# The Theoretical Maximum Throughput Calculation for the IEEE802.11*g* Standard

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**Summary**
Estimating the throughput of a WiFi connection can be quite complex, even when considering simple scenarios. Indeed, the varying number of parameters specified in the standards makes it hard to understand their impact in terms of delay and throughput. The main contribution of this work is to present a scheme to compute the exact maximum throughput for an IEEE802.11g network. The proposed scheme incorporates all the timings and settings, which allow one to calculate the throughput for different channel spacing and modulation techniques specified in the standard. Experimental and simulated results show the accuracy of the proposed scheme.

***Key words:***
*Theoretical Throughput, WiFi, IEEE802.11g, Maximum Throughput*

## 1. Introduction

The past decade witnessed enormous advances in wireless communication technologies. These advances have fostered the development of international standards aiming to cope with the increasing demand for wireless solutions. In this context, the IEEE published a set of standards for wireless local area network (WLAN) communication, known as IEEE802.11 or WiFi [1]. Since its publication, the IEEE802.11 has been quite popular and today it is commonplace for both home and office networking. Owing to its low cost, easy set up and deployment, most current mobile and portable devices are currently empowered with WiFi capabilities, allowing users to connect to nearby access points for Internet connection or, alternatively, to set up ad hoc networks for file sharing among other applications. The standard defines two operational modes: infrastructure and ad hoc modes. In the former, there is a presence of a coordination point while in the latter the wireless nodes can communicate directly with each other.
According to the standard, the highest achieved throughput for the IEEE802.11g standard is 54*Mbps*. However, the achievable data rate for user applications is far less than that. For this reason, several works have been devoted to estimate expected throughput of an IEEE802.11 network. These works can be classified in two major groups: (*i*) those works devoted to analyze the theoretical throughput of WiFi networks in the presence of a number transmitting nodes and; (*ii*) those works devoted to understand the intricacies of the WiFi standard so as to better understand the numerous timings and settings and how they affect the throughput. The works presented in [2], [3], [4], [5], [6], [7] are examples of the first group. The seminal work in [2] focus on the throughput of wireless networks where the nodes are randomly distributed in a network setting without mobility. Tse *et. al.* [3] have shown that mobility has a positive impact in terms of throughput. The work in [4] provides an analytical model to compute the maximum throughput in a single hop setting operating in a Distributed Coordination Function mode. Nguyen *et. al.* [5] have proposed an analytical model to show the throughput performance for IEEE 802.11 in a multi-hop setting. The work in [6] uses Markov Chain to model the exponential *backoff* scheme in order to define a theoretical throughput upper bound. Jun *et. al.* [7] provided a model that allows to compute the throughput upper bound of a node in a wireless mesh topology. The work in [8] falls in the second group, where the goal is to provide an easy and comprehensive way to compute the maximum throughput based on the timings and settings defined in the standard. The results apply for both IEEE802.11*a* and *b* networks. In the same group, Xiao *et. al.* [9] presented a scheme to improve the network performance by estimating the throughput upper bound and the delay based on the IEEE 802.11standard.
Our work extends the results presented in [8] to be applied to the IEEE802.11*g* networks, which is currently widely deployed. In other words, the main contribution of this work is to present a simple scheme to compute the exact maximum throughput of an IEEE802.11*g* network. Our scheme incorporates all the timings and settings, allowing the throughput calculation for different channel spacing and modulation techniques that have been defined in the standard. Differently from [8], we present a scheme to calculate the total delay for IEEE 802.11*g* and validate the theoretical model with both experimental and

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Table 1: Parameters table for IEEE802.11g composed from the summary of the standard defined by [1].

