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Strategy for Wireless Local Area Networks Planning and Performance Evaluation through Bayesian Networks as Computational Intelligence Approach

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1. Introduction

The use of wireless local area networks (WLANs), as well as the proliferation of the use of multimedia applications has grown fast in recent years, mainly due to their mobility, easy configuration and low cost deployment, so they have become an interesting alternative for industries, enterprises, among others. This technology, usually, supports data traffic generated by applications such as web browsing. In recent years, however, it has been used for voice communication, especially in offices (Medepalli et al., year 2004). The VoIP technology provides the transmission packages of voice over IP protocol, used inside the Internet, reducing significantly the cost of calls when compared with those carried out by public switched telephone network (PSTN). However, the VoIP application requires that WLAN must be able to support rigid QoS specifications for the voice transmission, it has been established in ITU-T(International Telecommunication Union) G.114 recommendation and (Zhai et al., year 2006). Some factors affect the quality of service (QoS) received by the user. The interference is an example.

Thus, some works focuses on the problem of achieving a high coverage level in terms of received signal quality (Rodrigues et al., 2000),(Mateus et al., year 2001),(Kamenetsky & Unbehaun, 2002),(Unbehaun & Kamenetsky, year 2003),(Lee et al., 2002). QoS oriented criterion was considered and performance was studied in (Molina & Alonso, 2004),(Amaldi et al., 2005),(Prommak et al., 2002),(Bianchi, year 2000),(Heusse et al., 2003),(Lu & Valois, 2006). Moreover, in (Jaffres-Runser et al., year 2007) is proposed mono-objective and multi-objective formulations for the wireless local area network planning problem including the coverage, the interference level and the quality of service (in terms of data throughput per user). Meta-heuristic methods are explored and the results show the assets of both approaches but mainly emphasize the benefit of the multi-objective search strategy that offers several alternative solutions. Finally, in (Bosio et al., year 2007) a framework for AP placement was developed with the maximization of network efficiency.

This chapter presents a strategy to evaluate performance based on hybrid approach that considers measuring and Bayesian inference applied to wireless networks, considering QoS pa-

rameters as power, jitter, packet loss, delay and PMOS. It differs from the other previous works developed by the fact that the model take into account a crosslayer vision of networks and the Bayesian network correlates aspects of the physical environment, on the signal propagation (power or distance) with aspects of VoIP applications (e.g., jitter and packet loss). Moreover, in order case studies were carried out considering two indoor environments and two outdoor environments one of them with important characteristics of the Amazon region (e.g., densely arboreous environments).

2. Measurement Campaigns

The indoor measurement campaigns were performed in two buildings at Federal University of Para (UFPA). The first one is a classrooms building, while the second is a building especially built for research laboratories and teachers' rooms. The outdoor measurements campaigns were performed in a square and at a parking lot of a university campus. The main differences between the aforementioned environments, are the equipments used because in the first ones, it was used an access point 802.11g Linksys@ WRT54G Router Speed Booster for indoor attendance and at the last, as they were an outdoor attendance, a HotZone Motorola@ equipment was used. In the next subsections these indoor environments will be presented.

2.1 Classromm Buildings

In this measurement campaign the metrics were collected in the second floor of a building of the Federal University of Pará. That building is made of bricks and concrete, with lateral glass windows while the other side there is a corridor along all the building (Fig. 1). In this building there are only classrooms, that are divided by walls built on bricks.



Fig. 1. Photograph of the building. In clockwise: external side with glass windows, classroom, corridor and external side with corridor along

2.2 Research Laboratories

The metrics are collected in a two-storey building made of bricks with rooms for Lectures, Computer and Telecommunication Labs and an anechoic camera, whose height occupies both

the floors. The building has side glass windows with aluminum frames except the anechoic camera. The rooms are divided by walls built on bricks. The building is still empty and with no furniture (Fig. 2).



Fig. 2. Photograph of the research laboratories building: corridors of the second and first floor, and laboratory classroom

In the next subsections the outdoor environments will be presented.

