Performance Evaluation of Wireless Transmissions in an Amazonian Climate

Thienne M. Johnson and Mauro Margalho

***Abstract*—This paper presents the INFOCLIMA project, which aims to study wireless transmissions in the Brazilian Amazon. The simulation results are useful for our initial research, showing that data transmissions over a long range wireless link in Amazonian climate will adversely affect the network performance. Therefore, environmental monitoring projects should pay special attention to the probability of data loss, since, for this application, delay and throughput do not much affect the monitoring application.**

***Index Terms*— Performance, Sensors, Wireless, Climate factors**

I. Introduction

Sensors are devices that receive and respond to signals or inputs and can be used to measure physical parameters, such as temperature or pressure, and convert the collected data into electronic signals. The use of sensors for monitoring has been done for several decades, being used for applications in climatology, biology, industry and military.

Research projects generally use traditional sensors (without network communications) and data loggers. This device is connected to the sensor and stores the collected data, allowing posterior synchronization with laptops and PDAs locally. This type of data collection is very laborious and susceptible to storage errors during transcription [1].

The cost for an institution that has sensors spread over different collection sites can very be high. Besides maintenance of the equipment (sensors and data loggers) there is the cost of transportation to (possibly) remote sites and the work collecting the data stored in the data loggers.. For example, the Savannah River Site manually collects forty thousand samples per year, with an analysis cost of USD $1000 per sample [2].

In some cases it may be impossible to carry out research inside the data collection environment since the presence of humans would interfere with and therefore invalidate the research results. For example, research carried out at Great Duck Island [3], where researchers could only enter the environment every nine months to avoid disturbing animals behavior.

A sensor network can be characterized by the use of a great number of communication-capable sensor units. Connecting sensors in networks started in military projects [4], like the Sound Surveillance System (SOSUS), and the Distributed Sensor Networks (DSN) project by Defense Advanced Research Projects Agency (DARPA) [5]. During the cold war, SOSUS deep ocean acoustic sensors were used for detection and tracking of Soviet submarines.

The use of networked sensors in agriculture and the food industry is in its initial stages. Environmental sensors are used to study vegetation response to climatic variations, and to track and to measure population of birds or other animals, for example.

Recent advances in communications have allowed the development of cheap small sensors based on micro electromechanical systems (MEMS), with wireless network communications capacity and low energy consumption processors. The use of cheap small devices makes possible their wide scale use in diverse types of applications.

The use of wireless technology allows sensors to be placed directly in the environment where parameters are to be monitored. In locations where wired communication could be restrictive or even interfere with measurements [6], wireless sensor networks offer great advantages.

The purpose of this article is to present the INFOCLIMA project of wireless sensor nets in an Amazonian climate. Simulation studies, using real parameters from the environment, showed signal attenuation due to climatic effects.

This paper is divided into 6 parts. Section 2 shows some existing applications of environmental monitoring. Section 3 presents some factors that influences wireless transmission performance. Section 4 details the INFOCLIMA project. Section 5 shows the parameters of the simulation study and its results. Section 6 concludes this article.

II. Environmental Monitoring

There are various systems for environmental monitoring, like Embrapa, GO!Sync and SIPAM.

Embrapa (Brazilian Agricultural Research Organization) carries out diverse types of monitoring applications, such as

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for forest fires, however, they still use traditional sensors and data loggers [7].

GO!Sync [8] is used in vineyards to capture relevant information. Teams of people collect data, which is later transferred to a GIS (geographic information system). Another variation of this type of collection system was shown in [9].

Project SIPAM (System for the Protection of the Amazon) [10], sponsored by the Brazilian Government, uses many types of sensors interconnected for monitoring the Amazon region.

Sensors are even used for planetary exploration and monitoring [11].

The automation of the monitoring process can be used in diverse types of climates and conditions. But, what is the effect of vegetation or climate on data transmissions between sensors and sinks? How does the amazonian climate effect wireless transmissions? These are questions that will be investigated by the INFOCLIMA project.

III. Wireless Interference Factors

Many factors may affect wireless network transmissions, such as climatic variations (rain, snow, wind) or solar interference (solar radio burst in frequencies above 1GHz) [12].

Climatic factors have been studied in some countries, such as the U.S.A. [13], where interference due to snow precipitation and accumulation of snow on the antennas has been shown.

It has also been shown that rain and fog have a negative impact on the performance of wireless networks operating in frequencies below 11GHz.

