# Communications Delay and Energy Consumption in IEEE802.11 Network Stations

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**Summary**
This paper had the objective of studying the relation between the communication delay and the electric power consumption in IEEE 802.11 network stations. In order to achieve this goal, tests were carried out, considering four different scenarios. The obtained results show that there is a direct relationship between the communication delay and the electric power consumption in IEEE 802.11 network stations.

***Key words:***
*Quality of Service; Communications Delay; IEEE802.11; Energy Consumption; Network planning.*

## 1. Introduction

The IEEE 802.11 standard is the most widespread wireless communication standard in the contemporary society for users' connection to wireless devices and to the Internet. Its development occurred in the beginning of the 1990 decade, and its final version was launched in 1999. The aim of the project was to add a new physical layer and data to the ISO model, promoting radiofrequency communication over ETHERNET [1, 2, 3, 4]. To control and operate such networks within Quality of Service (QoS), a set of parameters was defined.

One of the most important QoS parameters is the communications delay. The delay parameter can be defined as the transit time of a data package in a communication process. If the delay shows high rates, degeneration can occur in the synchronism as well as in the network packages. In applications which involve voice or video, the delay cannot reach up 150 ms, since over this value a dramatic influence can affect the communication link [4, 5, 6, 7].

In order to maintain quality of service parameters (such as the communications delay) in adequate levels, efforts must be made, in terms of investments and network maintenance. This involves equipment and link performance evaluation, including economic, social and environmental sustainability. One consequence of link performance degeneration is the increase in energy consumption required to maintain the communication link.

Sustainability has been an extremely relevant and recurring subject in the media nowadays. Consequently, electrical energy massive consumers must be identified and these high demands must be analyzed and mitigated. Over the years, the electrical energy consumption in communication networks has grown significantly. Also, the Telecommunications sector has shown a significant growth. The Gartner institute research shown that in 2010, nearly 727 TWh were used to power feed personal computers. On the other hand, for servers, in a global scale, approximately 138 TWh were used [1, 8]. This electrical energy consumption tends to increase since users are adopting and using new technologies every single day. In this context, the main objective of this paper is to relate the communication delay (that is a Quality of Service parameter) to the electrical energy consumption in IEEE 802.11 (Wi-Fi) networks, which are becoming more popular worldwide [1, 2, 10].

## 2. Materials and Methods

### 2.1 Access Point

To generate data traffic between the Access Point (AP) and the client station, the computer on Fig. 1 was used. The specifications of the machine are presented on Table 1. This is a smart AP which was developed by the Research Group on Energetic Efficiency (GPEE) from the Pontifical Catholic University of Campinas (PUC-CAMPINAS) in the context of the Post-graduate Programs in Urban Infrastructure and Telecommunications Networks

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Management. In Fig. 1, the Wi-Fi antenna is shown inside a yellow colored circle.

## 2.2 Client Station

The AP-client relation was set up using the AP (Fig. 1) and an Acer laptop. The laptop was connected to a specific network in order to send the packages to the AP. Since a device is connected to a network, it is identified by the network. Using the PING command (that is described in section 2.4), it was possible to check if the station used in the experiments was really integrated to the network. All technical information is presented in Table 2.

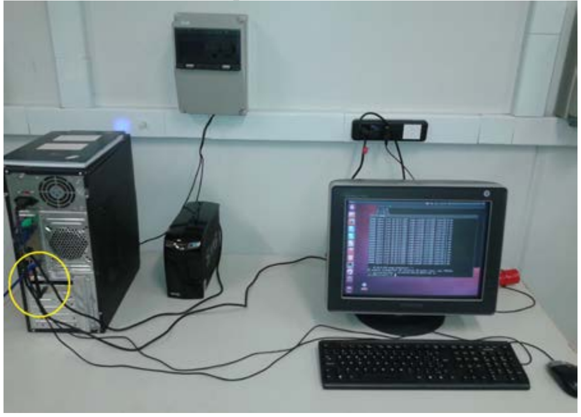

Fig. 1. AP (desktop model) used in the tests.

