PERFORMANCE EVALUATION OF AN ADHOC WIRELESS NETWORK IN A TYPICAL SCENERIO OF AN AMAZONIAN AREA (REGIONS IN AMAZON)

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ABSTRACT

This paper aims at verifying the viability of the application of an ad-hoc network for medical services rendered in a typical scenery of an Amazonian area. It had been evaluated the performance of an ad-hoc net considering the current technology. Four routing protocols (DSR, LOG, AODV and DSDV) were used and two radio propagation models (Two-ray Ground and Shadowing) were tested. Furthermore, two transport protocols (TCP - Transmission Control Protocol and UDP - User Datagram Protocol) were involved in the process. The analysis was made by means of simulation using the Network Simulator. Throughput, delay, blocking probability, number of established connections and scalability were the performance measures used.

1. INTRODUCTION

The Investigation of technological alternative solutions in areas where the communication infrastructure is precarious is the decisive point for the accomplishment of this research. In a typical scenery of an Amazonian area (Marajó Island) the performance of an adhoc network was evaluated. The technique used for evaluating the performance of this wireless network was simulation. Four multi-point protocols (DSR - Dynamic Source Routing, TORA - Temporally-Ordered Routing Algorithm, AODV - Ad-hoc On-demand Distance Vector Routing and DSDV - Destination-Sequenced Distance-Vector) were compared to two models of propagation of radio (Two Ray Ground and Shadowing) [12]-[15]. The objective was to test the behavior of the net in a range of applications that could vary from the common use to a wide program of medical service involving a distributed database or to support conferences in more specific situations (for instance, in events where is necessary to join a medical team in emergency situations).

2. AD-HOC NETWORKS

Wireless networks can be classified either as wireless networks or as ad-hoc. The former are those in which is necessary an infrastructure and the last one are those in which is not necessary an infrastructure [7].

In the infrastructured wireless networks, the covering area is divided into small areas that have well-known access points. So that it does not matter if two nodes are located at a minimum distance between each other, the communication between them will be always established through the access point. Access points are usually connected by a high-speed backbone, which provides a relative guarantee in the quality of the provided service.

In ad-hoc networks or MANET any infrastructure is required [3]. Once all the nodes move freely, teamwork is required to make the communication possible, even with the limits imposed by hardware devices and by propagation environments. So that, in certain moments a node can act as a transmitter, or as receiver or even as router.

In an ad-hoc network, there is continuous mobility, generating frequent changes in the network topology. It constitutes a major problem in these wireless networks, degrading the system performance due to the overload in the router.

2.1 TRANSMISSION SUPPORT IN ADHOC NETWORKS

A great variety of solutions involving routing protocols, MAC protocols and radio propagation models have been proposed to support transmissions in ad hoc networks. However only those used in experiments concerned to this work will be commented.

2.1.1 Standard IEEE 802.11

Due to certain limitations, wireless networks can be associated only to networks known as LANs. The term WLAN is an acronym to Wireless Local Area Network.

As an extension of wired LAN standard (IEEE 802 family), it was consolidated in 1999 the standard known as IEEE 802.11 [9] for wireless networks. Two layers were specified: the first one was the Wireless LAN Medium Access Control (MAC), which applied the CSMA/CA technique as a medium access protocol. The second one was the Physical Layer (PHY), which supports FHSS (Frequency Hopping Spread Spectrum), DSSS (Direct Sequence Spread Spectrum), and infrared [10].

Table 1 displays two extensions of the IEEE 802.11 standard, the 802.11a and the 802.11b. These extensions increased the ratio from 5Mbps to 54Mbps [9].

Standard	Frequency	Ratio
802.11	914 MHz	5 Mbps
802.11a	5 GHz	54 Mbps
802.11b	2.4 GHz	11 Mbps

Table 1. IEEE 802.11 Family

2.1.2 Routing protocols

Basically, ad hoc routing protocols act in two ways. In the first, a group of tables (known as table-driven) is maintained in each node, containing available paths between senders and receivers. The fast discovery of routes can be mentioned as an advantage; however, there is an overhead in the network caused by the periodic update of those tables. Among the appraised protocols we can mention the DSDV [15]. In the second way, also known as on-demand, routes are discovered only when required, lowering the overhead on the network. In this case the time for discovery of routes is larger. Among appraised protocols, three are classified in this category: DSR, TORA, and AODV [7].

