An Ad-hoc network simulator based on an optimized semi-deterministic channel characterization

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Abstract — **Classical studies on Ad-hoc networks use heuristic or statistical models to characterize the physical layer of each radio link. In this paper we present an original simulator allowing to quantify these links by a statistical or deterministic channel characterization. The main drawback of the deterministic approaches is the computation time. So, we consider for our study an optimized semi-deterministic characterization of the propagation channel. Finally, we quantify each radio link of an Ad-hoc network by a Bit Error Rate (BER) cost function thanks to a WIFI (norm 802.11) digital transmission chain, and we study the routing results obtained by the Dijkstra algorithm.**

I. Introduction

Nowadays, an increasing interest is devoted to wireless network. Ad-hoc networks [1] represent an interesting alternative to current wireless networks, because we can deploy them quickly. Indeed, there are no centralized infrastructures to connect each mobile: they communicate directly each other. Nevertheless, this lack of infrastructures involve problems and notably in Ad-hoc network routing.

Firstly, we describe the Ad-hoc network simulator developed in our laboratory. It allows to determine the routing of the information based on the physical layer quality. Secondly, we propose an optimized semi-deterministic solution consisting in limiting the cost function computation. Finally, we present some results to observe the computation time gain and the accuracy of this method, before conclude and develop different future works.

II. Ad-hoc network simulator : **AdNS**

AdNS allows to simulate an Ad-hoc network at the physical layer. Firstly, this simulator permit to create several scenarios in different 3D realistic environments. Secondly, it quantify radio links thanks to the given deterministic or not cost function. Finally, it determine the optimal route between a source and a destination in the network by using of the Dijkstra algorithm [2].

A. Creation of the scenario

It consists in defining the initial position, route and speed of each mobile in a real 3D environment. Each trajectory can be cyclic or not and is composed of several points called checkpoints. Mobile's speed can be changed at each one. Fig. 1 illustrates our studied scenario.

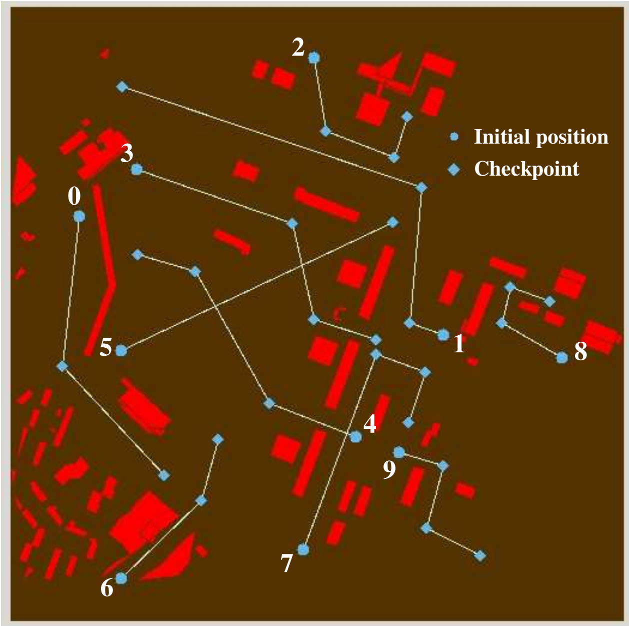

Fig. 1. The studied scenario illustration

This last one takes place in the campus of Poitiers's University environment and is composed of ten mobiles. Mobiles 1 and 7 are considered as vehicles, so their speed can be greater than 3 m/s. The others mobiles are pedestrians (low speed close to 3m/s).

B. Simulation

For the simulation step, we define the sample time (the elapsed time between two successive iterations during the simulation) and the number of iterations. Then, at each iteration, the simulator evaluates:

- The real mobiles positions according to their trajectories, speeds and sample time;
- The quality of each radio link thanks to the cost function.

In our scenario, the sample time is equal to 1 second and we consider 100 iterations. Moreover, we use a semi-deterministic BER cost function to quantify each radio link. This cost function is based on a 3D ray tracing software developed in our laboratory, a WIFI digital transmission chain and the WSSUS assumption associated to the radio channel study. The next section

(III), present in detail this semi-deterministic cost function.

C. Results

Before calculate the routing results between a given source and destination at each iteration, the simulator construct a connectivity graph corresponding to the scenario. Each node represents a mobile and each edge is equal to the resulting BER cost function. This graph is reinitialised at each iteration and the Dijkstra algorithm determines the optimal routing path leading to a given source and destination. Consequently, AdNS enables to follow the optimal routing evolution.