2.3 Marituba's Square

The metrics were collected in a square. The presence of densely arboreous environment typically of the Amazon Region was found there. The testbed was done in a real system, because the Government of the State of Pará has a digital inclusion program. The Marituba city is the first digital network city of this program (NAVEGAPARA, 2010). Fig. 3 shows a picture of the square. The scenario is highlighted by the black rectangle and the black circle at the left side of the rectangle indicates the access point under study.

2.4 Parking Lot

The metrics were collected in a parking lot of a Federal University of Pará. Fig. 4 shows a picture of the parking lot. The scenario is highlighted by the red line and the blue circle at the right side of the picture indicates the access point under study.

3. Measurement Methodology

The methodology of measurement was done as described below:

- Measurement points and the access point positioning: some points were marked to perform the measurements. Their distances from the walls were also measured to the



Fig. 3. Photograph of the Marituba's square



Fig. 4. Photograph of the parking lot

indoor environments and to the outdoor environment the GPS coordinates were collected. Firstly, the network under study was installed.

- Connection of the Network under Study - the architecture of the network under study (channel 7, central frequency of 2.442GHz) it is shown in Fig. 5, where APS in Fig. 7 is connected, through a cable to the protocol analyzer ethernet port. The second ethernet port is connected to a computer. This computer was used as a VoIP receiver, using CallGen323 (Callgen, 2010) software;
- Traffic Generation at Network under Study - A notebook computer, located in the first plan in Fig. 5, was used to generate traffic in the WLAN network. Files were transferred to a server located at the cable network through APS.
- VoIP Transmitter - to transmit the VoIP calls another notebook was used. It was located on a cart Fig. 6, and it was positioned in the selected measurement points;
- Power Measurement - The cart carries also another notebook. The power measurement was done in each point, through the Network Stumbler@ software (Netstumbler, 2010). This notebook was necessary because the Network Stumbler, while in use doesn't allow the connection of the computer to any WLAN.

With the methodology and equipments described in the stages, the first phase of the measurement campaign was performed. In this case there was only a transmitter in the environment in study. During the measurements, the following parameters were stored: received power (through the Netstumbler software), distance transmitter-receiver, jitter, delay, packet loss and PMOS (measured by the protocol analyzer). After that first measurement phase, a second one was performed using the same procedure of the first, but now, with the presence of another network using the same channel of the network under study, called interference network. The access point of the interference network was positioned in the second floor in the same direction of the network under study, APT in Fig. 7. The Iperf program (Iperf, 2010) was used to generate traffic in the interference network, it is allowed specify the time during which this traffic is generated. After this second measurement phase, the data were treated and compared to find a parameters variation in the presence of a interference network. The following section presents the results of those comparisons. The only difference among the procedures used at the two buildings is the application used to compete traffic with VoIP in the network under study. In Fig. 8 is showed the layout, the location of the measured points and the location of the access points to the classrooms building. After this measurement campaign, data were treated and the measurements were compared.



Fig. 5. Network under study



Fig. 6. The cart with notebook running Network NetStumbler (the lower side of the picture) and the notebook running VoIP calls (the upper side of the picture)

4. Strategy using Bayesian Networks for Planning and Performance Evaluation of Wireless Networks

The process of knowledge discovery in database (KDD) stands as a technology capable of widely cooperating in the search of existing knowledge in the data. Therefore, its main objective is to find valid and potentially useful patterns from the data. The extraction of knowledge from data can be seen as a process with, at least, the following steps: understanding of the application domain, selection and preparation of the data, data mining, evaluation of the extracted knowledge and consolidation and the use of the extracted knowledge. Once in the data mining stage, considering the core of the KDD process, methods and algorithms are applied for the knowledge extraction from the database. This stage involves the creation of appropriate models representing patterns and relations identified in the data. The results of these models, after the evaluation by the analyst, specialist and/or final user are used to predict the values of attributes defined by the final user based on new data. In this work, the computational intelligence algorithm used for data mining was based on Bayesian networks.