| | OFDM PHY Characteristics | | | | Modulation Dependent Parameters | | | Timing Related Parameters | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Scheme** | **Channel Spacing** | **Slot Time** | **Sifs** | **Difs** | **Modulation** | **Data Rate** | **N_DPBS** | **T_Sym** | **T_Signal** | **T_Preamble** | **T_BO** | **T_ACK** |
| ERP-OFDM-6 | 20 | 9 | 16 | 34 | BPSK | 6 | 24 | 4 | 4 | 16 | 67.5 | 26.67 |
| ERP-OFDM-9 | 20 | 9 | 16 | 34 | BPSK | 9 | 36 | 4 | 4 | 16 | 67.5 | 25.11 |
| ERP-OFDM-12 | 20 | 9 | 16 | 34 | QPSK | 12 | 48 | 4 | 4 | 16 | 67.5 | 24.33 |
| ERP-OFDM-18 | 20 | 9 | 16 | 34 | QPSK | 18 | 72 | 4 | 4 | 16 | 67.5 | 23.56 |
| ERP-OFDM-24 | 20 | 9 | 16 | 34 | 16-QAM | 24 | 96 | 4 | 4 | 16 | 67.5 | 23.17 |
| ERP-OFDM-36 | 20 | 9 | 16 | 34 | 16-QAM | 36 | 144 | 4 | 4 | 16 | 67.5 | 22.78 |
| ERP-OFDM-48 | 20 | 9 | 16 | 34 | 64-QAM | 48 | 192 | 4 | 4 | 16 | 67.5 | 22.58 |
| ERP-OFDM-54 | 20 | 9 | 16 | 34 | 64-QAM | 54 | 216 | 4 | 4 | 16 | 67.5 | 22.52 |
| ERP-OFDM-3 | 10 | 13 | 32 | 58 | BPSK | 3 | 24 | 8 | 8 | 32 | 97.5 | 26.67 |
| ERP-OFDM-4.5 | 10 | 13 | 32 | 58 | BPSK | 4.5 | 36 | 8 | 8 | 32 | 97.5 | 25.11 |
| ERP-OFDM-6 | 10 | 13 | 32 | 58 | QPSK | 6 | 48 | 8 | 8 | 32 | 97.5 | 24.33 |
| ERP-OFDM-9 | 10 | 13 | 32 | 58 | QPSK | 9 | 72 | 8 | 8 | 32 | 97.5 | 23.56 |
| ERP-OFDM-12 | 10 | 13 | 32 | 58 | 16-QAM | 12 | 96 | 8 | 8 | 32 | 97.5 | 23.17 |
| ERP-OFDM-18 | 10 | 13 | 32 | 58 | 16-QAM | 18 | 144 | 8 | 8 | 32 | 97.5 | 22.78 |
| ERP-OFDM-24 | 10 | 13 | 32 | 58 | 64-QAM | 24 | 192 | 8 | 8 | 32 | 97.5 | 22.58 |
| ERP-OFDM-27 | 10 | 13 | 32 | 58 | 64-QAM | 27 | 216 | 8 | 8 | 32 | 97.5 | 22.52 |
| ERP-OFDM-1.5 | 5 | 21 | 64 | 106 | BPSK | 1.5 | 24 | 16 | 16 | 64 | 157.5 | 26.67 |
| ERP-OFDM-2.25 | 5 | 21 | 64 | 106 | BPSK | 2.25 | 36 | 16 | 16 | 64 | 157.5 | 25.11 |
| ERP-OFDM-3 | 5 | 21 | 64 | 106 | QPSK | 3 | 48 | 16 | 16 | 64 | 157.5 | 24.33 |
| ERP-OFDM-4.5 | 5 | 21 | 64 | 106 | QPSK | 4.5 | 72 | 16 | 16 | 64 | 157.5 | 23.56 |
| ERP-OFDM-6 | 5 | 21 | 64 | 106 | 16-QAM | 6 | 96 | 16 | 16 | 64 | 157.5 | 23.17 |
| ERP-OFDM-9 | 5 | 21 | 64 | 106 | 16-QAM | 9 | 144 | 16 | 16 | 64 | 157.5 | 22.78 |
| ERP-OFDM-12 | 5 | 21 | 64 | 106 | 64-QAM | 12 | 192 | 16 | 16 | 64 | 157.5 | 22.58 |
| ERP-OFDM-13.5 | 5 | 21 | 64 | 106 | 64-QAM | 13.5 | 216 | 16 | 16 | 64 | 157.5 | 22.52 |

simulated results. We simulated our proposal in the Qualnet [10] wireless network simulator, which is a well-known network simulator that incorporates the details of the IEEE802.11g standard.

