occurs in time, it is essential to make this comparison by taking into account the time constraint. Moreover, we suppose at each end of interval Δt that the ad hoc network is steady. In this work, the comparison is made at the end of simulation between the following measures: the time average of ad hoc mobility measure M_λ , and the average normalized link change rate.

In all the scenarios, the calculation of each measure during simulation is evaluated by quantification at the same discrete time intervals. For this study, the step chosen for the quantification of these two measures is equal to $\Delta t = 0.05\text{s}$. We chose Δt , a relatively small value, so as to have a better estimation of the link change rate. To calculate the average normalized link change rate, we initially define $L(t)$ as the number of link changes that oc-

curred at time interval $[0, t]$. Then, the number of link changes $l(t)$ occurring in Δt time is as follows:

$$l(t) = \frac{\Delta L(t)}{\Delta t} = \sum_k \delta(t - t_k) \quad (4)$$

where t_k is the time instance of the k -th link change. The time average of the normalized links change rate is given by:

$$\bar{l} = \frac{\Delta t}{T} \sum_k \frac{l(t)}{N(t)(N(t)-1)} \quad (5)$$

where $k \in \{0, \Delta t, 2\Delta t, \dots, E\left(\frac{\Delta t}{T}\right)\}$. $E(x)$ is the integer

part of x , $N(t)$ is the total nodes at the instant t , and T is the total simulation time. As the total of nodes is supposed to be fixed in this study, Equation (5) can be written as follows:

$$\bar{l} = \frac{2\Delta t}{N(N-1)} \frac{L(T)}{T} \quad (6)$$

After simulations, the results show that the time average ad hoc network mobility M_λ has a good linear relationship with the average normalized link change rate for the two network scenario types. This good linear relationship is not influenced by the considered values of λ ($\lambda = 0.00, 0.25, 0.50, 0.75, 1.00$), but these values have an impact on the slope of the line approximating the linear relationship. On the other hand, we can consider our metric of mobility measure M_λ as an alternative mobility measure evaluated at discrete times, contrary to the mobility measure proposed in [14] which is based on uninterrupted time. Moreover, our unified mobility metric is more trivial and independent of all pattern motions of nodes.

Figures 9-a and 9-b show the simulation results for the mobility metric M_λ with the first type of mobility models (entity mobility models) with different values of λ . As shown in figure 9, the average normalized link change rate \bar{l} shows a strong linear relationship with M_λ for the entire network scenarios. By considering $\lambda = 0.50$, the first type of scenarios related to the entity mobility model (RWP and RGM models), the good linear relationship is well maintained even if we change the number of nodes N ($S1-S2-S3$ for RWP, and $G2-G4-G5-G6$ for RGM), the physical dimension of the network ($S4-S5-S6$ for RWP, and $G1-G2-G3$ for RGM), and the pause time ($S6-S7$ for RWP). As shown in figure 10, the same behaviour is detected in the results obtained with the second type of network scenarios relating to the group mobility model (RPGM model), by varying the groups' number ($P1-P3-P6$), total of nodes ($P1-P5$), and the intra-group motion ($P1-P2$, and $P3-P4$).

This shows that our mobility metric M_λ has the same behaviour in terms of link change rate in the ad hoc network.

By construction, our mobility measure approach is based on the link status change undergone in the vicinity of the communication range. We compare our studies to [14], who have found a relationship between the remoteness concept and the link status change.

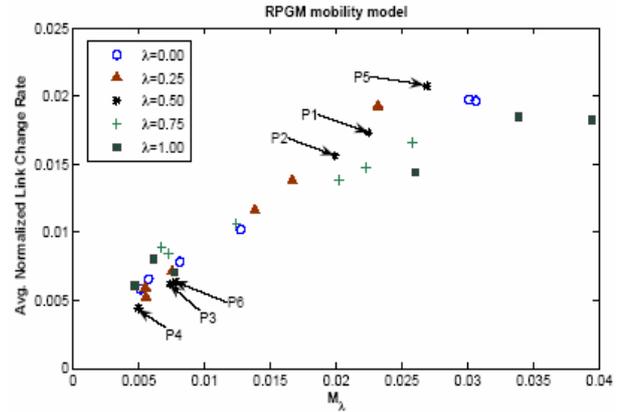


Figure 9. Normalized link change rate vs. mobility metric in group mobility model