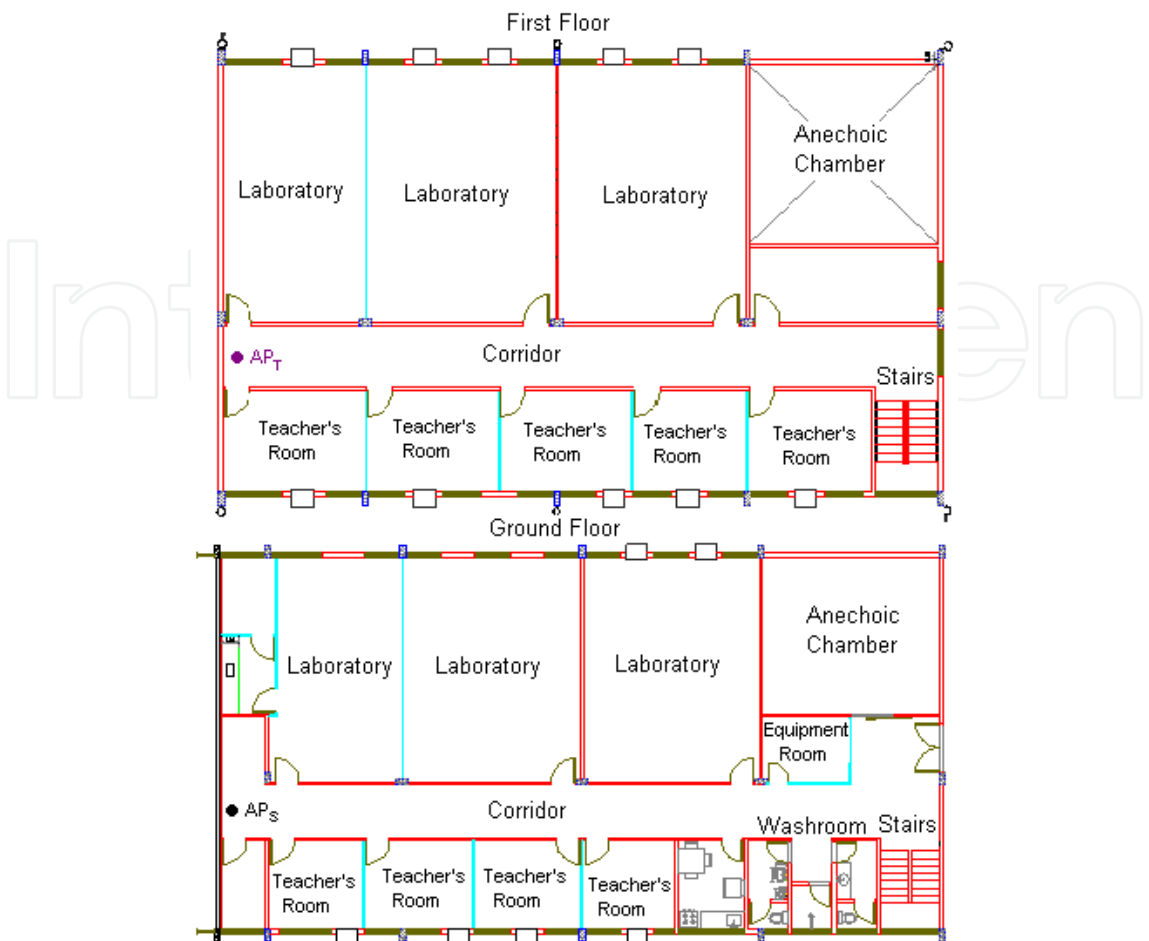


Fig. 7. Layout of the research laboratories(first and second floor) with the location of the measurements points and APs

A Bayesian network is composed of several nodes, where each node of the network represents a variable, that is, an attribute of the database; directed arcs connecting them implies in the relation of dependency that the variable can possess over the others; and finally probability tables for each node. The Bayesian networks can be seen as coding models of the probabilistic relationships between the variables that represent a given domain. These models possess as components a qualitative representation of the dependencies between the nodes and a quantitative (conditional probability tables of these nodes) structure, that can evaluate, in probabilistic terms, these dependencies. These components together provide an efficient representation of the joint probability distribution of the variables of a given domain.