Table 1: Features of the AP used in the tests

| | |
|---|---|
| **PC** | Tower desktop with LINUX |
| **I.P.** | 10.10.0.1 |
| **O.S.** | Ubuntu 12.04.LTS |
| **PROCESSOR** | Central INTEL i3 3.1GHz/32bits |
| **MEMORY** | 4GB (RAM) |
| **WIRELESS NETWORK BOARD** | Wireless network board and cabled connection ETHERNET connected to the local network PUC-Campinas |
| **NETWORK INTERFACE** | IEEE802.11g standard wireless |

Table 2: Features of the Client used in the tests

| | |
|---|---|
| **MODEL** | Acer Aspire E5-571-56R0 |
| **PC** | laptop |
| **I.P.** | 10.10.0.120 |
| **S.O.** | Windows 8.1 |
| **PROCESSOR** | Intel® CoreTM i5-4210U |
| **MEMORY** | 6GB (RAM) |

## 2.3 Current and Voltage Analyzer – INDRA

The electrical energy consumption data collection was made using a network aspects analyzer from INDRA® company [9] shown in Fig. 2. Using this analyzer, the energy consumption of the station could be checked while the delay parameter was collected. Among other parameters, the equipment measures active power (KW), Reactive Power (KVAr), power factor, voltage and electrical current. The equipment was adapted in order to get the current (i) and voltage (V) values. Two analyzers were used in a parallel way so that each one could inform the current and voltage value at the moment of the experiments. In order to measure the effective electrical energy consumption of the station, the laptop battery was removed. This adaptation was applied and can be seen on Fig. 3.

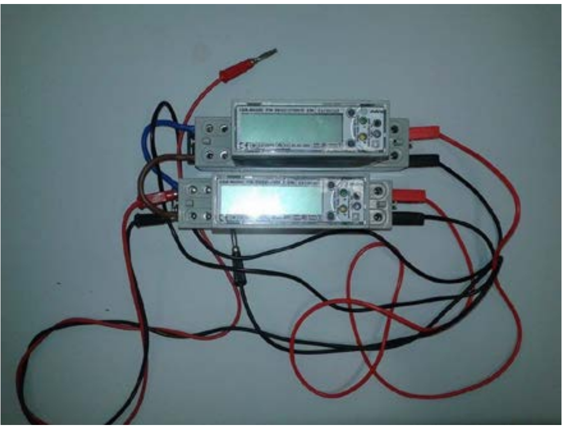

Fig. 2. Power network analyzer used in the experiments

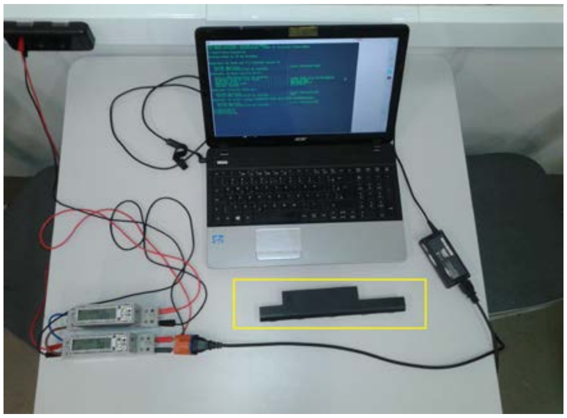

Fig. 3. Client Laptop Adaptation (battery removal and instrumentation).

## 2.4 Using OS PING command

This command is available in operational systems (OS) such as Windows and Linux, via operational system's command window. The objective of using this command is to determine how long a package of information (payload) takes to reach its destination and get back [2]. So, the PING command sends packages to the destination device and waits for a "response" about the package delivery. The

PING command provides measurements associated to the RTT (Round trip Time) - which is the time it takes for a package to be sent added to the time interval that it takes for an acknowledgment about that information to be received - and to the intensity of the signal. The RTT is also known as Ping Time [2, 10].

The PING command works with command lines and, consequently, it is possible to determine the size of the package to be sent as well as the quantity of packages. Table 3 shows the expected parameters for standard voice payload, extracted from ref. [2]. The highlighted part presents voice service payloads (Bytes) that will be adopted as base case for the tests in the first scenario in the next section (Results).