High frequencies need lots of energy to penetrate objects, and, because of this, blockages can be problematic in these frequencies, which are used in wireless transmissions. There are some studies about the impact of forest vegetation on wireless transmission in the Brazilian Amazon: the presence of foliage causes great attenuation of the radio waves and reduces the reach of the radio equipment [14]. In the Amazon, data loss ratios are very high for long range transmissions inside the jungle [15].

IV. Infoclima Project

Climatology, the scientific study of the climate, monitors and analyzes climatic elements of major importance to other practical activities, such as meteorology, industry, agriculture, transport, architecture, etc. The main aspects of the agro climatic research carried out in the State of Pará (Brazilian Amazon) are the components that most affect the productivity of production systems and climatic fluctuations. The elements more commonly observed are: temperature, humidity, evaporation, rain, wind, global radiation, solar brightness and ground temperature.

The knowledge in real time of this information allows greater reliability in agro climatological forecasts, and the more frequent collection of the necessary climatic data helps refine research [16].

Online access to this data allows its verification more quickly, and its availability to the community of agriculturists and researchers. To allow this real time update, a communication infrastructure must be available at all times. However, the climate of the Amazon region is very different of other parts of the planet, where the studies on quality of communication and error-correction techniques are tested.

The Northern Region of Brazil, located in an equatorial band, is characterized by high temperatures (associated with intense solar radiation) and elevated pluvial indices [12]. The study of the behavior of the wireless communication in our region will allow us to generate new data-communication techniques, more adequate to the hot, humid climate and the massive presence of foliage between communication points.

The advantage of networked sensors for environmental monitoring can be measured by its ability to allow new applications. In this study, a WSN (Wireless Sensors Network) makes possible data collection over longer periods and with greater frequency and resolution than would be practical if done manually.

We have not seen any studies about short range transmission in this environment. Transmissions of short range, as in wireless sensors, are also probably affected by this kind of environment.

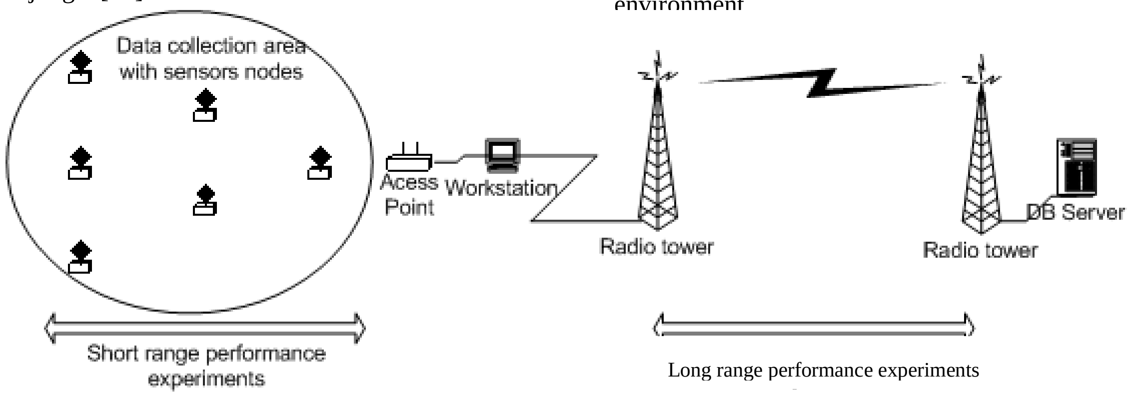

Figure 1: Infoclima Project

This study will also bring new knowledge and techniques that could be used in our region for the improvement of data communications. The problems identified will indicate which methods must be added to the communications infrastructure to improve transmissions.

A. Application Characteristics

Experiments in the project cover 2 parts: short range (between sensors) and long range (data transmission between the collection point and the main repository) transmissions.

Prior studies of short range transmissions were done in [18]. In this article, we will summarized the obtained results. And then, analyze long range transmissions. Figure 1 shows the general configuration of the project.

The classification of the project INFOCLIMA WSN, according to methodology proposal by Römer [17], is detailed in Table 1.

TABLE I. PROJECT WSN CLASSIFICATION

Parameters	Value
Deployment	Manual
Mobility	Fixed
Nodes size	Matchbox
Heterogeneity	Heterogeneous
Communication Technology	Radio
Infrastructure	Ad hoc
Topology	Multihop, tree
Coverage	Sparse
Connectivity	Connected
Network size	6 nodes

In the long range transmission directional long range antennas were used, to transmit environmental data collected by the Wireless Sensors Network (WSN) to main repository.