One of the major advantages of the Bayesian networks is their semantics, which facilitates, given the inherent causal representation of these networks, the understanding and the decision making process for the users of these models. Basically, due to the fact that the relations between the variables of the domain can be visualized graphically, besides providing an inference mechanism that allows quantifying, in probabilistic terms, the effect of these relations (Santana et al., year 2007).

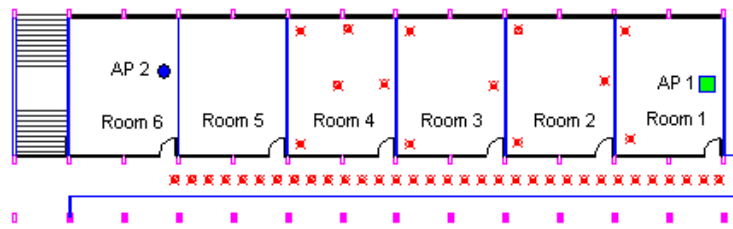


Fig. 8. Layout of the classrooms building with the location of the measurements points and APs

4.1 Bayesian Inference Results

This section discusses the measurements of the application and physical layers as well as the results obtained by using Bayesian networks. The study involved treating the measured data acquired with the novel strategy using any intelligence computational technique, i.e. the Bayesian network technique (Araújo et al., 2007). In any process of knowledge discovery, there is a pre-analysis phase of treatment (soft mining) of the data where information that is not going to contribute to the final result are removed. Hence, the input fields for the Bayesian network were obtained from the protocol analyzer after the pre-analysis. They worked as input to the free version Bayesware Discoverer(BDD) commercial software (Discoverer, 2010).

4.1.1 Indoor Environment - Research Lab

According to Fig. 9, the inference results related to distance with the best value are presented. The probability of throughput lying within 142760.0 to 149180.0 bps is 67.7%. The results for other metrics are described as follows: in the case of packet loss, the probability of loss lying within 0 to 0.14% is 60.0%. This value added to the second interval of larger probability (31.6%) results in the probability of 91.6% of packet loss for lying within 0 to 0.55% (recommended less than 1%). Considering now the jitter, its probability for lying within 0.86 to 2.72 ms is 75.5% (maximum recommended 30 ms). Finally, the PMOS probability values for lying within 4.0 and 4.9(Good) is 94.1% (the values of PMOS were codified in agreement with ITU-T Recommendation P.800 (ITU-TP800, 1996)).

Another inference performed is the selection of the lowest throughput in the Fig. 10. The packet loss for the network with inference of lowest throughput is 32.8% lies within 2.15% to 7.67%. The jitter probability to be greater than 8.4 ms is 35.7% and smaller is 64.3%. The PMOS has the probability value of 62.7% for lying within 3 and 3.9 (Fair). Finally, the distance metric presents relevance values for this second inference scenario. Its probability is 48.9% to be located beyond 19 meters of the access point (distances less than 19 meters can be guaranteed acceptable QoS parameters for half of times).

4.1.2 Indoor Environment - Classrooms Building

According to Fig. 11, the inference results related to best power. In the case of throughput, the probability value of 63.3% for lying within 152110 to 152520 bps. Considering now the packet loss, its probability of loss being equal to zero was 59.4%. The jitter probability value was 75.1% for lying within 2.2107 ms and 4.3643 ms. PMOS had the probability value of 52.8% for lying within 3.9386 and 4.1095. Finally, the delay has a 80.9% probability of lying within 74.032 ms and 150.87 ms.

