

On the Complexity of an Accurate and Precise Performance Evaluation of Wireless Networks using Simulations

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Résumé—In wireless multi-hop networks, there is a growing need for the performance evaluation of protocols and distributed applications. Due to the high complexity of analytical models and the difficulty of setting up large scale testbeds, simulations are generally considered as the most convenient methodology for evaluating the performance of wireless systems. However, evaluating a protocol can be a tedious task as it depends on several factors including the physical layer modeling and the dimensioning of protocol or environment parameters. In this work, we highlight some main factors that may affect the accuracy of the performance evaluation of protocols using simulations. First, we focus on the physical layer (PHY) modeling. Second, we discuss the impact of some protocol parameters on the behavior of the evaluated protocols.

I. INTRODUCTION

In wireless multi-hop networks, there is a growing need for the performance evaluation of networking protocols. Contrarily to the reliable physical medium of wired networks, wireless systems rely on a radio medium which is prone to failure. In such a context, the medium is shared by several nodes increasing packet loss due to collision and interference. In particular, interference is a major limiting factor for wireless communication. This issue makes it harder the performance evaluation of wireless networking protocols.

Three main approaches are generally adopted for the performance evaluation of networking protocols : *analytical analysis*, *experimentation* and *simulation*. Due to the high complexity of wireless communications, analytical analysis are often based on unrealistic assumptions and inaccurate physical layer (PHY) models (*e.g.*, node synchronisation, ideal MAC layer, homogeneous location model, symmetric radio links, disk model, *etc.*). In addition, theoretical analysis always focuses on a given layer, ignoring the other network layers. Concerning the experimentation approach, it can provide valuable insight into the behavior of protocols in wireless environments. However, setting up large scale testbeds is a tedious task and is not always feasible. Moreover, the obtained results are strongly correlated to the surrounding environment and are not easily reproducible.

For these reasons, the use of simulations is generally considered as the most convenient methodology to analyse the performance of protocols and distributed applications. Several wireless network simulators have been proposed in

the last years. Examples are NS-2, GloMoSim, JiST/SWANS, GTSNetS, *etc.* They all provide an advanced and complete simulation environment to investigate and evaluate networking protocols and wireless systems. However, the complexity of the wireless physical layer (PHY) leads to implementation choices during the simulators design. As a consequence, the PHY simulation accuracy varies drastically from one simulator to another. In particular, interference management is probably the point where current simulators differ the most largely. The reason that generally justifies a low accuracy is performance [1]. Moreover, some protocol and environment parameters are generally tuned arbitrarily during the performance evaluation of high level protocols. In this context, it is hard to obtain a representative and an overall performance evaluation of protocols. In fact, several previous publications have shown that the behavior of wireless networking protocols may radically differ from a simulation environment to another one [2], [3], [4].

In this work, we highlight the main factors that may affect the accuracy of the simulation results. First, we focus on the physical layer modeling which represents a key point for the sake of realism and confidence. Second, we investigate the impact of some protocol parameters on the performance evaluation of application-layer protocols.

II. IMPACT OF THE PHY-LAYER MODELING

We propose a short case study to clearly summary the impact of PHY modeling on the scalability and accuracy of simulations. We consider a varying number of nodes randomly deployed in a $200 \times 200 \times 0$ area. Each node emits periodically a hello packet ($100B/s$) through an IEEE 802.15.4 868Mhz compliant radio. We consider three metrics : the *speedup*, the *average number of discovered neighbors* and the corresponding *average number of connex components*. The first metric allows to assess the impact of radio models on the scalability while the two latter metrics show the impact of the PHY layer modeling on the evaluation of higher level protocols in terms of network connectivity. We performed the same set of simulations with various PHY models. Starting from (i) a basic disk model (*range* = 50) with no interference nor modulation, we slightly increased the PHY simulation accuracy through the introduction of (ii) path-loss and (iii)