The reminder of this article is organized as follows. *Section 2* presents an overview of the IEEE802.11 standard. Following it, *Section 3* shows how to compute the Theoretical Maximum Throughput (TMT) for an IEEE802.11*g* network. *Section 4* presents numerical and experimental results based on the discussion presented in the previous section. Finally, *Section 5* concludes this work.

## 2. Preliminaries

The IEEE802.11$x$, $\{x \mid x \in \{a, b, g\}\}$ standards sets the grounds for mobile wireless communications with a wide range of data transmission strategies, both at the physical and link layer [1]. These standards define a *nominal transmission speed*. However, in practice, the nominal transmission speed does not reflect in an intuitive expectation of the data flow capacity. Indeed, the defined protocols include a number of timers (both fixed and non-fixed) that have a direct impact on the protocol's performance.

*Table 1* shows a summary of the constants and equations present in the standard [1]. The table gathers all the relevant information in order to calculate the Theoretical Maximum Throughput and the Theoretical Total Delay for IEEE802.11*g*. As can be seen in the table, the IEEE802.11*g* defines the physical Extended Rate PHY OFDM (ERP-OFDM) static characteristics, which includes: *timeslot*, *Short Inter Frame Spacing* (SIFS), *DCF Inter Frame Spacing* (DIFS), and the timing specifications for the PLCP headers. As an aside, the IEEE802.11*g* can operate in compatibility mode with the IEEE802.11*b* networks. In this work we consider IEEE802.11*g* only. The results for IEEE802.11*b* can be found in [8].

The IEEE802.11*g* standard defines the physical and data link layer. The data link layer is sub-divided into LLC - (*Logical Link Control*) - and MAC (*medium access control*) sub-layers. The LLC adds both the LLC and SNAP headers. At the MAC sub-layer an additional header is added before the frame is passed to the physical layer. At the physical layer, a PLPC header and preamble are added. The IEEE802.11*g* uses *orthogonal frequency division multiplexing* (OFDM) [11] operating at *2.4* GHz frequency bands. The supported date rates are *6*, *9*, *12*, *18*, *24*, *36*, *48*, and *54* Mbps.

In the *Distributed Coordination Function* (DCF) mode the use of RTS/CTS message exchange are employed to lessen the effects of hidden terminal problems [12]. Each of these packets contains the proposed duration of communication and the destination address. Neighboring nodes that overhear any of these packets must themselves defer communication for the proposed duration.

When the MAC protocol at a transmitting node *S* wishes to send a packet, both physical and virtual carrier sensing are performed. If the medium is found idle for an interval of DIFS (*DCF Inter Frame Space*) time, then *S* chooses a random *backoff* (*BO*) period for additional deferral. When the backoff period expires (i.e., reaches zero), *S* transmits the Data packet (or the RTS). If a collision occurs, a new backoff interval is selected. A Short Inter Frame Space (SIFS) is used to separate transmissions belonging to the same dialog.

## 3. TMT for IEEE 802.11g Networks

As discussed in the previous section, the maximum throughput at the upper layers depends on the overhead of the layers below. Also, the TCP protocol dynamics has a direct impact on the throughput as well. In this work we do not consider the effects of the TCP protocol on the throughput. Following the definition in [8], the *Theoretical Maximum Throughput* (TMT) observed by an application is described by the Eq. 1, when no fragmentation is involved in the lower layers:

$$APP_{TMT} = \frac{\beta}{\alpha + \beta} \times MAC_{TMT} \quad (1)$$

In Eq. 1, the $APP_{TMT}$ represents the TMT of the application layer, $\alpha$ is the total overhead above MAC layer, $\beta$ is the application datagram size and $MAC_{TMT}$ is the TMT of the IEEE802.11*g* MAC layer. In what follows, the $MAC_{TMT}$ is defined under the following assumptions:

- Bit error rate (BER) is zero;
- There are no losses due to collisions;
- DCF mode is used;
- No packet loss occurs due to buffer overflow at the receiving node;
- Sending node always has sufficient packets to send;
- The MAC layer does not use fragmentation;
- Management frames such as beacon and association frames are not considered.