In this work nodes are assumed as notebooks, so that they are fed from a battery. Thus, economy of energy should be considered as being a factor of high relevance. In this case, on-demand protocols are more efficient because they only send control data when is really necessary.

2.1.3 Radio propagation models

When the matter is mobility, different situations can happen in an adhoc network. In certain moments, nodes can be transmitting without any obstacle among them, which is an ideal situation. In others, several obstacles can make the transmission more difficult, what requires more specific radio propagation models.

To make the experiment closer to a real situation, two propagation environments were investigated: two-ray ground and shadowing.

Two-ray ground model, shown in Eq. 1, considers that antennas, transmitters, and receivers are located on a plane surface, without obstacles among them [2].

$$P_r(d) = \frac{P_t G_t G_r h_t^2 h_r^2}{d^4 L} \quad (1)$$

Nevertheless, shadowing model, shown in Eq. 2, considers the existence of several obstructions between transmitter and receiver, so that effects of direct and reflected rays are difficult to be captured by the receiver.

$$\left[\frac{\overline{P_r(d)}}{P_r(d_0)}\right]_{dB} = -10\beta \log\left(\frac{d}{d_0}\right) \quad (2)$$

where “Pr” and “Pt” are the transmission power and the reception power, respectively. “G” is the gain, “h” is the height of antennas and “d” is the distance.

3. CONSIDERATIONS ABOUT THE PERFORMANCE EVALUATION PROCESS

The choice for simulation as solution technique for the performance evaluation process happen due to the high cost involving acquisition of equipments for a group of measurements in loco and the availability of a simulator widelyadapted in the academic environment, with support to mobile networks: the Network Simulator (NS).

3.1 THE NETWORK SIMULATOR

Developed from the VINT project (Virtual InterNetwork Testbed), the NS is a discreet events simulator [1], with support to a wide variety of researches that include the stack of TCP-IP protocols, LANs, WANs, and satellite networks.

The NS is open source code and free, what has attracted several researchers, making the simulator robust and reliable. One of those contributions, made by the Monarch group of the Carnegie Mellon University [6], was responsible for the incorporation of the module of wireless mobile networks on the NS.

A support tool denominated NAM (Network Animator) allows a better visualization of the simulation through a graphic interface. The evaluation of the results begin with the analysis in a trace file generated in the simulation process.

The version used for obtaining the results of this work was 2.1b9a, released on August 2002 [1]. The operating system was Linux with the kernel version 2.4.

3.2 SCENERIO

The proposed scenery portrays a typical environment of an Amazonian area characterized by a series of narrow channels with clay soil and with constant flooding, what makes difficult the installation of a permanent communication infrastructure. In this context, where one can find so much unsheltered areas as forest vegetation, the network was evaluated considering the two models of the radio propagation described in the section 2.1.3.

3.3 SIMULATION

It was considered a hypothetical situation of medical service involving 30 nodes, representing agents of health, being moved at an average speed of 20 km/h. The displacement happens in small boats, dispersed in an area of one squared kilometer. The communication among the nodes occurs based on the pattern IEEE 802.11b and involves a situation of file transfer, by way of FTP flows, characterizing a connection-oriented reliable service that reflects the described situation. In order to study the effect of the traffic increase in the network performance, the number of nodes is raised to 50 nodes. To evaluate the network growth, the experiment was reproduced with 50 nodes.

After analyzing the results, it was evident that the protocol with the best performance was achieved using CBR flows. This happens because they characterize very well the multimedia traffic that would support the accomplishment of conferences.

The simulation time is 400 units of simulation, where one unit of simulation is considered to be one second. No flow of data was transmitted in the warm-up period so that the initial update of the routing tables did not influence in the results [4].

3.4 TRAFFIC GENERATION AND MOBILITY OF NODES

The traffic generation and the nodes mobility follow the Random Waypoint Mobility distribution proposed for wireless ad-hoc network models [5]. They were created from all-in-one scripts, which are obtained in the distribution of the NS [1]. In each simulation 15 random connections among the nodes were established. To certify a larger consistence in the results, the experiment was repeated 5 times, with a variation of the seed values in the generation of the traffic file. The confidence intervals of the available measures (throughput and delay) are discriminated on Tables 2 and 3.