III. SEMI-DETERMINISTIC COST FUNCTION

The main problem of the deterministic BER cost function achievement is the computation time. Indeed, we must execute the propagation tool [3] and the digital transmission chain for each existing radio link at each iteration. This propagation tool, presented in Fig 2 and allowing to calculate deterministic impulse responses of the channel consumes a great computation time.

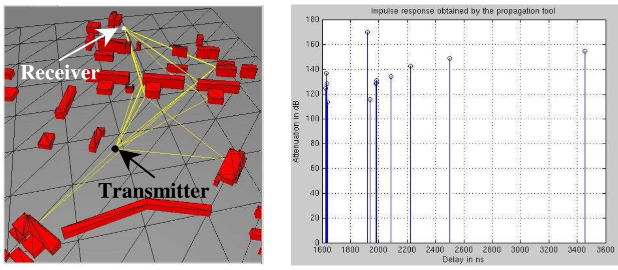

Fig. 2. Propagation tool and resulting impulse response

For example, in our scenario the calculation time, which is associated to an accurate simulation and uses a 9000 complex impulse responses, is equal to 18107 seconds[1].

Moreover, the computation time used by the digital transmission chain is also important. For example, it is close to 68100 seconds[1] for a Signal to Noise Ratio (SNR) equal to 8 dB. This last one is associated to 10^6 transmitted samples for the calculation of the resulting BER. The used digital system is based on WIFI 802.11b [4] norm at 2 Mb/s and its synoptic is shown on Fig 3.

So, our target is to optimise the BER cost function computation in accordance with two complementary works:

- The first one, thanks to the WSSUS properties of radio channels, is associated to the reduction of the calculated impulse response number;
- The second one, thanks to a statistical study and a several impulse responses, consists in pre-computing the digital system behaviour.

[1] Computation realized on Athlon XP 1600+ with 256 Mo Ram

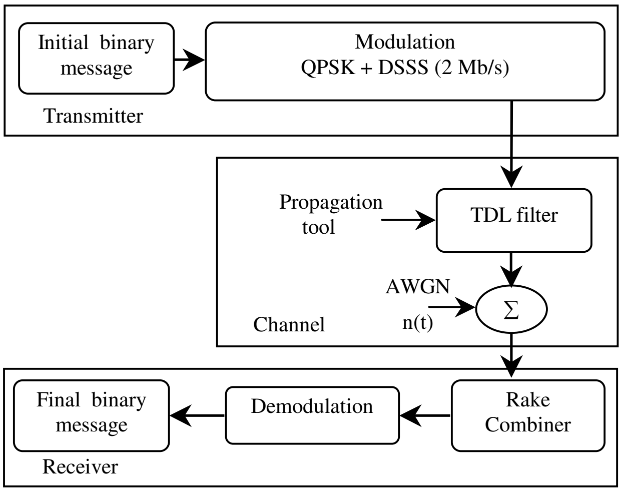

Fig. 3. WIFI digital system

A. Reduction of the impulse response number: stationarity area

The first optimisation is based on a prior study, realized in the same environment of the Fig 1, which determines the stationarity property of the channel, characterized by areas where the channel impulse response is considered as constant. When a mobile moves in such an area, we can reuse the same impulse response without any new computation and thus, realize a significant gain in computation time.

So, to minimize the computation time, the optimization consists in limiting the use of the deterministic propagation tool. It is associated to the analysis of the delay spread wide-band parameter maps computed for 10 transmitter locations and six reception areas such illustrated in the Fig 4.

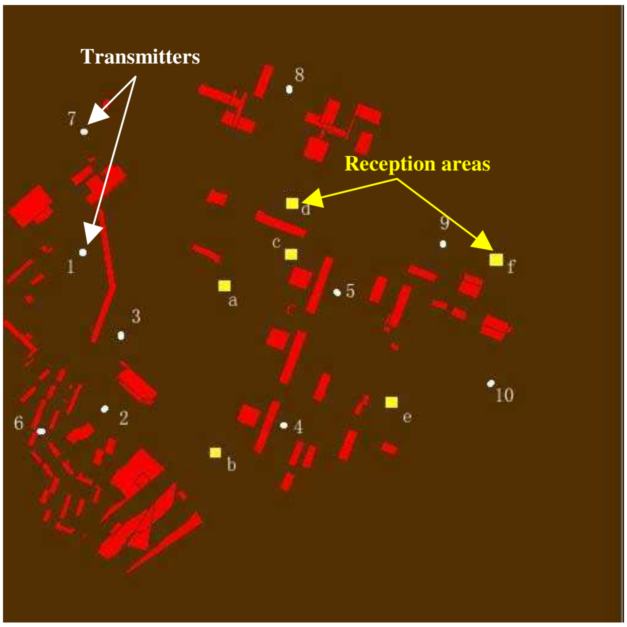

Fig. 4. Stationarity areas scenario

In each of these areas, we have chosen a constant density of receivers, uniformly distributed, equal to 13 receivers/m². For different area sizes we have simulated impulse responses due to all the transmitter-receiver couples and we have determined the probability cumulative function (CF) according to the delay spread average and standard deviation ratio noted R.