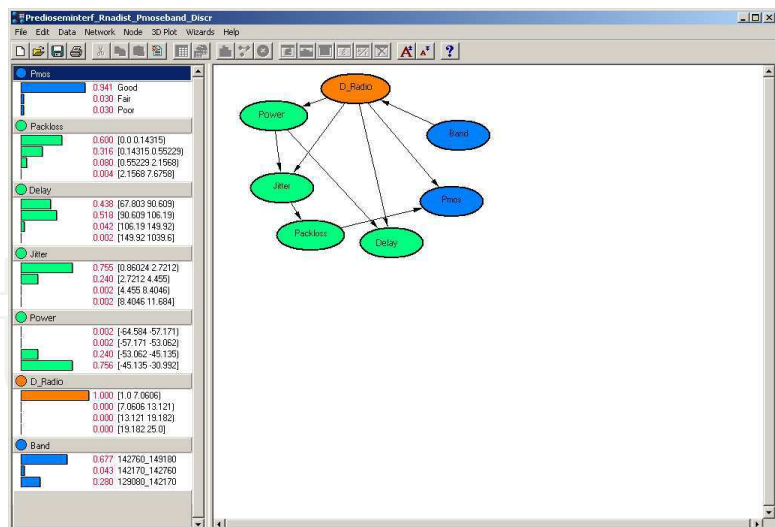


Fig. 9. Bayesian networks with best distance inference applied to ground floor

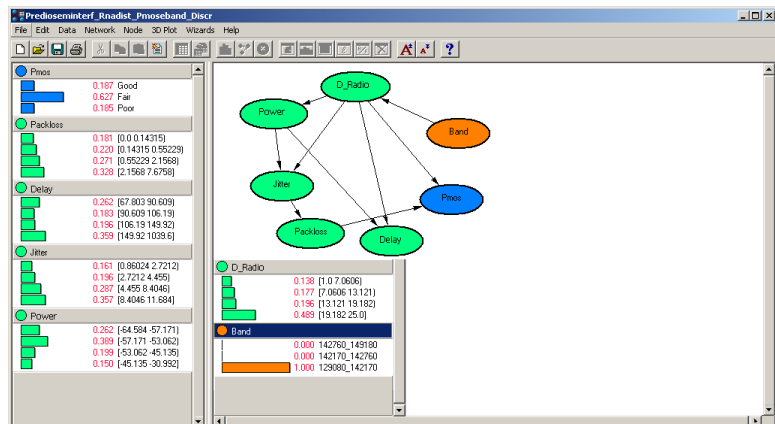


Fig. 10. Bayesian networks with worst throughput inference applied to ground floor

Another inference performed was the selection of the worst throughput, as shown in Fig. 12. The packet loss probability value was 47.8% for lying within 1.255% to 3.899%. Considering now the jitter, its probability for lying within 7.9975 ms to 12.43 ms was 51.7%. PMOS had the probability value of 43% for lying within 0.2645 and 3.3536. Finally, the delay has a 71.4% probability of lying within 150.87 ms and 3229.9 ms.

4.1.3 Outdoor Environment - Marituba’s Square

Fig. 13 presents the inference results related to throughput with the best value. In the case of packet loss, the probability of loss lying within 0 to 0.85% is 44.3%. Considering now the jitter, its probability for lying within 4.66 to 7.33 ms is 33.2%. Finally, the PMOS has the probability values for lying within 3.8(Fair) to 4.02(Good) is 48.1% (the values of PMOS were codified in agreement with ITU-T Recommendation P.800 (ITU-TP800, 1996)). Another inference performed is the selection of the worst distance in Fig. 14. The packet loss for the network with inference of worst distance is 51.8% lies within 2.04% to 6.81%. The jitter probability to be greater than 16.5 ms is 47.8%. The PMOS has the probability value of 51.8% for lying within 2.45 and 2.92 (Poor). Finally, the throughput metric has probability lying within 68496 bps and 70774 bps is 51.8%.