Throughput	**Protocol**	**Medium Throughput**
Two-Ray (FTP) 30 nodes	DSR	0,0438 $\pm$ 0,0279
	TORA	0,0350 $\pm$ 0,0276
	AODV	0,0246 $\pm$ 0,0192
	DSDV	0,1118 $\pm$ 0,0889
50 nodes	DSR	0,0224 $\pm$ 0,0193
	TORA	0,0487 $\pm$ 0,0311
	AODV	0,0303 $\pm$ 0,0158
	DSDV	0,0542 $\pm$ 0,0313
Shadowing (FTP) 30 nodes	DSR	0,0077 $\pm$ 0,0688
	TORA	0,0028 $\pm$ 0,2811
	AODV	0,0749 $\pm$ 0,0476
	DSDV	0,1156 $\pm$ 0,0525
50 nodes	DSR	0,0049 $\pm$ 0,0996
	TORA	0,0442 $\pm$ 0,0224
	AODV	0,0313 $\pm$ 0,0266
	DSDV	0,0828 $\pm$ 0,0528
Two-Ray (CBR) 50 nodes	DSDV	0,0012 $\pm$ 0,0001
Shadowing (CBR) 50 nodes	DSDV	0,0007 $\pm$ 0,0001

Table 2 - Medium Throughput

Delay	Protocol	Confidence Interval
Two-Ray (FTP) 30 nodes	DSR	2,6065 ± 1,9446
	TORA	2,1414 ± 3,3799
	AODV	0,6915 ± 1,0370
	DSDV	0,2796 ± 37,9255
50 nodes	DSR	1,2348 ± 2,4017
	TORA	1,3202 ± 7,4593
	AODV	0,5215 ± 0,1211
	DSDV	0,5171 ± 0,2314
Shadowing (FTP) 30 nodes	DSR	4,0573 ± 9,2826
	TORA	7,0280 ± 92,3513
	AODV	0,1772 ± 0,0859
	DSDV	0,2584 ± 0,0464
50 nodes	DSR	7,3388 ± 14,0554
	TORA	3,7042 ± 32,9762
	AODV	0,2964 ± 1,5283
	DSDV	0,6564 ± 13,2304
Two-Ray (CBR) 50 nodes	DSDV	0,0510 ± 0,2959
Shadowing (CBR) 50 nodes	DSDV	0,0294 ± 0,2849

Table 3 - Average end-to-end Delay

In the case of the CBR flows the experiment was only reproduced for the DSDV protocol with 50 nodes once they are based on the TCP transport protocol.

3.4 USED PARAMETERS

It was considered that each agent of health carried a notebook equipped with an adapter Lucent WaveLan (Orinoco) [11]. The used parameters are presented on Table 4.

Parameter	Value	Unit
Capture threshold	10.0	dB
Carrie Sense threshold	1.559×10^{-11}	W
Receive Power Threshold	3.653×10^{-10}	W
Bandwidth	2×10^{6}	bps
Power	0.2818	W
Frequency	2.4×10^{9}	Hz
Loss Factor	1.0	-
Omni directional Antenna	1.5 (height)	m
For Shadowing		
Shadowing deviation	10	dB
PathlossExp	5	-

Table 4. Parameters used in the simulation

4. RESULTS

The performance measures used to analyze the wireless network were throughput, delay, blocking probability, number of discard packets, scalability, and number of connections established. Also it was established a comparative study between the FTP and CBR applications for the protocol with the best performance. [8]

Fig. 1 shows the end-to-end throughput vs the two radio propagation models for the four evaluated protocols. It can be observed that the best performance was obtained in the DSDV table-driven protocol. In this case, the periodic updating of the routes tables contributed significantly to a better performance. That is due to the constant change in the network topology caused by the mobility.