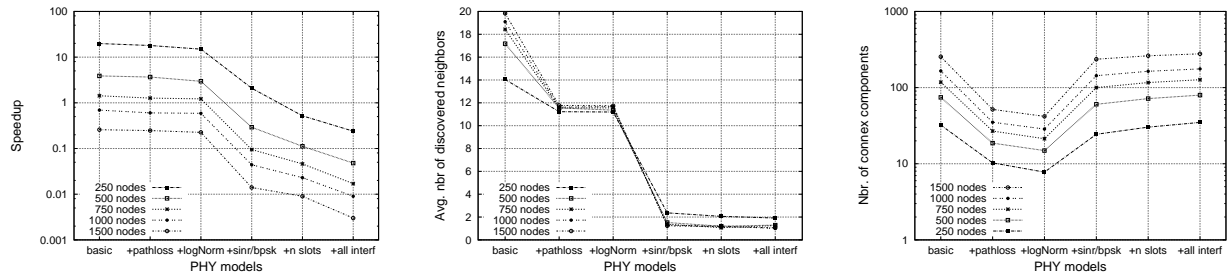


FIG. 1. Impact of the PHY modeling accuracy on simulation speedup and results.

log-normal shadowing with a transmission power of $0dBm$. Then, we considered cumulative interference with a limited interference model (range of 50) and BPSK modulation for (iv) one slot per packet and (v) n slots per packet. We finished with the (vi) full interference model. Simulations are performed using WSN¹ and the obtained results are shown on Figure 1.

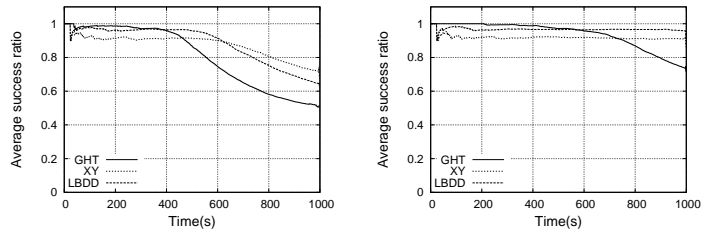
We first notice that the addition of path-loss and fading to the range model induces a low impact on the speedup. Still considering the speedup, the main gap occurs with the introduction of interference and modulation support which increase the computation overhead. Regarding the behavior of higher level protocols under variable PHY models, it can be observed that the average number of discovered neighbors and the average number of connex components varie systematically. If the largest gap also occurs when interference and modulation are introduced, the results still degrade when the accuracy of the interference modeling is increased. This degradation is more important with a high number of nodes. As the number of nodes increases, so does the level of interference and its impact on higher protocols. Sensibility to PHY accuracy increases with the network size.

III. IMPACT OF PROTOCOL PARAMETERS

In this section, we analyze the effect of the hello protocol dimensioning on the behavior of application-layer protocols. This issue is important, particularly in the context of wireless sensor networks (WSN) where most of the layer-3 protocols are based on a hello protocol. We consider three data dissemination protocols (GHT, XY and LBDD) implemented on top of a greedy geographic routing protocol which exchange periodic hello packets. We assume the same simulation parameters of last section and we evaluate the average success ratio obtained at application layer protocols according to two hello protocol dimensioning (*i.e.*, 1 hello packet / 5s, and 1 hello packet / 10s). Results are shown on Figure 2. We can observe from Figure 2, that the obtained success ratio vary in function of the hello protocol parameters. Indeed, we notice a high sensitivity of the application-layer protocols to the layer-3 parameters.

IV. CONCLUSION

Through intensive simulations, we have found that the physical layer, in particular interference management, impacts



(a) 1 hello packet per 5s (b) 1 hello packet per 10s

FIG. 2. Impact of the hello protocol dimensioning on the behavior of high level protocols.

strongly the network connectivity as well as the behavior of networking protocols. For the sake of realism and confidence in simulation results, using accurate and detailed PHY models is thus a key point, despite an increase of the computation overhead. Moreover, we have found that the dimensioning of some protocol is also important as it impacts the global performance of protocols. Thus, the question that arises is which parameters should we use when evaluating the performance of a protocol? and what simulation results must be considered as representative when comparing the performance of several protocols?. In general, it is a problem of representativeness of the obtained simulation results.

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¹WSN¹ is available at : <http://wsnet.gforge.inria.fr>.