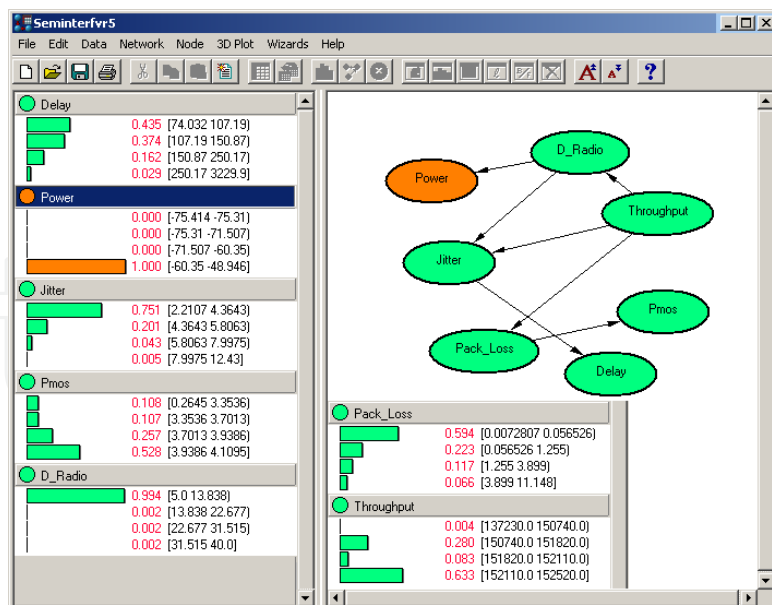


Fig. 11. Bayesian networks with best power inference applied to classroom’s building

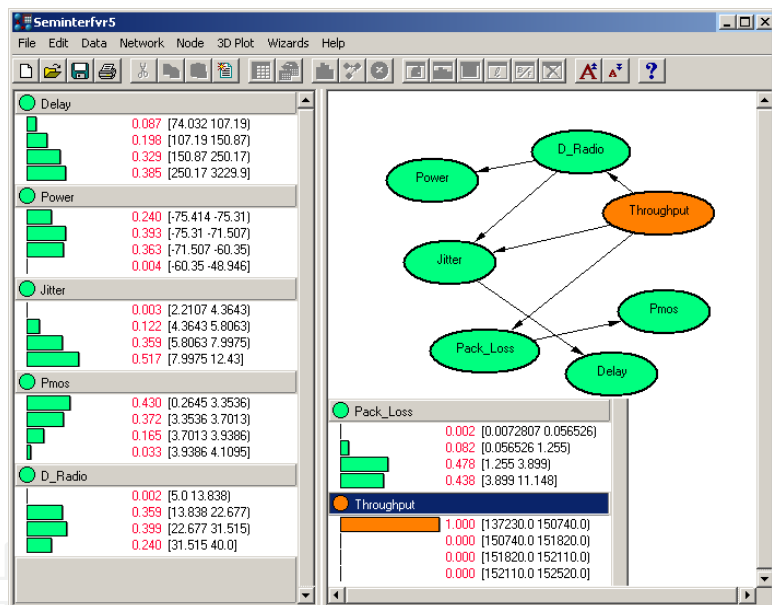


Fig. 12. Bayesian networks with worst throughput inference applied to classroom’s building.

Through the use of Bayesian networks can be noticed that the QoS parameters applied to outdoor environment were degraded even in the best situation of the network, i.e. the best throughput. Referring to the worst case collected, can be seen that the parameters degraded, but the achieved distances are bigger than the measures at the indoor environment, i.e. 155 meters and 19 meters for the indoor environment . The difference between the equipments used can be the reason of this, but the densely arboreous environment contributes either. The use of this computational intelligence aids the decision maker to decide which is the best point to locate the access point, and how the Qos parameters will behave.

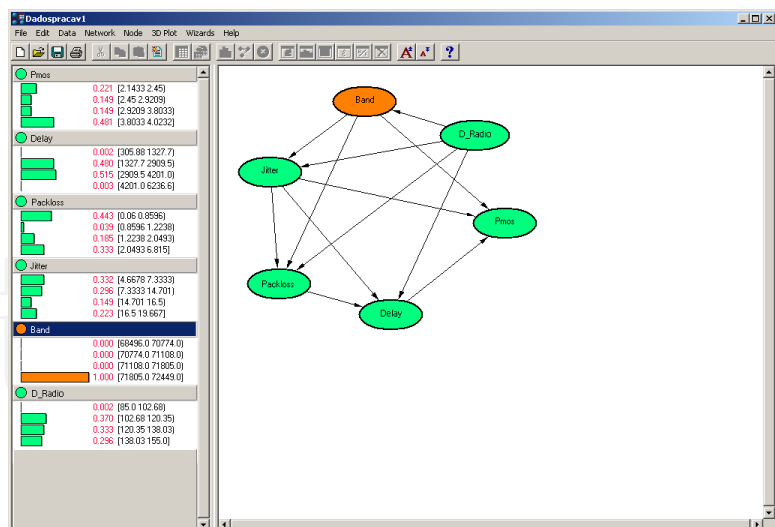


Fig. 13. Bayesian networks with best throughput inference applied to Marituba’s square