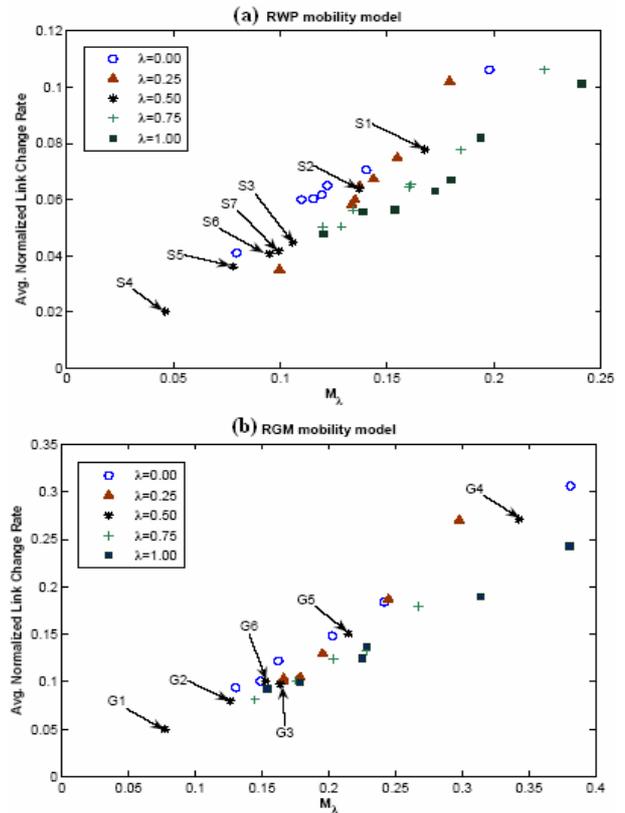


Figure 10. Normalized link change rate vs. mobility metric in entity mobility model

They define a distance function between two nodes as a relation of remoteness between them. Moreover, this distance function should satisfy the following requirements. It increases from 0 to 1 monotonically. The derivative of remoteness is 0 at distance 0. It goes up as the distance increases, reaches its maximum at the communication boundary, then decreases as distance increases further, and approaches 0 as the distance approaches the infinite value. In short, their mobility measure is defined as the average derivative of remoteness over all node pairs. Several remoteness functions fulfilling these requirements can be found. So it is quite clear that the returned measure of mobility depends on the chosen remoteness function. On the other hand, these remoteness functions are complex in a lot of cases and contain many parameters which require

hard operations in a network simulator environment where resources are needed (CPU and memory). To measure mobility with a remoteness function, hard operations (such as derivation and integration calculation) are needed; these could saturate resources and make the network down. In a real ad hoc network, we can have two nodes next to each other in the absence of a link (e.g: presence of an obstacle such as a button wall). Therefore, the concept of remoteness cannot reflect exactly the rate of link status change in an ad hoc network.

In the literature, it is difficult to compare the performance results of several protocols simulated in different mobility models, even if they have the same simulation parameters. To this end, we find that comparative studies on protocol performance are based on the same mobility model (often RWP model). This makes it possible to put simulations under the same *mobility condition*; in other words, in the same mobility measure. Then, to meet this condition, it is necessary to know how the changing ad hoc network parameters influence our mobility measure: to know the mobility measure behaviour when the ad hoc network parameters change. The main ad hoc network parameters characterizing it are: number of nodes, network dimension, and node transmission range.

VII. APPLICATION

As an application of this mobility measure, we have exploited the node mobility parameter defined in Section 4 to adapt MANET routing protocols to topology changes. The protocol that we have considered is the OLSR protocol.

A. The Optimized Link Routing Protocol

1) Overview

The OLSR (Optimized Link State Routing) [15] protocol is a proactive table-driven routing protocol designed for mobile ad hoc networks. As a link state routing protocol, OLSR periodically advertises information about links to build the network. However, OLSR optimizes the topology information flooding mechanism by reducing the amount of links that are advertised. It also reduces the number of forwarding messages by limiting them to the set of Multipoint Relays (MPRs). Information topology is sent by a Topology Control (TC) message and exchanged using broadcasted messages into the network. TC messages only originate from nodes acting as MPRs. The latter are selected in such a way that a minimum set of MPRs, located one-hop away from the node doing the selection (called MPR Selector), are sufficient to reach every single neighbour located two-hops away of MPR selector. By applying this selection mechanism, only a reduced number of nodes (depending on the network topology) will be selected as MPRs. Every node in the network recognizes its one-hop and two-hop neighbours by periodically exchanging HELLO messages containing the list of its one-hop neighbours. On the other hand, TC messages will only be advertised between MPRs and their electors. Then, only a partial set of network links (the topology) will be concerned by advertising control messages, also MPRs are the only nodes allowed to forward TC messages and only if messages come from a MPR Selector node. These forwarding constraints considerably decrease the amount of flooding retransmissions.