As collisions are not considered in this work, the backoff $T_{BO}$ is selected randomly following a uniform distribution from (0, $CW_{MIN}$) giving the expected value of $CW_{MIN}/2$. Thus, the total delay time needed to transmit the MSDU (*MAC Service Data Unit*) ($MSDU_{DELAY}$), including the various frame spacing and the backoff, can be computed as follows [13]:

$$MSDU_{DELAY} = (T_{DATA} + T_{SIFS} + T_{ACK} + T_{DIFS} + T_{BO}) \times 10^{-6} \ (s) \quad (2)$$

At the physical layer, the modulation and other timing related parameters are responsible for the physical layer overhead. *Table 1* shows the values for each of these parameters, including different channel spacing, modulation schema and data rates. The time spent to transmit a data frame $T_{DATA}$ of length $L$ can be computed as follows [1]:

$$T_{DATA} = T_{preamble} + T_{signal} + \left\lceil T_{sym} \times \frac{16 + 8 \times L + 6}{N_{DBPS}} \right\rceil \quad (3)$$

The *equation 3* can be simplified to:

$$T_{DATA} = T_{preamble} + T_{signal} + \left\lceil \frac{T_{sym}}{2} + \frac{22 + 8 \times L}{DataRate} \right\rceil \quad (4)$$

Clearly, the $T_{DATA}$ in *equation 2* includes the physical layer overhead. Following the notation in [2], the total delay per *MSDU* can be simplified to a function of its size in bytes, $x$ as:

$$MSDU_{DELAY}(x) = (ax + b) \times 10^{-6} \ (s) \quad (5)$$

The *Table 2* presents the values for $a$ and $b$ above for both the case with RTS/CTS and without them. The numerical and the empirical results are shown in the next section.

### 3.1 Calculating the Total Delay Table

The constants values for $a$ and $b$, shown in *Table 2*, were computed using the values from the *Table 1* and also the equations presented previously. Due to the lack of space, some equations have been omitted and just final results are presented.

In this subsection, we show an example of how the constants values in the *Table 2* can be computed. Let us begin with the first line, taking values for $a$ and $b$ represented by *1.3333x + 169.8333* (CSMA/CA) for

Table 2: Total Delay for MAC and Phy layers for the IEEE802.11g.

| Scheme | Channel Spacing | ax + b (CSMA/CA) | ax + b (RTS/CTS) |
|---|---|---|---|
| ERP-OFDM-6 | 20 | $1.3333 * x + 169.8333$ | $1,3333 * x + 257,1667$ |
| ERP-OFDM-9 | 20 | $0.8889 * x + 167.0556$ | $0,8889 * x + 250,6111$ |
| ERP-OFDM-12 | 20 | $0.6667 * x + 165.6667$ | $0,6667 * x + 247,3333$ |
| ERP-OFDM-18 | 20 | $0.4444 * x + 164.2778$ | $0,4444 * x + 244,0556$ |
| ERP-OFDM-24 | 20 | $0.3333 * x + 163.5833$ | $0,3333 * x + 242,4167$ |
| ERP-OFDM-36 | 20 | $0.2222 * x + 162.8889$ | $0,2222 * x + 240,7778$ |
| ERP-OFDM-48 | 20 | $0.1667 * x + 162.5417$ | $0,1667 * x + 239,9583$ |
| ERP-OFDM-54 | 20 | $0.1481 * x + 162.4259$ | $0,1481 * x + 239,6852$ |
| ERP-OFDM-3 | 10 | $2.6667 * x + 265.5$ | $2,6667 * x + 384,8333$ |
| ERP-OFDM-4.5 | 10 | $1.7778 * x + 261.5$ | $1,7778 * x + 377,0556$ |
| ERP-OFDM-6 | 10 | $1.3333 * x + 259.5$ | $1,3333 * x + 373,1667$ |
| ERP-OFDM-9 | 10 | $0.8889 * x + 257.5$ | $0,8889 * x + 369,2778$ |
| ERP-OFDM-12 | 10 | $0.6667 * x + 256.5$ | $0,6667 * x + 367,3333$ |
| ERP-OFDM-18 | 10 | $0.4444 * x + 255.5$ | $0,4444 * x + 365,3889$ |
| ERP-OFDM-24 | 10 | $0.3333 * x + 255$ | $0,3333 * x + 364,4167$ |
| ERP-OFDM-27 | 10 | $0.2963 * x + 254.8333$ | $0,2963 * x + 364,0926$ |
| ERP-OFDM-1.5 | 5 | $5.3333 * x + 456.8333$ | $5,3333 * x + 640,1667$ |
| ERP-OFDM-2.25 | 5 | $3.5556 * x + 450.3889$ | $3,5556 * x + 629,9444$ |
| ERP-OFDM-3 | 5 | $2.6667 * x + 447.1667$ | $2,6667 * x + 624,8333$ |
| ERP-OFDM-4.5 | 5 | $1.7778 * x + 443.9444$ | $1,7778 * x + 619,7222$ |
| ERP-OFDM-6 | 5 | $1.3333 * x + 442.3333$ | $1,3333 * x + 617,1667$ |
| ERP-OFDM-9 | 5 | $0.8889 * x + 440.7222$ | $0,8889 * x + 614,6111$ |
| ERP-OFDM-12 | 5 | $0.6667 * x + 439.9167$ | $0,6667 * x + 613,3333$ |
| ERP-OFDM-13.5 | 5 | $0.5926 * x + 439.6481$ | $0,5926 * x + 612,9074$ |