B. Application Requirements

The experiment has the following requirements:

- Internet delivery: data must be sent to a central office, where data will be available for consulting;
- Longevity: the batteries of the sensors must be able to work for at the very least 2 months, in order to economize researcher's travel to data collection points.
- Long-distance maintenance: the distance between the research station and the agro climatological stations (in the interior of Pará State) makes it necessary that the WSN be managed over the Internet.
- Long range radio links will allow access to the remote systems.
- Sensors and Samplings: the collected data will be basically meteorological data. A high collection frequency refines the necessary climatic characterization for the research.
- Storage of data: a data base is necessary to store the collected data and to allow it to be made available on the Internet for research and visualization in real time.

IV. SIMULATION RESULTS

The simulation studies' objective is to verify how the environment interferes with short and long range data transmissions. The used simulator, Network Simulator (ns-2) allows the characterization of a parameter that indicates the loss factor (caused by radio signal attenuation). This parameter was used to compare the performance of data transmissions.

A. Simulation Parameters

In the first stage [18], a simulation study embraced only data transmission between sensors. 6 nodes, being 05 sensor nodes and 01 node that receives the transmissions (sink node) were used. The WSN internal traffic was 64Kbps, and the sink received 54Kbps. This traffic was used to feed the long range transmission between the sensors site and the main repository (Figure 2)

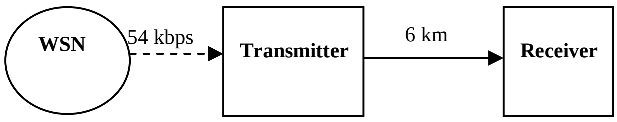

Figure 2: Long range transmission

The simulation was configured with the following specifications, shown in Table II:

TABLE II. SIMULATION PARAMETERS

Network	Item	Value/Quantity
All	Simulation Time	100 simulation units
	Traffic	CBR (Constant Bit Rate) - 4 Kbps
		1 and 4 (Varies from 1 to 5. The higher, the greater obstructions)
	Standard deviation	5
Sensors Network	Nodes	6 (5 sensors nodes and 1 sink node)
	Coverage area	100 m^2
	Loss factor	1 and 4 (Varies from 1 to 5. The higher, the greater obstructions)
	Sensor node antenna height	10 cm
	Antennas gain	12 dBi
	Transmission Frequency	914 MHz
	Routing Protocol	AODV
	Topology	Ad-hoc
Long range	Distance	6 Km
	Nodes	2
	1, 2, 5.5, and 11 Mbps	Data rate
	Loss factor	1, 1.5 and 2
	Antennas gain	24 dBi
	Transmission Frequency	2.4 GHz
	MAC_RTSThreshold	2000
	Power	100mW

B. Results

The studies with the sensors network showed that the network had performance sufficiently degraded with loss factor 4 (assuming many obstacles in the forests).

The short range results can be summarized as:

- Results were obtained for end-to-end delay, throughput, and data loss for each sensor node. Results generated for individual sensors were used to characterize the transmission behavior in relation to the fixed positions of the sensors. Sensors further from the sink had reduced performance in relation to sensors in closer proximity to the sink. Analysis of the data allows us to decide if individual node performance is adequate for its projected use.
- In relation to end-to-end delay, considering loss factor equal to 1, nodes closest to the sink had the largest delays due to their role as routers for traffic to the sink. In the case with loss factor equal to 4, more distant nodes had diminished performance, but for nodes closest to the sink, performance remained static.
- For throughput, more distant nodes suffered a performance loss, while nodes closer to the sink maintained their throughput levels.
- In relation to the probability of data loss, considering loss factor equal to 1, the probability is practically null, while in the case of using a loss factor of 4, the probability for data loss for the more distant nodes becomes very high.

For long range transmission, loss factors of 1, 1.5 and 2 were used. Above this, the receiving point did not receive anything.

Figure 3 shows the throughput for long range transmissions. The use of loss factor 1 and 1.5 did not generate significant changes, keeping the throughput steady. With the use of loss / factor 2, there is a significant reduction. Using loss factor above 2 (3 and 4 would be used for loss factor), there was no reception of the signal.