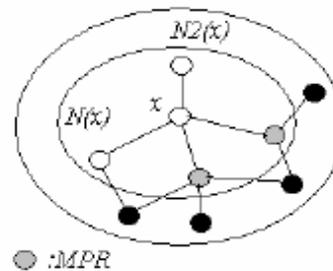


Figure 11. Example of MPR Selection

2) The MPR Selection algorithm

Computing the MPR set with minimal size is a NP-complete problem [11]. The standard MPR selection algorithm currently used in the OLSR implementation is as follows:

For a node x , let $N(x)$ be the neighbourhood of x . $N(x)$ is the set of nodes which are in the range of node x and share a bidirectional link with it.

We denote by $N2(x)$ the two-neighbourhood of node x , i.e, the set of nodes which are neighbours of at least one node of $N(x)$ but that do not belong to $N(x)$ (Figure 11).

The standard algorithm of MPR selection is defined as follows [16]:

Algorithm 1 : standard MPR selection algorithm

1. $U \leftarrow N^2(x)$
2. $MPR(x) \leftarrow \emptyset$
3. while $\exists v : v \in U \wedge \exists w \in N(x) : v \in N(w)$ do
 - (a) $U \leftarrow U - N(w)$
 - (b) $MPR(x) \leftarrow MPR(x) \cup \{w\}$
4. while $(U \neq \emptyset)$ do
 - (a) choose $w \in N(x)$ such as: $CRITERIA(w) = |N(w) \cap U| = \max(|w' \cap U| : w' \in N(x))$
 - (b) $U \leftarrow U - N(w)$
 - (c) $MPR(x) \leftarrow MPR(x) \cup \{w\}$
5. return $MPR(x)$

B. The proposed Criteria of MPR selection

1) Link mobility estimation

Some OLSR experiments [15] show that links must be more stable and less mobile to avoid fragile connections which involve data loss and frequent route changes. OLSR protocol constantly maintains the shortest paths to reach all possible destinations in the network. So, it is judicious to estimate the quality of links before adding them in the topological information used to calculate the best routes. The quality of a link can be estimated based on the received signal's power. This information is provided by some wireless cards. If this information is not available, OLSR estimates the link quality based on the number of control messages lost. A link failure can be detected using the timer expiry or by the link layer informing upper layers of the failure with a neighbour node after reaching the maximal number of retries.

With the aim of estimating the quality of links in terms of mobility, we define the mobility of a link $L(A,B)$ between two nodes A and B as the average mobility of the involved nodes (Figure 12), as shown in the following equation:

$$M_{L(A,B)}(t) = \frac{1}{2}(M_A(t) + M_B(t)) \quad (7)$$



Figure 12. Mobility of the link $L(A,B)$ is $(50\%+40\%)$

Evaluating the link mobility alone is not significant because we can have a normal value of link mobility with a high mobility value of one of the involved nodes. The dependence between the mobility of nodes composing a link (in the network core) at time t can be seen as the probability of the link loss $L(A,B)$, as follows:

$$P_{L(A,B)}(t) = \frac{1}{2}|M_A(t) - M_B(t)| \quad (8)$$

Therefore, a reliable link $L(i,j)$ can be seen as a link meeting the two following criteria:

1) link $L(i,j)$ mobility is lower than a threshold link S_L which depends on the characteristics of the wireless network (network density, network mobility, network scalability, network dimension, etc.):

$$M_{L(i,j)}(t) < S_L \quad (9)$$

2) The dependence factor $P_{L(i,j)}(t)$ of nodes (i and j) mobility is near to zero:

$$P_{L(i,j)}(t) \rightarrow 0 \quad (10)$$

The choice of a link meeting these two conditions ensures a low mobility to link, with a strong dependence between the involved nodes.

2) The proposed criteria

In this section, we propose two new criteria for the operation of MPR selection. These criteria are based on estimating the quality of links between one-hop neighbours and two-hop neighbours. The link quality is given by this link's dependence factor. A reliable link is a link with a dependence factor near 0. The new selection of MPRs nodes is a compromise between the number of links towards the nodes at two-hops and these links' reliability is presented by these links loss probability. The selection of a neighbour node as a MPR node can be viewed as a maximization of the selection criterion. The first criterion suggested, 'the simple criteria', is based on nodes' mobility (Equation (11)). The second is based on sum (Equation (12)) and the third on the product (Equation (13)). The principal advantages of these criteria are the facility of calculation and fewer requirements in terms of memory and CPU resources.

$$DIR - CRITERIA(w) = \min_{w \in N(x)} M_w(t) \quad (11)$$

$$SUM - CRITERION(w) = 1 - \frac{\sum_{i=1}^N L(w,i)}{N} \quad (12)$$

$$PRD - CRITERION(w) = 1 - \prod_{i=1}^N L(w,i) \quad (13)$$

VIII. CONCLUSION AND PERSPECTIVES

In this paper, we have introduced the architecture of an intelligent beacon for ad hoc wireless sensor networks named MIS (Mobile Intelligent System). This beacon may obtain data from the environment and detect possible defaults (great variations). When an alarm is triggered, data is sent on a wireless network such as Bluetooth or Wifi.