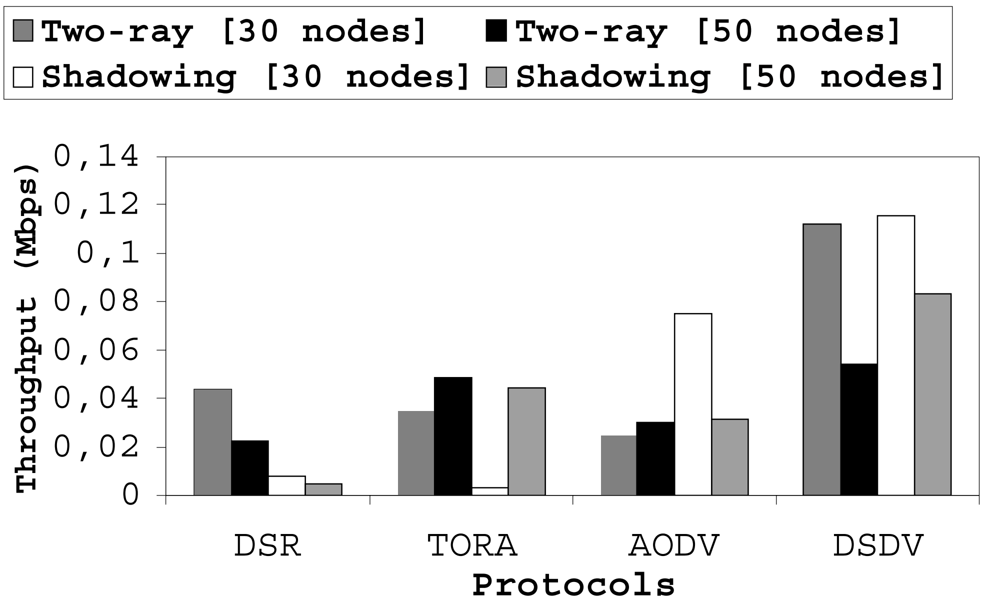

Figure 1. Average throughput in TCP flows

Fig. 2 compares the average throughput between FTP and CBR flows for the DSDV protocol. It can be observed that conferences accomplishment would not be feasible due to the very low levels of throughput. These levels are distant from the transmitted flow levels, which are around 0,384 Mbps. This happens due to a very high blocking probability, as shown in Fig. 6.

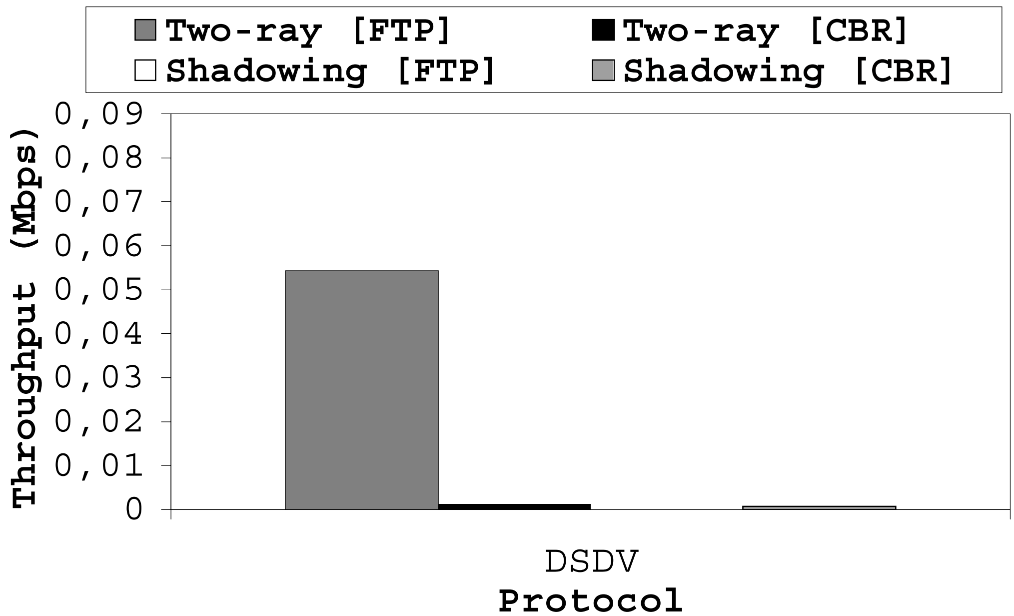

Figure 2. Average throughput for 50 nodes

Another evaluated measure, end-to-end delay, can be observed in Fig. 3. Once again the best obtained performance is associated to the DSDV protocol, which presented the lowest delay.

