A Mobility Prediction Model for a Role Management Dynamic Algorithm for Wireless Sensor Networks

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ABSTRACT

The main goal of this paper is the analysis of the problem of joint dynamic re-assignment of node role and a Mobility Prediction Model (MPM). Based on the consideration that in almost all wireless sensor networks nodes can assume different roles it is fundamental to manage the rotation of the roles in order to realize a better energy distribution and prolong, in this way, the lifetime of the network. We focused on considering two different roles: a *passive* and an *active* role. When a sensor device assumes an *active* role it uses a greater amount of energy than the *passive* role. We considered a Role-dynamic Management Algorithm (RMA) that allows to realize a better energy distribution in the network varying in a dynamic fashion node role under different mobility conditions and permits longer lifetime to be obtained. In order to evaluate in a more opportunistic way node role changing times we developed a Mobility Prediction Model (MPM) and we jointly considered RMA and MPM on a known cross-layer approach, the EYES Source Routing (ESR) and EYES MAC (EMAC). Through extensive simulations, conducted with a well-known simulation tool, OMNeT++, we evaluated and validated the effectiveness of joint MPM and RMA.

Categories and Subject Descriptors:

C.2.1 [**Computer-Communication Networks**]: Network Architecture and Design – *wireless communications.*

General Terms

Algorithms, Management, Performance.

1. INTRODUCTION

In this paper a Role Management dynamic Algorithm (RMA) has been considered [1]. RMA runs on top of any MAC or routing protocol in which nodes can assume different roles. In [1] two different approaches have been developed, a first one that does not consider the routing instances in the decisional mechanism and another approach in which routing instances were considered. In this work, we focus on the second approach, where the decision if a node can substitute another node is based on the consideration if the substituting node satisfies certain conditions. Specifically, if a node N1 would like to change its state from passive to active and a neighbor node N2 would like to change its role from active to passive, this role changing can occur if and only if N2 is on a certain number of active paths of N1. RMA has been evaluated on top of a cross-layered protocol for WSNs, EYES Source Routing (ESR) and EYES MAC [2]. RMA is dynamic, in the sense that each node is able to change its role independently of the particular protocol considered, based on the surrounding area (i.e., a node can change its state from active to passive state only if another node can substitute it). RMA works in a fashion that no inconsistence in the network occurs, that is, based on the information derived from the exchange of messages of the protocol over which RMA is running, it evaluates whether a node can change its role (from active to passive or from passive to active). Based on the consideration that different portions of a network could be characterized with different mobility we developed in this work a Mobility Prediction Model (MPM). The main goal of this paper is the evaluation of the joint RMA and MPM. In this way, each node will be able to decide whether it wants to change role in a local, dynamic and asynchronous way and the values of the expiration time of the timers are established in a dynamic fashion and not heuristically as in [1]. A characteristic of this algorithm is that nodes do not have to be synchronized to each other. In this way, this approach is very scalable because the decision to change role is made in a local manner, the interval time of changing is dynamically established and each node does not have information about the rest of the topology but only about its surrounding area.

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2. A MOBILITY PREDICTION MODEL

Different mobility conditions in the network require different expiration times for the timer in order to obtain better results in terms of Network Lifetime, Throughput and Latency. Based on these considerations we developed a Mobility Prediction Model (MPM). MPM permits the dynamic evaluation of the mobility of different portions of the network to be realized and a different expiration timer to be set based on the local mobility evaluation. In this section the time in which a node re-considers its role in the network will be related with the mobility degree in the network. In fact, in static scenario, where there are not topological changes in the network, shorter interval times are more desirable than in mobile scenarios. In these latter scenarios topological changes are more frequent and a node is constrained to re-consider its role based on the particular characteristics of the ESR+EMAC. For this reason, a node should perceive the mobility condition in the network or better in the portion of the network where it is. A mobility evaluation in the network and, consequently, a dynamic timer adaptation, can be obtained, for each node, in the following manner:

1. Once a node fixed its role, active or passive role, it sets a own timer (called re-decision timer) with a value ranging in [MIN_TIME, MAX_TIME]. Simultaneously, it sets to 0 a counter CE recording the number of *events* detected in an observation period. Here, an *event* is the loss of a neighbor (due to the mobility) or a new neighbor.
2. Once a new *event* is detected the counter is incremented.
3. At the end of the observation period (it can be periodic or it can coincide with the expire of the timer) the coefficient of the mobility evaluation can be estimated considering a weighed mobile exponential average:

$$CM_i = \alpha \frac{CE}{T} + (1-\alpha)CM_{i-1} \quad , \alpha = \text{forgetfulness factor} = 0.125$$

Two different case can be distinguished:

- CM_i-CM_{i-1}>TH1 -> increase of mobility presumed;
- CM_i-CM_{i-1}<TH2 -> decrease of mobility presumed;

TH1 and TH2 values are threshold values that have to be experimentally determined. Based on the increase or on the decrease presumed of the mobility the interval time [MIN_TIME, MAX_TIME] will be consequently adjusted, increasing or decreasing MIN_TIME and MAX_TIME values. The new window size has to be contained in a specific window size [MIN_VAL, MAX_VAL]. The MIN_TIME value cannot be lesser than a minimum threshold value and the MAX_TIME cannot be greater than a maximum threshold value. The evaluation formula considered is based on a simple assumption that the greater is the mobility network, the greater will be the loss or acquiring events, and vice-versa. Of course, this method is effective when nodes move independently to each other, and in the RWP (Random Way Point, used in our simulations) model this hypothesis is respected. Using this mechanism to detect and to evaluate the mobility in the network some simulations have been conducted considering the ESR*+EA_MAC_v2 scheme. Results about these simulations are reported in Figures 1, 2 and 3. Let's consider ESR+EA_MAC_v2+dynamicTimer the second approach as explained in [1] and where the MPM is considered, ESR*+EA_MAC_v2+incrTimer(mobile) represents the second approach in which timers were fixed in a static manner and they do not change dynamically (their values were set greater than those fixed in the static simulations as in [1]) and finally, ESR*+EA_MAC_v2(mobile) is the second approach in which timers were set as in the previous, static simulations considered in [1], without considering some amount of mobility has been introduced in the network, the timers were set as in the static case.

3. SIMULATION RESULTS

Simulations were conducted in order to verify the effectiveness of the proposed joint RMA and MPM. The simulation tool used is an Object Oriented simulator OMNET++ [3]. In the simulator a physical layer was implemented in order to consider an energy model to compute the energy consumption of the transceiver in the transmitting phase and in the receiving phase. Additionally, delays and energy consumption spent switching from the transmission state to the receiving state were considered. In the network 45 sensor nodes were positioned in a rectangular area of 5.5 X 3.5 times of the transmission range. Five nodes were chosen as sources nodes to send data and the packet length was 5 byte. An active node (there are other types of active nodes as we already seen) is a data sink and it receives data from the source nodes. The parameters evaluated to verify the effectiveness of the RMA are: lifetime (Figure 1), throughput (Figure 2) and latency (Figure 3) in the network. The lifetime has to be considered as the amount of the time spent so that a fixed percentage of the nodes consumes its energy. Both the source nodes and the sink node have unlimited energy, also they do not influence the lifetime. During the simulation campaigns when 30% of the sensor nodes has consumed its energy (fixed to 3 Joule), the whole network is considered dead. In Figure 1 Lifetime Network is shown. If a dynamic mechanism to perceive the mobility network is considered a better response in terms of timer adaptability is obtained and a better distribution of energy between the nodes in the network is obtained.

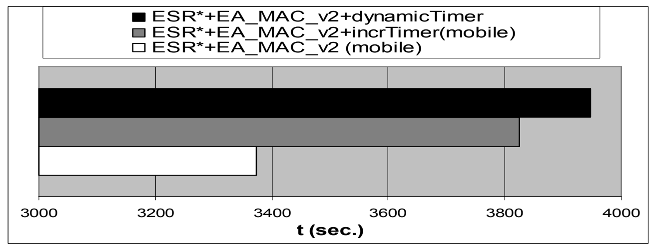

Figure 1. Lifetime Network (sec.).

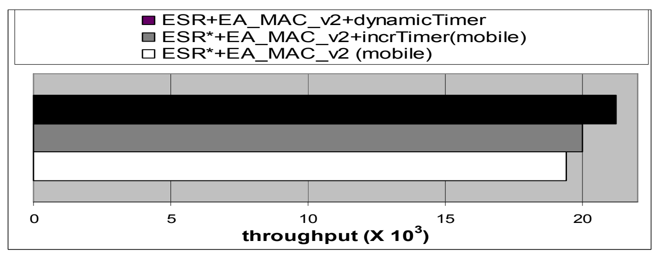

Figure 2. Throughput Network.

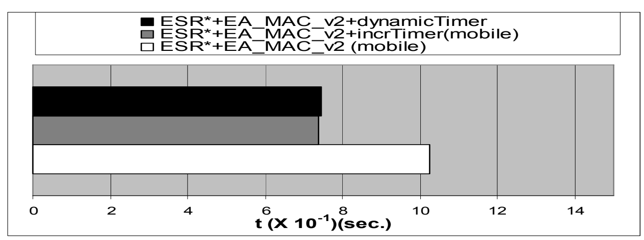

Figure 3. Latency Network.

4. REFERENCES

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