In a real world situation, in transmissions carried out in the city of Belém (Amazonian City), using the same parameters of the simulation experiments, in communication between 2 Campuses of the University of Amazonia, the transmissions on rainy days showed degraded performance, and with strong rains, the signal fell, not allowing any type of communication, as happened in the simulation.

The end-the-end delay, shown in figure 4, showed that the delay with loss factor of 1 and 1.5 does not generate great variation (according to systems comparison using confidence intervals and visual test), however a loss factor of 2 generated a higher delay.

During the use of the link between University Campuses, higher delays were experienced while it was raining, harming the real time applications performance.

Jitter, which is also affected by the increase of the loss factor, did not showed great variation with loss factors of 1 and 1.5, but did increase with a loss factor of 2.

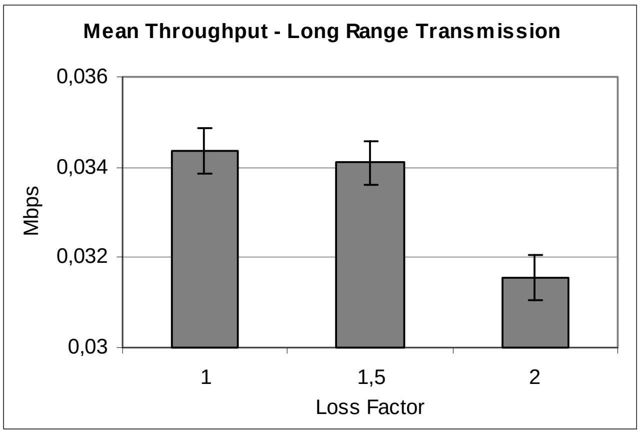

Figure 3: Mean Throughput

These results, corroborated by real use of wireless transmissions in the Amazonian climate, show that long distance communication data applications must have special attention during heavy rains. The use of QoS or data buffering at critical transmissions times must be used to guarantee the reception of the transmitted data.

V. CONCLUSIONS

This paper presented the INFOCLIMA project, which aims to study wireless transmissions in the Brazilian Amazon. The simulation results are useful for our initial research, showing that the loss factor caused by signal attenuation affects wireless links performance, this was also verified in real experiments.

These studies are of great importance for the Amazon region and other places of the planet that possess the same climatic characteristics: heavy rains, high humidity and high solar radiation.

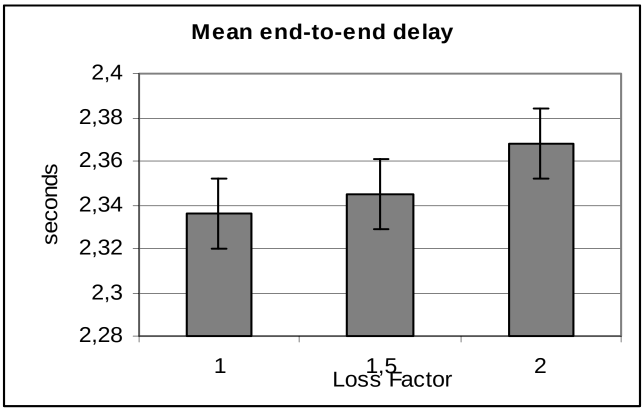

Figure 4: Mean end-to-end delay

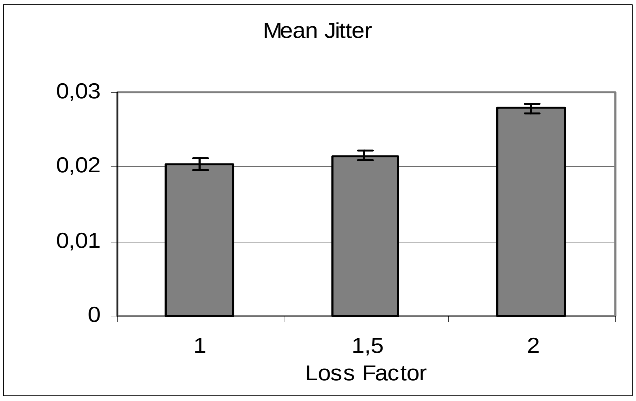

Figure 4: Mean end-to-end jitter

VI. Future Work

This project's next step is a more detailed study of the effects of strong solar radiation, high temperatures, heavy rains, and dense vegetation on wireless transmissions. Real wireless climatological sensors and a long range network will be used for practical experiments with real data.

Acknowledgments

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