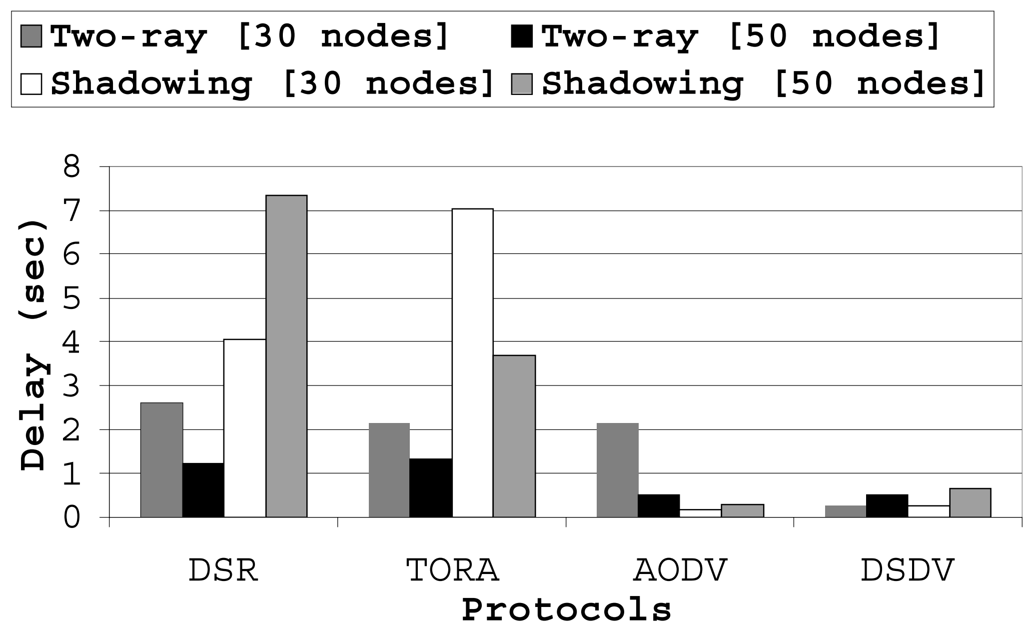

Figure 3. Average end-to-end delay (TCP)

Delay is a factor of relevance for this experiment and implicates directly in the viability of the conference operations that could be requested. Furthermore, the high discard values made unviable the conference operations. This can be observed in the throughput values.

Fig. 4 displays a comparison between the delays of FTP and CBR flows available in the DSDV protocol. It can be verified that in the case of CBR flows, the average delay stays below the tolerable limit for multimedia applications that is approximately three hundred milliseconds [16] .

Fig. 5 displays the blocking probability. It can be observed that the worst performance in the delivery of packages happens in the DSR and TORA protocols, exactly in the transmissions that are based on the shadowing model. The percentile of packets that are not received are close to 90% in the shadowing model with 30 nodes.

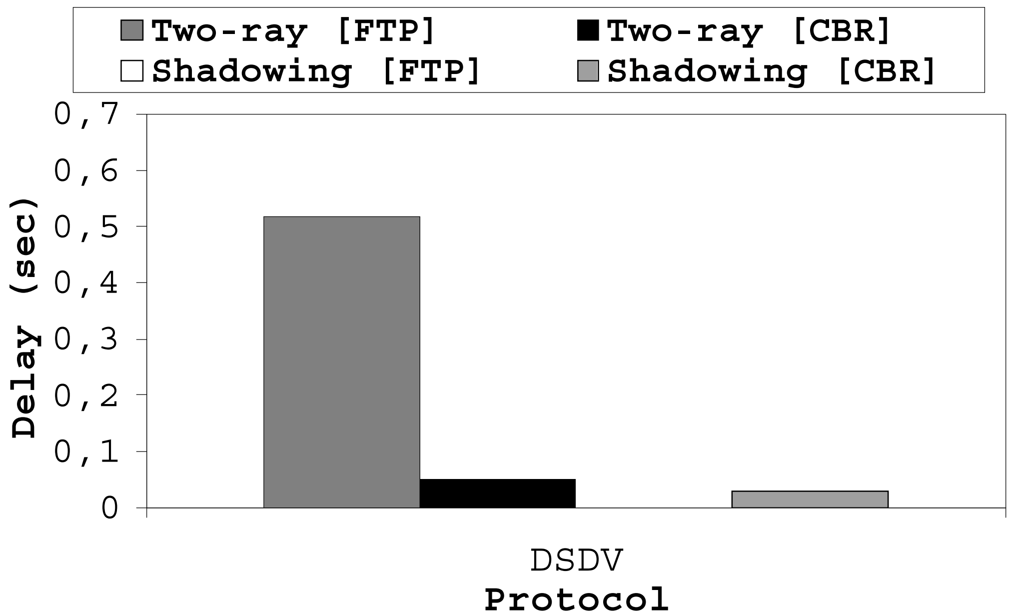

Figure 4. Average delay with 50 nodes (FTP x CBR)