Thus, for a given area size and whatever its location, these CFs allow us to know the probability associated to a wished stationarity.

For our study, we have considered three different area sizes equals to 30 m², 50 m² and 100 m². The obtained results of these CFs are given in the Fig 5. In the following we have chosen a probability equal to 75 %. So, we determine the ratio R inherent to each size such as:

- R = 40 % for 30 m²;
- R = 50 % for 50 m²
- R = 70% for 100 m².

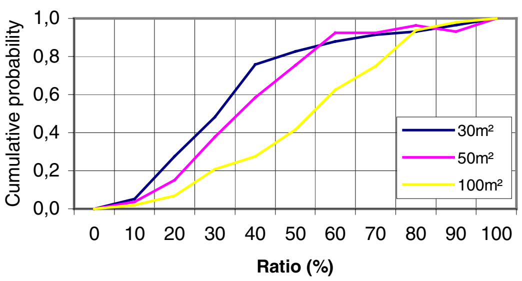

Fig. 5. The CFs of the delay spread ratio R associated to three area sizes

B. Pre-compute of the digital system behaviour

Even if we reduce the number of calculated impulses responses, we must execute the digital transmission chain at each iteration for each radio link. Consequently, the computation gain would be not interesting.

To resolve this problem, we propose a solution which allows to quantify the behaviour of the studied digital system, presented in the Fig 3, by a statistical pre-study. The main advantage of this last one is that we could directly determine the BER of the radio link during the simulation without execute the digital system. Thus, the obtained computation time gain is close to 73%.

Nevertheless, to realize this statistical pre analysis of the system, we did not taken into account the Doppler effect. To characterize its behaviour, we consider 10 statistical impulse responses profiles, associated to those given by the ITU[(2)] and correlated to the studied environment. Then we compute, for each of these impulse responses, the evolution of the BER according to the delay spread (i.e. the root mean square). This last one parameters varies from 0 to 1000 ns with a step equal to 20 ns. This study is realised for a SNR equal to 8 dB.

Finally, we take the envelop of the different obtained curves to characterized the behaviour of our digital system. So, during the simulation of the scenario, we estimate the delay spread of the deterministic impulse response computed in stationarity areas presented in the previous section. Then, we compute a random BER obtained thanks to a uniform probability function where the minimum and maximum BER are given by the curves of the Fig 6. So, to illustrate this method, if a deterministic impulse response give a delay spread equal to 600 ns, we obtain a random BER between $1.7e^{-03}$ and $3.9e^{-03}$.

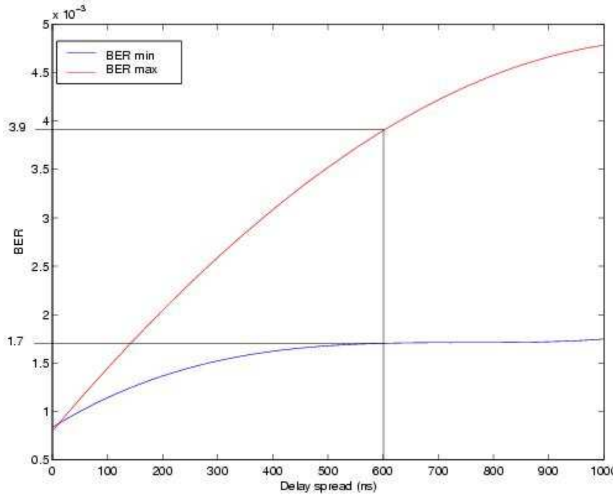

Fig. 6. BER characterization of the WIFI digital system

IV. RESULTS

In this section, we present the obtained results for the studied scenario in terms of computation time and accuracy. So, we will consider as reference, results due to a classical Ad-hoc simulation method (which do not consider the WSSUS assumption) using the pre-computation BER cost function of the subsection III.B. Then, this last method is compared with two optimized ones obtained for the three area sizes of the subsection III.A:

- The first (noted opt1), reuses the same impulse response while each transmitter and receiver node stays, during successive iterations, in the same stationarity area which contains it.
- The second (noted opt2), considers stationarity areas only for the receiver nodes whatever the transmitter position.