*Scheme ERP-OFDM-6* and *Space Channel* equal to *20*. Let us take a look at the $T_{DATA}$. The *Equation 4* is a representation of the standard specifications about the time needed to transmit a data frame. Taking the respective values in *Table 1*, we get:

$$T_{DATA} = 16 + 4 + \left\lceil \frac{4}{2} + \frac{16 + 8 \times L + 6}{6} \right\rceil$$

$$= 1.3333 \times L + 25.6667$$

The values of the $T_{SIFS}$ and $T_{DIFS}$ can be obtained directly from the *Table 1*. For the $\boldsymbol{T_{ACK}}$ value, the standard of IEEE 802.11 [1] defines the equation below:

$$T_{ACK} = T_{preamble} + T_{signal} + \frac{L_{ACK}}{N_{DBPS}} \quad (6)$$

Replacing the correct values from the line one of *Table 1* the $T_{ACK}$ value can be calculated as follows:

$$T_{ACK} = 16 + 6 + \frac{8 \times 14}{24}$$

$$= 26.667\ (\mu s)$$

The next step is to compute the $T_{BO}$ value, which can be computed by the following equation:

$$T_{BO} = \left( \frac{W_{MIN}}{2} \right) \times SlotTime \quad (7)$$

Replacing the correct values from the line one of *Table 1*, the $T_{BO}$ value can be calculated as follows:

$$T_{BO} = \left( \frac{15}{2} \right) \times 9$$

$$= 67.5\ (\mu s)$$

Finally, the $MDSU_{DELAY}$ can be calculated by replacing the computed values from *Equation 2*, as presented below:

$$MSDU_{DELAY} = (1.3333 \times L + 25.6667) + 16 + 26.667 + 34 + 67.5$$

$$= 1.3333 \times L + 169.833$$

When RTS/CTS packets are used, their corresponding timings must be added to the *Equation 2*, that is:

$$MSDU_{DELAY(RTS/CTS)} = T_{RTS} + 2 \times T_{SIFS} + T_{CTS} + MSDU_{DELAY} \quad (8)$$

The RTS/CTS transmitting timings are shown in *Table 1*. By replacing the *Equation 8* with the values showed on *Table 1*, we can compute the maximum *MSDU delay* with *RTS/CTS* frames as shown below:

$$MSDU_{DELAY(RTS/CTS)} = 28.66 + 2 \times 16 + 26.667$$

$$+ 1.3333 \times L + 169.833$$

$$= 1.3333 \times L + 257.1667$$

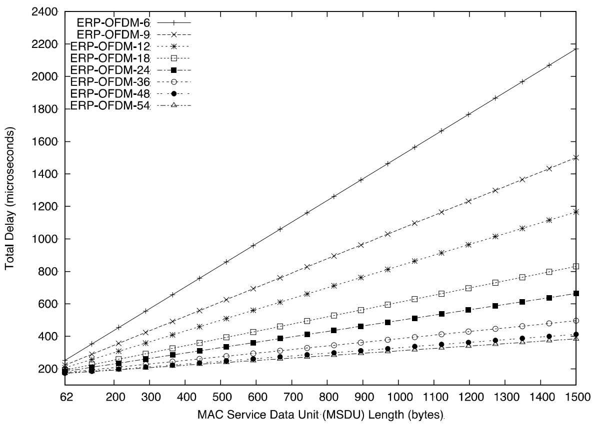


Figure 1: The theoretical total delay.