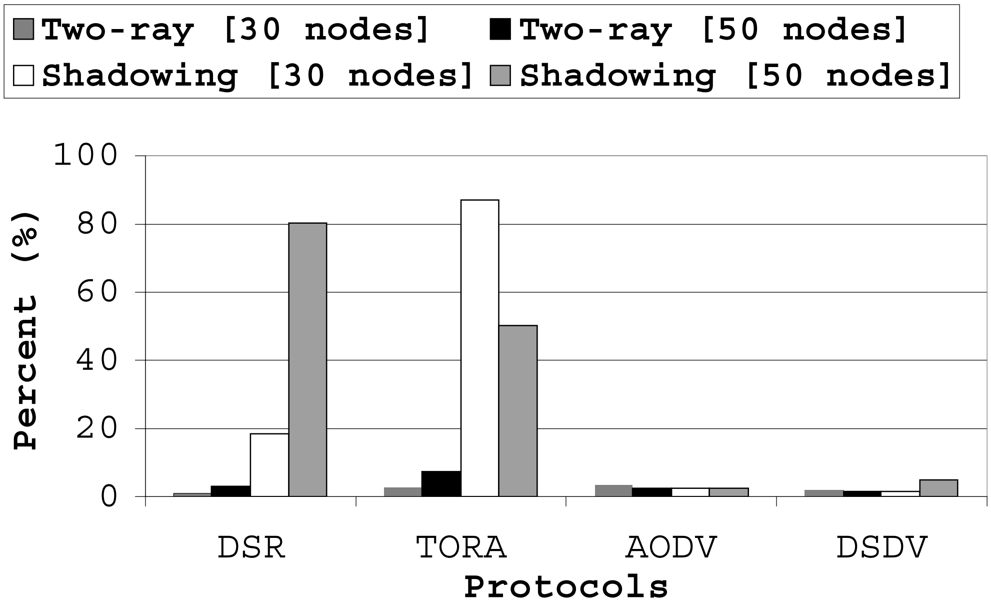

Figure 5. Blocking probability (FTP)

Fig. 6 shows the comparison between FTP and CBR flows for the blocking probability. It can be observed the high values in the CBR flows.

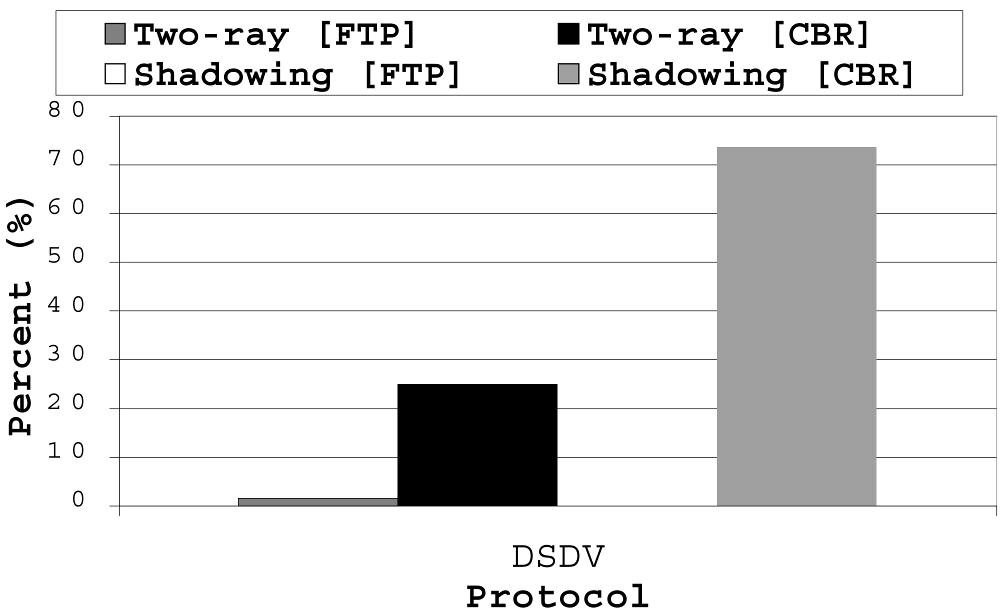

Figure 6. Blocking probability (FTPxCBR)

Analyzing the packets discard (loss) in Fig. 7, it can be observed that the protocol with the highest values is the AODV protocol.