Table 3: Calculated parameters for standard voice payload [2]

| **Voice payload size (Bytes)** | **Voice payload time (ms)** | **Package by seconds (PPS)** | **Bandwidth ETHERNET (Kbps)** |
|---|---|---|---|
| **160 Bytes** | 20 ms | 50 | 87,2 Kbps |
| **20 Bytes** | 20 ms | 50 | 31,2 Kbps |
| **24 Bytes** | 30 ms | 34 | 21,9 Kbps |

## 3. Results

All experimental tests took place inside the Thermal Comfort Laboratory at PUC- Campinas. Fig. 4 illustrates the network architecture used in the tests. Output monitored data was saved in text files stored inside the AP station memory. Then, data output was formatted for usage in spreadsheets containing information about package times and station power, include true-rms voltage and current.

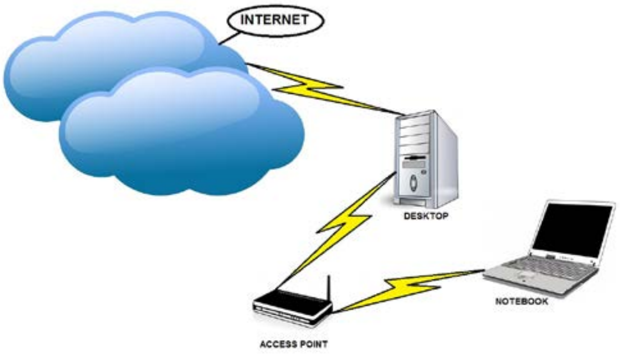

Fig. 4 Test Network architecture

For each performed test, 60 PING commands were issued, and the corresponding 60 values of voltage, current and power were registered. Fig. 5 illustrates the output spreadsheet structure for voice packages with payload size of 160 bytes. The 8 bytes added to the package size (that results in 168 bytes) is automatically made by the PING command, and can be interpreted as the attached heading in every package sent to the station. For the experimental tests, it was fixed the minimum size of 160B for the payload, considering that is the typical package for voice services, considered critical in wireless IEEE802.11 communications [2].

| SIZE (B) | PACKAGE NUMBER | RTT (ms) | VOLTAGE (V) | i (A) | CONSUMPTION (W) |
|---|---|---|---|---|---|
| 168 | 1 | 1,7 | 131,3 | 0,2 | 26,26 |
| … | … | … | ……. | … | …… |
| 168 | n | 1,69 | 132,0 | 0,12 | 26,0 |

Fig. 5. Output Format (exported to text file).

### 3.1 Tests for 160 bytes package size (Scenario 1)

In the first experimental scenario, using 160 bytes sized packages (that result in a payload size of 168 bytes), two different test cases were experimented. In the first case (Case A), the distance between the access point and the mobile station was 13 meters. The received signal power at the station was about -63 dBm. In these conditions, the average delay obtained was 3.67 ms, for an average power of 26.37 W at the station.

In the second case (Case B), station and access point were positioned more distant from each other, in order to cause a greater interference in the signal transmission and a drop in the received power at the station. The distance between AP and station was 30 meters, and the received power was -90 dBm. For the same 168 bytes payload packages, the average delay was slightly higher, of about 4.14 ms; and the average power at the station also suffered a small increase, resulting in a 27.30 W demand. Fig. 6 illustrates the obtained results for Cases A and B.

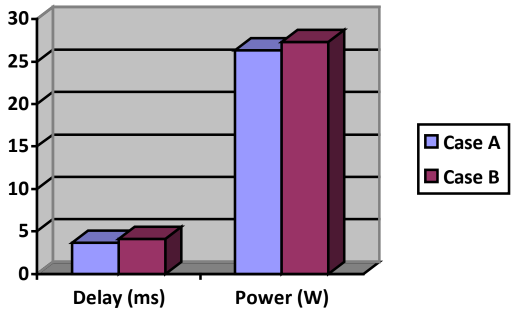

Fig. 6. Delay and Power comparison for different conditions using packages of 160 bytes

### 3.2 Tests for 35000 bytes package size (Scenario 2)

In the second experimental scenario, tests were made in order to identify the PING command capacity to send huge sized packages. These tests showed that the programmer can send packages of a size up to 35000 bytes without losses, depending on the distance and the influence that may be among the propagation. So, the payload size of 35008 bytes was adopted for Scenario 2.