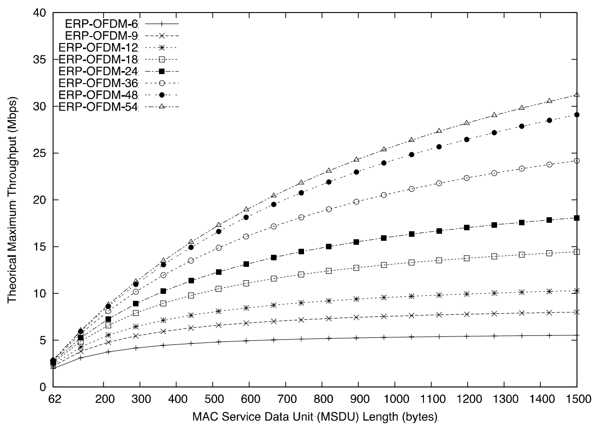


Figure 2: The theoretical throughput.

## 4. Analysis

This section presents both numerical and experimental results for the Theoretical Maximal Throughput (*TMT*) and the Theoretical Total Delay behavior in an IEEE802.11*g* network with both pure *CSMA/CA* and with the *RTS/CTS* mechanism enabled.

### 4.1 Numerical Results

We begin by showing the numerical results for the *TMT* values based on *Table 2*. The numerical results show the maximum theoretical throughput for a single source node without the presence of collision or interference, as described in *Section 3*. *Figure 1* shows the theoretical total delay and *Figure 2* the throughput when *RTS/CTS* is not enabled. Different *MSDU* packet sizes are used, varying from *62 bytes* up to *1500 bytes*. As can be seen, even when a higher data rate is used, the *TMT* reaches its maximum at about *31 Mbps*, which is nearly *43%* below the maximum advertised (*54 Mbps*) when the *MSDU* is set to *1500 bytes*. When employing shorter *MSDU* packets, the maximum theoretical throughput decreases much faster. For lower data rates, the size of the *MSDU* has little impact in terms of throughput. This is the case for *MSDUs* varying from *62* up to *500 bytes* when using data rates of *6*, *9* and *12 Mbps*. On the other hand, longer *MSDU* packets are necessary to obtain a better throughput with higher data rates.

*Figure 3* shows the total delay and *Figure 4* throughput with *RTS/CTS* enabled for different *MSDU* packet sizes, varying from *62 bytes* up to *1500 bytes*. When operating on higher data rates, the delay decreases along with the *MSDU* packet size. This is the case for data rates of *54*, *48* and *36 Mbps*. For lower data rates, particularly at *6 Mbps*, the delay can be *10* times higher as compared to the a *CSMA/CA* scheme. At higher data rate, the delay difference decreases significantly. At *54 Mbps*, the delay is about double of that for the *CSMA/CA* scheme.

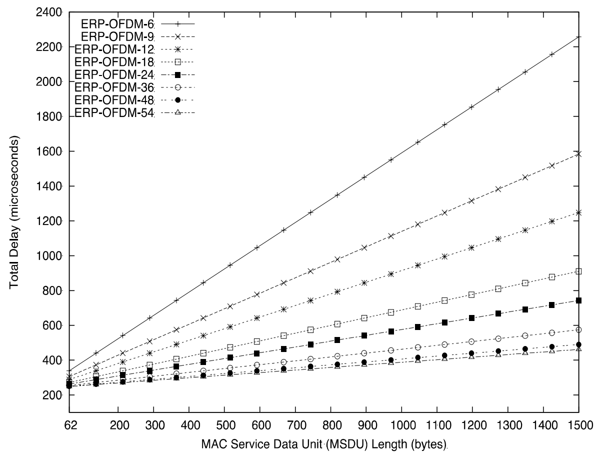


Figure 3: The theoretical total delay with RTS/CTS enabled.