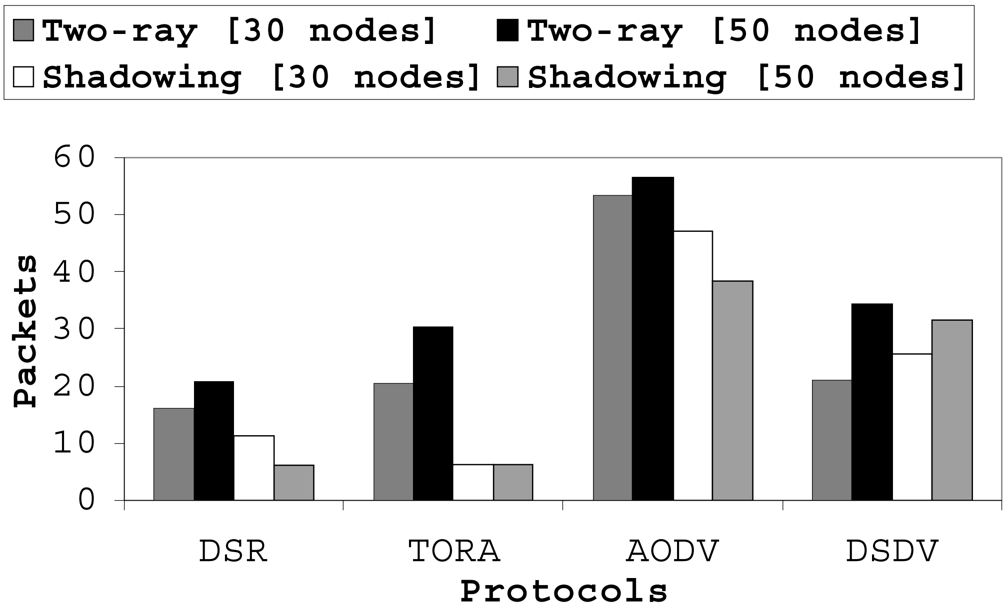

Figure 7. Packets Discard (FTP)

The number of connections established, in an universe of fifteen, is presented in fig. 8.

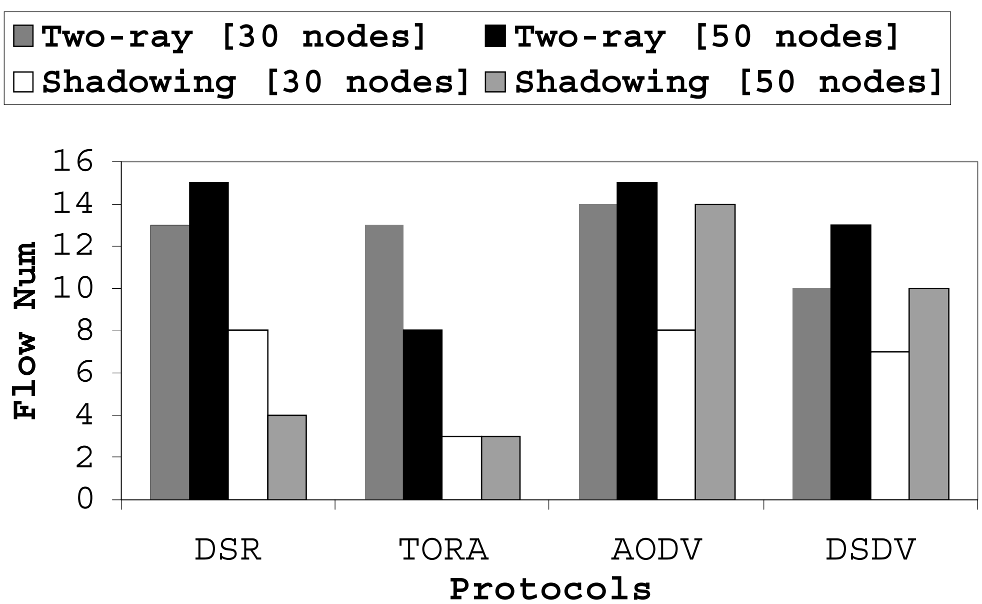

Figure 8. Established connections (FTP)

