Comparative Analysis of Wireless Devices

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***Abstract*—In this paper, we attempt to compare the quality of communication wireless equipment manufactured by different vendors. A range of smart devices operating in the various standards are available on the market today. Special attention is paid to the *WiFi* standard as the most popular and affordable due to cheap hardware. The dependence of packet loss on the signal power level and load bus is described using linear approximation. The resulting model coefficients have been found in the experiment and compared. A description is given of the experiment, which was conducted for several types of equipment, and the main features of the equipment are identified.**

Keywords-quantitative comparison of the WiFi equipments; packet loss; connection quality of the wireless standard IEEE802.11b/g/n

I. Introduction

Modern mobility requires fast connection to the global Internet network at any point in the shortest time. The most popular and cheapest type of wireless connection is a wireless Ethernet of Wi-Fi standard (*IEEE 802.11g/n*) [6]. A Wi-Fi network can be easily deployed in any building, including historic buildings where cabling is not possible.

The question of choosing the best wireless device for each user arises during the connection [12], [20]. Existing methods of comparison are based on qualitative methods [4], [22], which rely on subjective human experience. The purpose of this work is the construction of a universal analytical model to allow us to compare quantitatively several parameters that describe objectively the quality of wireless connection.

For example, streaming has been hard to implement in wireless networks using the old standards (*Wi-Fi, GSM, 3G*) because of a large percentage of packet loss. The percentage of packet loss should not exceed 0.5% for the quality of the wireless connection to be good. Streaming is generally not possible if the percentage of packet loss is over 1.5% [15]. Therefore, in this paper special attention will be given to minimizing the percentage of packet loss.

This paper is organized as follows. First, in Section II, we note the basic parameters affecting the quality of network connectivity, and based on these, we construct a simple analytical model that allows a quantitative comparison of several parameters describing objectively the quality of the wireless connection. In order to verify the model, an experiment in the wireless network is proposed in Section III. The kernel of this experiment will be the investigated wireless equipment. Finally, Section IV discusses the ramifications of the experiments.

II. The model of comparative analysis

According to the IETF standard from RFC 2544 [1], the quality characteristics of a TCP/IP based network are described by the following parameters [5]:

- D - packet delay (measured in milliseconds, *ms*);
- p - packet loss (measured in percent, %);
- j - delay variation or network jitter (measured in milliseconds, *ms*);
- B - available bandwidth for end to end connections (measured in Megabits per second, *Mbps*).

For wireless networks the main parameter of network connection quality is packet loss. In [13], it was shown that video quality in wireless networks due to packet loss of 80% and only 20% of network jitter. The aim of this work is to identify the main parameters of wireless networks that have the greatest impact on the quality of network connection (packet loss).

Preliminary tests in wireless networks show that the following parameters have the greatest impact on the quality of wireless network connections:

- I is the signal power of the wireless network, measured in *dBm* where the zero reference point corresponds to one milliwatt;
- B is the average load of the wireless switch.

Each type of wireless network equipment can communicate within certain limits. The range of values for signal strength and network load will form an operations region (gray area in Fig. 1)

$$S \in \left[\overline{I_{min} : I_{max}}; \overline{0 : B_{max}}\right], \tag{1}$$

where

- I_{max} is the maximum signal power, which can be obtained by the client;
- I_{min} is the minimum power level at which the network connection will still be carried out;
- B_{max} is the maximum load of the wireless hub, that is, the total rate of all channels passing through a wireless device.

This area is an inherent characteristic of wireless equipment and should be displayed in its documentation. The limit values of the operation region are determined by packet loss rate p,

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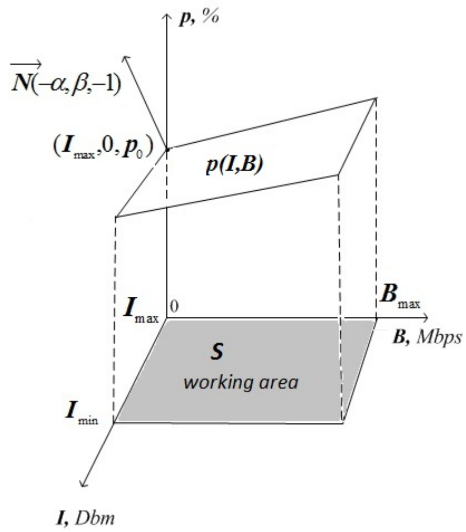