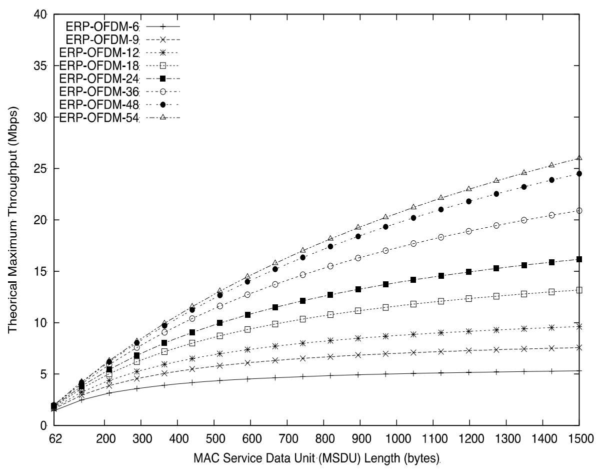


Figure 4:The theoretical throughput with RTS/CTS enabled.

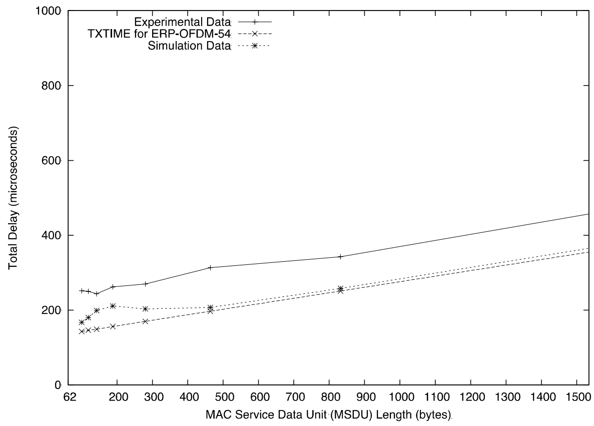


Figure 5: Experimental and simulation delay results.

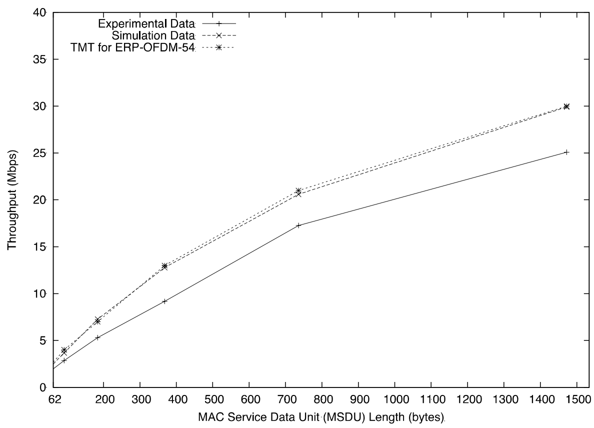


Figure 6: Experimental and simulation throughput results.

## 4.2 Experimental and Simulation Results

The numerical results presented in section 4.1 were validated with experimental and simulation results. Firstly, we described the experimental environment and then the configurations used in the simulations. At the end, a discussion on the obtained results is provided.

Figure 8 shows the topology used in the experimental environment. The experiments have been conduced on *Intel core 2* machines enabled with a *Realtek RTL 8187B*, IEEE 802.11*b/g* cards. During the experiment, the terminals have been set to operate in *g* only mode without auto-rate fall back. The terminals have been positioned in such way that the antenna gain would allow for a maximum throughput of *54 Mbps* to be obtained. The utility program test *TCP* (*ttcp*), which is a popular tool for traffic generation and throughput analysis, has been used to generate *UDP* traffic and to measure the network throughput 14]. The generated *UDP* packets have been set to match the *MSDU* size defined in the numerical results. In this experimental, terminal *A* is the transmitting node for terminal *B*, while terminal *C* is monitoring the channel in promiscuous mode to verify the channel conditions during the experiment. Figure 7 shows the status of the channel with the Wi-Spy spectrum analyzed [15]. In the experiment, we chose the channel with the lowest interference level in order to minimize data loss.