5. FINAL REMARKS

The technology of wireless networks still needs solutions for important applications, such as multimedia, to be able to consolidate itself in the market. The attained results point to the transmission of conventional data to make viable this technique. However, the use of audio and video applications in this network segment requires specific mechanisms, such as QoS, as well as more efficient routing protocols. In the investigated scenario, the susceptibility of the media transmission to constant interferences, allied to the movement of the nodes, makes impracticable the accomplishment of conferences, though the data service is acceptable. This service could consolidate social projects that would allow the marginal population of Amazon, as an example, to make appointments in their own houses for possible surgeries or specific exams from the periodic visits of the health agents, using only a wireless network linked to the Sistema Único de Saúde (SUS).

Increasing the amount of nodes could extend the number of routing options, what would minimize the problem in the establishment of the connections. However, this could also create a higher delay in the network, along with the extreme load of signalling of the protocols. All of this brings forth the need for a well consistent project.
The evolution of the 802.11 standard and the perspective to incorporate a QoS support to it indicates a clear trend to overcome these difficulties. The reserch for new proposals, hardware or software, should define in the next few years, the routes that will characterize a true revolution in the current communication process, mainly in unusual scenarios such as the Amazonian forest.

6. REFERENCES

1.Fall, K.; Varadhan, K.; "The NS Manual"; Network Simulator 2.1b9a, VINT Project; 2002 , http://www.isi.edu/nsnam/ns/
2.Faruque, Saleh; "Cellular Mobile System Engineering" Artech House, Inc., Norwood, 1996.
3.MANET Group, "Mobile Ad Hoc Networks (MANET)", http://www.ietf.org/html.chaters/manet-charter.html
4.MacDougall, M. H.; "Simulating Computer System Techniques and Tools", The MIT Press, Cambridge, Massachusetts, London, England, 1987.
5.Bettstetter, Christian; Resta, Giovanni; Paolo, Santi; "The Node Distribution of the Random Waypoint Mobility Model for Wireless Ad Hoc Networks", Mobicom, 1998.
6.Monarch Project, Mobile Networking Architectures, http://www.monarch.cs.cmu.edu/
7.Lough, Daniel; Blankenship, Keith; Krizman, Kevin; " A Short Tutorial on Wireless LANs and IEEE 802.11". The Bradley Department of Electrical and Computer Engineering & Virginia Polytechnic Institute and State University, 2002
8.Corson, S.; Macker, J.; "Routing Protocol Performance Issues and Evaluation Considerations"; RFC 2501, 1999.
9.IEEE Standard 802.11a; "Wireless LAN Medium Access Control (MAC) and physical layer (PHY) Specifications"; 1999, http://grouper.ieee.org/groups/802/11/
10.Tanenbaum, A. S.; "Computer Networks", Prentice Hall PTR, 3rd edition. ISBN: 0-13-349945-6.
11.WaveLAN, ORiNOCO Products, http://www.wavelan.com
12.Johnson, D.; Maltz, D., "Dynamic Source Routing in Ad Hoc Wireless Networks", Mobile Computing, Kluwer Academic Publishers, 1996.
13.Perkins, C.; Royer, E., "Ad-hoc On Demand Distance Vector Routing," Proceedings of the 2nd IEEE Workshop on Mobile Computing Systems and Applications, New Orleans, LA, 1999.
14.V. Park and S. Corson, “Temporally-Ordered Routing Algorithm (TORA) Version 1 Functional Specification”, corson-draft-ietf-manet.tora-spec-00.txt, IETF, Internet draft, 1997.
15.C.E. Perkins and P. Bhagwat, "Highly Dynamic Destination-Sequenced Distance-Vector Routing (DSDV) for Mobile Computers", Computer Communications Review, 1994.
16.Tobagi, F.; "Issues Underlying Supporting Multimedia Aplications in IEEE 802.1"; 1995.