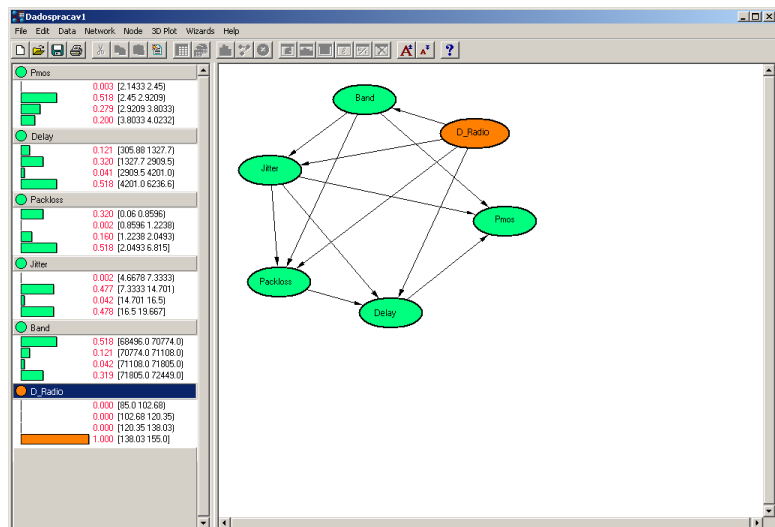


Fig. 14. Bayesian networks with worst distance inference applied to Marituba’s square.

4.1.4 Outdoor Environment - University Parking lot

According to Fig. 15, the inference results related to best distance. In the case of packet loss, the probability of loss being equal to zero was 87.1%. Considering now the jitter, its probability for lying within 2.66 to 3.33 ms was 61.5%. Finally, the probability that PMOS values would lie within 3.89 (Fair) to 4.02 (Good) was 39.3% (the values of PMOS were codified in agreement with ITU-T Recommendation of P.800 (ITU-TP800, 1996))

Another inference performed was the selection of the worst distance, as shown in Fig. 16. The packet loss for the network with inference of worst distance had a 61.4% probability of being greater than 5%. The jitter probability value was 77.5% for lying within 15.95 and 34.66 ms. PMOS had the probability value of 76.9% for lying within 0 and 2.48 (Poor). Finally, the throughput metric has a 75.5% probability of lying within 57297 and 69527 bps.

The use of this computational intelligence aids the decision maker to decide which is the best point to locate the access point, and how the Qos parameters will behave.