In this work, we have also proposed and discussed the theoretical aspect of the proposed relative and lightweight network mobility measure, based on the quantification of link changes at regular time intervals. Simulation results show that the proposed mobility measure have a strong relationship with MANETs environment and MIS parameters. This mobility measure has been implemented in the OLSR protocol (work in progress) and incorporated into the FPGA platform.

In the future, we plan to further this work in two main directions: finding the relation between the network mobility measure and some parameters like link duration and path duration, through variant network scenarios; and positively integrating this new mobility measure in other MANET routing protocols and MIS.

The interest of such a work has a big impact on the applications relating to the networks of wireless mobile sensors, in particular those dedicated to the military sector. The implementation and test are currently underway.

REFERENCES

- [1] A. Habbani, J. abbadi, And P. Garda, " versatile platform for AD-HOC, wireless sensor network node in FPGA". International Journal in *Physics and Chemistry PCN* (Physical and Chemical News). EL JADIDA, 2007.
- [2] A. Habbani, J. abbadi, And Z. Guennoun, "MIS: Mobile Intelligent System". IJCSNS -International Journal of *Computer Science and Network Security*, Korea, 2007.
- [3] Habbani, A., Romain, O And Garda, P. MIS and I2C Bus, IJCSNS -International Journal of *Computer Sciences and Engineering Systems*, China, Vol.1, No.2, 2007
- [4] T. Camp, J. Boleng, and V. Davies. "A Survey of Mobility Models for Ad Hoc Network Research". In *Wireless Communications and Mobile Computing (WCMC): Special issue on mobile ad hoc networking: research, trends and applications*, volume 2, pages 483–502, 2002.
- [5] C. Bettstetter, G. Resta, and P. Santi. "The Node Distribution of the Random Waypoint Mobility Model for Wireless AdHoc Networks". IEEE Transactions on *Mobile Computing*, 2(3):257–269, 2003. (doi:10.1109/TMC.2003.1233531)
- [6] K. Ouididi, N.Enneya. and M. Elkoutbi. " Mobilité et routage OLSR", 9th African Conference on Research in Computer Science and *Applied Mathematics -CARI'08*, Rabat, Morocco, 27-30 October 2008.
- [7] M. Ouididi, N. Enneya, M.Elkoutbi. "Une Mesure Intelligente de la Mobilité dans les MANETs". SITA. mai 2008. pp172-174.
- [8] F. Bai, N. Sadagopan, A.Helmy,"The important framework for analyzing the Impact of Mobility on Performance" University of Southern California, Los Angeles, CA 90089, USA pp 10-15 2003.
- [9] F. Bai and A. Helmy, "A survey of mobility models in wireless ad hoc networks", (Wireless Ad Hoc and Sensor Networks, Chapter 1, Kluwer Academic Publishers, June 2004), pp. 1-29.
- [10] Thomas Clausen (ed) and Philippe Jacquet (ed). "Optimized Link State Routing protocol (OLSR)". RFC 3626 Experimental, October 2003.
- [11] A. Qayyum, L. Viennot and A. Laouiti. "Multipoint relaying for flooding broadcast messages in mobile wireless networks". In Proceedings of the Hawaii International Conference on *System Sciences* (HICSS'02), Big Island, Hawaii, January 2002.

- [12] B. J. KWAK, N. O. SONG, and E. M. Leonard, "A Standard Measure of Mobility for Evaluating Mobile Ad Hoc Network Performance", *IEICE TRANS. COMMUN.*, vol. E86-B, no.11, pp 3236-3243, November 2003.
- [13] J. Boleng, W. Navidi, and T. Camp, "Metrics to enable adaptive protocols for mobile ad hoc networks", In Proceedings of the International Conference on *Wireless Networks* (ICWN02), (pp 293-298, 2002).
- [14] T. Clausen (ed) and P. Jacquet (ed). "Optimized Link State Routing protocol (OLSR)". RFC 3626 Experimental, October 2003.

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