Whatever the considered optimised method, when we use the same impulse response for a radio link, we noise the value of its delay spread with a standard deviation equal to the ratio R of the area size considered.

(2) International Telecommunication Union

A. *Computation time gain*

If we simulate the scenario completely, we obtain the computation time gains described in table 1. These last ones, are given in percentage in comparison with the reference results.

		Area size		
		30 m²	50 m²	100 m²
Methods	Opt1	26%	25%	40%
	Opt2	46%	47%	59%

Table. 1. Computation time gain results

We observe for the both methods that these optimizations reduce significantly the computation time. Moreover, more the stationarity area size is large, more the computation time gain is important. We can also note that the second optimization (opt2) gives best gains than the first one (opt1). Indeed, opt2 method is near twice faster than opt1 method. Its normal because we consider in the second case a stationarity area only for one of the two nodes of the radio link.

The computation time study must be completed by a accuracy analysis in comparing routing results due to optimized methods with the reference one.

B. *Accuracies of the optimizations*

If we execute the reference Ad-hoc simulation several times, the obtained routing results are different. This fact can be explained by the computation of the random BER for each radio link.

So, a thorough statistical study, which simulate the same scenario several times, have shown that the Dijkstra algorithm provided different optimal routes in 16 % of cases. Moreover, we have quantified the average and standard deviation (in %) of the relative BER difference due to this statistical analysis. They are respectively close to 0.035 % and 2 %.

Its important to realize this comparison because we must quantify the result divergence existing in a same simulation scenario whatever the used method. So, in the following we will take into account this previous percentages of optimal route divergence, average and standard deviation of relative BER difference.

Then, we compare the results routing between the reference method and optimized ones. The table 3 illustrated these results.

		Area size		
		30 m²	50 m²	100 m²
Methods	Opt1	18.28% 0.864% 13.124%	18.42% 1.025% 13.503%	19.5% 2.143% 17.450%
	Opt2	20.179% 1.646% 17.316%	19.74% 1.678% 17.533%	21.82% 3.09% 21.571%

Table. 3. Comparison of different routing results

Whatever the used optimised method, the percentage of optimal routes divergence increases weakly with the area size. Its average is near to 19 %. This last one represents only 3 % of more in comparison to 16 % of reference. Moreover, the average and standard deviation obtained with this methods are respectively close to:

- 1.2% and 15% for the opt1;
- 2.3% and 18% for the opt2.

So, the accuracies of this methods is really good and its results confirm the high accuracy performance of our optimised methods.

IV. CONCLUSION AND FUTURE WORKS

To conclude two optimised methods for the Ad-hoc network simulation have been proposed. The obtained results confirm the important computation time gain of this two methods and their strongly accuracy. Nevertheless, several future work must be realized to improve this study.

Future works of this study concern firstly a comparative study of different digital systems used in Ad-hoc networks like the others WIFI norms (802.11a and 802.11g) or HiperLan2. Moreover, we can generalized the system characterization to different environment and SNR and in taking into account to the Doppler effect. Secondly, we can simulated the behaviour of Ad-hoc network routing protocols, as AODV [5] or OLSR [6], in a real environment and compare theirs efficiencies. For this, we must considered the Ad-hoc network not only at the physical layer and realize the implementation of different routing protocols.

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REFERENCES

[1] P. Tortelier "Les réseaux Ad-hoc" *Assemblée Générale / Séminaire du CNFRS (Comité Français de Radioéléctricité Scientifique)*, January 2003.

[2] T.H. Cormen, C.E. Leiserson, R.L. Rivest and C. Stein *Introduction to Algorithms*, 2nd ed., MIT Press and McGraw-Hill, 2001, Part IV, Chapter 25.

[3] F. Escarieu, Y. Pousset, L. Aveneau and R. Vauzelle, "Outdoor and indoor channel characterization with a 3D ray tracing propagation model in urban environment" *IEEE PIMRC*, September 30 – October 3 2004. San Diego.

[4] IEEE Std 802.11b-1999, "Part 11: Wireless Lan Medium Access Control (MAC) and Physical Layer (PHY) specifications: Higher-Speed Physical Layer Extension in the 2.4GHz band", 1999.

[5] C.E. Perkins and E.M. Royer, "Ad-hoc on-demand distance vector routing" *Proc. Second annual IEEE workshop on mobile Computing Systems and applications*, pp. 90-100, February 1999.

[6] T. Clausen, P. Jacquet, A. Laouiti, P. Muhlethaler, A. Qayyum and L. Viennot, "Optimized Link State Routing Protocol", *IEEE INMIC*, December 2001.