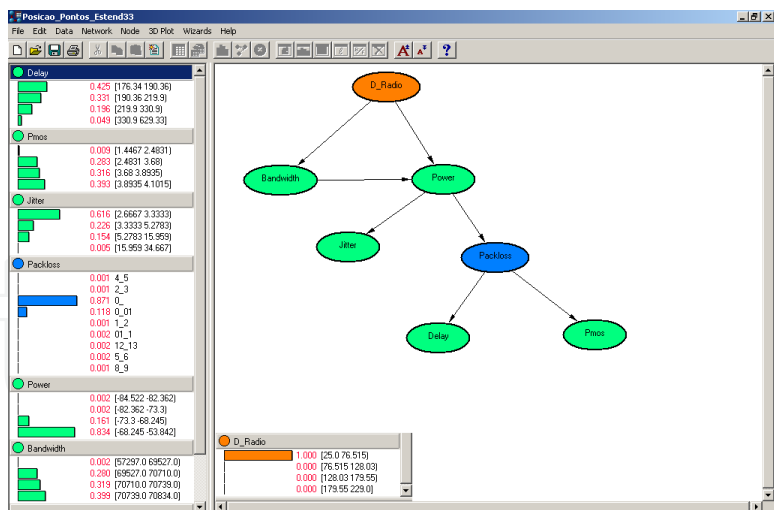


Fig. 15. Bayesian networks with best distance inference applied to parking lot

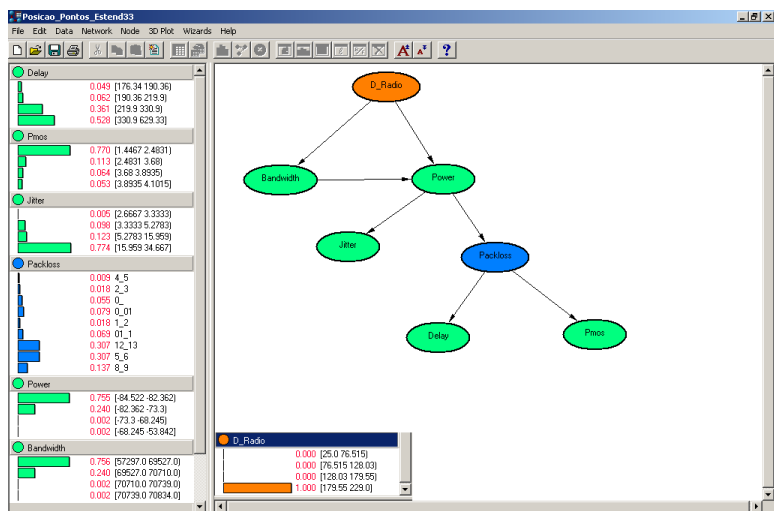


Fig. 16. Bayesian networks with worst distance inference applied to parking lot

5. Conclusion

In this chapter a novel WLAN planning and performance evaluation strategy with computational intelligence approach, i.e., bayesian networks was presented. The measuring technique was used through an empirical study concerning the behavior of the QoS parameters of an VoIP application in 802.11g network. This study was performed in two different indoors and outdoors environments, characterizing two types of scenarios. This was done to establish the correlation between the behavior of the QoS parameters and the distance.

The main contribution of the Bayesian strategy is the use of computational intelligence to differentiate the two environments and to validate the robustness of the methodology proposed here. Another contribution is about the installation of new hot spots at digital cities, that must be installed at State of Pará. In addition, due to the large application of wireless LAN, this strategy can be applied in real engineering design. This methodology will aid the decision makers where to locate the access point to better attend the public offices, according on the applications that must be used. It is important to mention that Bayesian network offers an

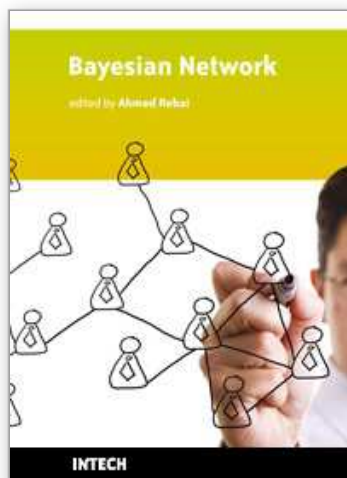
approach to select several scenarios of QoS. Therefore, it is possible to guarantee a minimum distance to the AP for VoIP application in an indoor or outdoor WLAN environment. Finally, in real building there is a very strong trend to find similar scenarios to the presented ones in this paper, where different networks cohabit and where it is desirable that applications with rigid parameters of QoS carry out.

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Bayesian networks are a very general and powerful tool that can be used for a large number of problems involving uncertainty: reasoning, learning, planning and perception. They provide a language that supports efficient algorithms for the automatic construction of expert systems in several different contexts. The range of applications of Bayesian networks currently extends over almost all fields including engineering, biology and medicine, information and communication technologies and finance. This book is a collection of original contributions to the methodology and applications of Bayesian networks. It contains recent developments in the field and illustrates, on a sample of applications, the power of Bayesian networks in dealing the modeling of complex systems. Readers that are not familiar with this tool, but have some technical background, will find in this book all necessary theoretical and practical information on how to use and implement Bayesian networks in their own work. There is no doubt that this book constitutes a valuable resource for engineers, researchers, students and all those who are interested in discovering and experiencing the potential of this major tool of the century.

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