In the third case (Case C), the distance between the access point and the mobile station was set to 13 meters. The resulting received signal power at the station was -68 dBm, and the average delay obtained was 24.82ms, for an average station power of 15.25W.

In the fourth case (Case D), station and access point were turned apart, as before. The new distance between AP and station was set at 30 meters, and the corresponding received power was -92 dBm. For payload packages of the same size (35008 bytes), the delay significantly increased, for an average value of 431.92ms, leading to an increase in the average station power demand that became 26.12W.

Fig. 7 illustrates the comparison among the tested cases for the second scenario. It should be noted that Fig. 7 y-axis maximum value was set at 50 in order to provide a better data comparison view, but in truth the delay in Case D exceeds this value by large, being equal to 431.92ms.

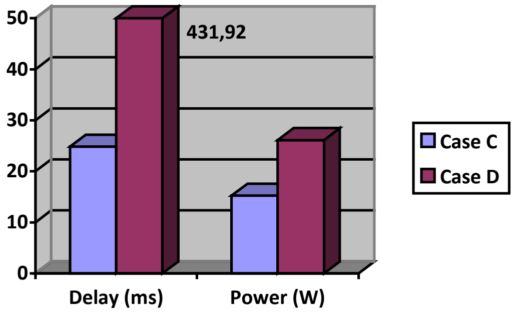

Fig. 7. Delay and Power comparison for different conditions using packages of 35000 bytes

### 3.3 Results Summary

The obtained results related to Scenario 1 (Cases A and B) and to Scenario 2 (Cases C and D) are summarized in Table 4. In this Table, the column “Distance” represents the distance between the AP and the client station. From this Table it is possible to observe the influence of the distance in the delay and in the station power demand. Considering the comparison between Cases A and B (that have the same payload), it is possible to verify that as the distance increases, the delay increases (an increase of approximately 13.4%) and the power demand also increases (an increase of approximately 3.5%).

Similar conclusions can be obtained when considering the comparison between Cases C and D (that have the same payload). It is possible to verify that as the distance increases, the delay increases (an increase of approximately 1640.2%) and the power demand also increases (an increase of approximately 71.3%).

Table 4: Summarized test results

| Scenario/ Case | Distance (m) | Payload (kByte) | Received Power (dBm) | Average Delay (ms) | Average Power (W) |
|---|---|---|---|---|---|
| **S1/Case A** | 13 | 0.16 | -63 | 3.65 | 26.37 |
| **S1/Case B** | 30 | 0.16 | -90 | 4.14 | 27.30 |
| **S2/Case C** | 13 | 35 | -68 | 24.82 | 15.25 |
| **S2/Case D** | 30 | 35 | -92 | 431.92 | 26.11 |

## 4. Conclusion

This paper was focused on determining the relation between the communication delay and the electric power consumption in IEEE 802.11 (Wi-Fi) network stations. In order to verify this relation, tests were carried out, at the Thermal Comfort Laboratory of PUC-CAMPINAS, considering four different cases (A, B, C and D). These tests were based on the communication between an Access Point and a station, using the IEEE 802.11 standard.

The obtained results show the influence of the distance between the AP and the station on the signal propagation and degradation, since an increase in this distance results in an increase in the communication delay and in an increase in the station power demand. So, there is a direct relationship among the distance, the communication delay and the electric power consumption in IEEE 802.11 network stations, considering situations that maintain the same payload.

From the results, it was also possible to verify that there is an influence of the payload on the communication delay, since an increase on the payload causes an increase on the delay and a decrease on the station power demand. This is an interesting result that must be better explored, by carrying out more tests, in order to confirm this preliminary analysis.

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