In the experiments, we have not been able to set for different data rates, as the driver does not allow for this option. Hence, all the experiments have been conduced with fixed data rate of *54 Mbps*. In the experiments, *RTS/CTS* option has been turned off. Because of the driver limitation, we also decided to validate our scheme in the Qualnet simulator, version 5 [10]. We configured the simulator scenario with the same characteristics used in the experimental environment. Table 3 shows the main configuration options of the Qualnet Simulator. The traffic generator model used in Qualnet was the CBR (Constant Bit Rate) [16] and the parameters were proportional to the MDSU packet sizes.

The *Figure 5* shows the experimental and simulation delay and the *Figure 6* shown the throughput results for different *MSDU* packet sizes. The experimental results show that the delay is quite close to the estimated (≈ *60 µs higher on average*). Such difference can be due to a number of factors, including the hardware (both at the *PC* and *NIC* as well as the interface that connects them) and software. Similarly, the experimental throughput is also closed to the estimated *TMT* for reasonable small *MSDU* packet sizes. The simulation results are much closer to the theoretical values. The reason is that the simulator does not have the impact of network cards and other software related aspects.

Table 3: The parameters used in the Qualnet Network Simulator.

| ***Parameters*** | **Values** |
|---|---|
| NUMBER-OF-NODES | 3 |
| MOBILITY | None |
| PROPAGATION-PATHLOSS | Two-Ray |
| RADIO-TYE | Radio-Accnoise |
| RADIO-FREQUENCY | 2.4e9 |
| RADIO-BANDWIDTH | 54000000 |
| MAC-PROTOCOL | 802.11 |
| NETWORK-PROTOCOL | IP |
| ROUTING-PROTOCOL | BELLMANFORD |

*Figures 5* and *6* show that, as the *MSDU* size grows, the difference between the estimated and the experimental throughput increases. For an *MSDU* comprising of *1500 bytes*, the difference between the two can be as high as

*20%*. One of the reasons for this gap is the higher delay found in the experiments. Again, the hardware and software involved are likely to impact on the performance, which results in a lower than predicted throughput. Nevertheless, the curves follow the same pattern for all *MSDU* sizes, showing that the experiments and the numerical results are consistent. That is, the presented results allows one to verify that both experimental and simulation results are in line with the numerical scheme proposed in this work.

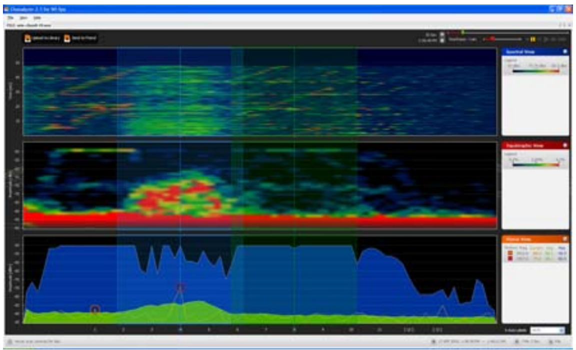

Figure 7: Output of the Software Wi-Spy Spectrum Analyzer [15].

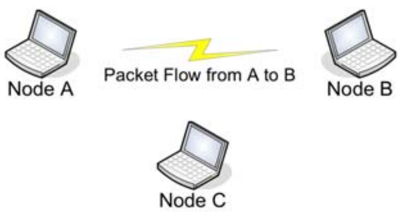


Figure 8: The Topology scenario of the Experimental Environment.

## 4. Conclusions

The IEEE802.11g standard sets the ground for mobile wireless communications with a wide range of data transmission strategies, both at the physical and link layer. However, the nominal transmission speed does not reflect in an intuitive expectation of the data flow capacity. This work presented a simple scheme to compute the maximum throughput for an IEEE802.11g network, which the most popular WLAN standard at the moment. The proposed scheme has been devised in such a way that it enabled us to incorporate all the timings and settings necessary to calculate the throughput for different channel spacing and modulation techniques specified in the standard. This work also presented experimental and simulation results, which have shown the accuracy of the proposed scheme.

**Acknowledgments**

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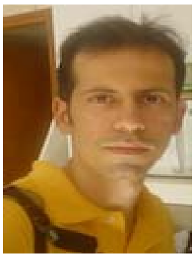

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