Fig. 1. The working plane $p(I, B)$ and operations region S

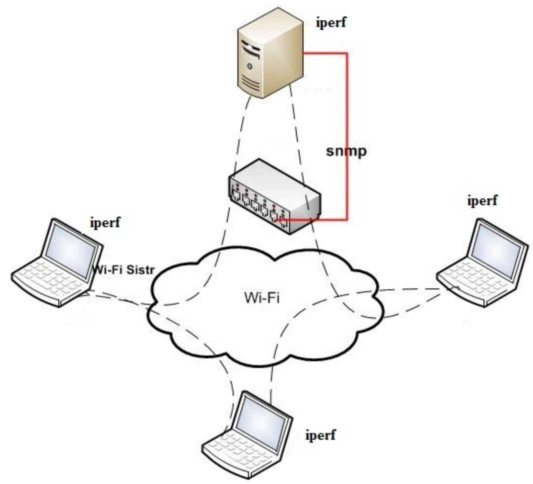

Fig. 2. Scheme of experiment with *iperf* utility

which should not exceed 15% [11]. For this level of error, it is easy to find the upper limits of the operation region, respectively, I_{min} and B_{max}. Averaged values of packet loss $p(I, B)$, depending on the channel loading B and power of wireless signal I, will form some kind of surface (I, B, p), which characterizes the quality of the network connection.

In the first approximation, dependence $p(I, B)$ can be described by a linear function. In other words, a surface (I, B, p) is a plane which can be described by a normal vector $\vec{N}$ and the initial point $(p_0, I_{max}, 0)$. This surface is shown in Fig. 1.

Thus, we obtain a set of parameters that will be evaluated as a wireless connection:

- I_{max} is the maximum signal power;
- I_{min} is the minimum signal power;
- B_{max} is the total loading of the wireless equipment;
- $\vec{N}\,(-\alpha, \beta, -1)$ is the normal vector to the working plane;
- $(I_{max}, 0, p_0)$ is the starting point.

The equation of the working plane can then be written as:

$$\vec{N}\left(\vec{R} - \vec{R_0}\right) = 0, \tag{2}$$

where

- $\vec{R}\,(I, B, p)$ is a vector that characterizes the wireless network state at the current time;
- $\vec{R_0}\,(I_{max}, 0, p_0)$ is a vector characterizing the wireless network state at maximal signal power.

Turning to the variables, we obtain a linear dependence for function $p(I, B)$:

$$p = p_0 + \alpha\,(I_{max} - I) + \beta B \tag{3}$$

where, coefficients α and β reflect the linear relationship between packet loss p *vs* signal strength I and packet loss p *vs* the bus load of switch B correspondingly.

The question arises, in which case a linear approximation can be used. During the experiment three values I_i, B_i, p_i are measured. Next, we try to formulate the conditions that should be applied to experimental data in order to be able to use a linear approximation of Eqn. (3). As main criterion, it is advisable to choose the following condition: the maximum change of value p on the working area *S* of Eqn. (1) should be two times higher than the experimental error. This condition in an analytical form can be written as follows:

$$\max \Delta p^{theor} > 2\Delta p^{exp}. \tag{4}$$

The values of the linear coefficients α and β of Eqn. (3) are found by the least squares method from the minimum to the experimental error:

$$\Delta p^{exp} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(p_i - \alpha I_i - \beta B_i)^2}, \tag{5}$$

where α and β should satisfy the condition

$$\sum_{i=1}^{N} p_i = \alpha \sum_{i=1}^{N} I_i + \beta \sum_{i=1}^{N} B_i, \tag{6}$$

and they should be run through a range of possible values with a step $\Delta\alpha$ and $\Delta\beta$, that is easy to implement for a grid with parallel programming. Then the condition of sufficiency of the linear approximation looks like:

$$|\alpha(I_{max} - I_{min})| + |\beta(B_{max} - B_{min})| \geq 2\sqrt{\frac{1}{N}\sum_{i=1}^{N}(p_i - \alpha I_i - \beta B_i)^2}, \tag{7}$$

N is the number of measurements.

III. Experiment tests

In order to verify the above model and to calculate the model coefficients α and β, it is necessary to organize an experiment with the wireless network, the core of which will be the investigated equipment. The loading of wireless

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switch B is removed using **snmp** protocol (simple network management protocol [3]) directly with the wireless devices. The scheme of the experiment is shown in Fig. 2.

Wireless switch is connected to the network via a twisted pair. During the experiment, we study only one wireless communication channel between the switch and the laptop. In the proposed scheme, only the switch is replaced under test, all tests were performed under equal conditions. In this experiment, we compare the packet loss at equal signal power and switch load.

In order to measure the signal power of the wireless networks, the following utilities were installed on the computer and tested: *NetStumbler*, *inSSIDer*, *Wi-Fi SiStr*, *Wi-Fi Hopper*. Next, we present a comparative analysis of these products:

- **NetStumbler** is a tool for Windows that facilitates detection of Wireless LANs using the *802.11b*, *802.11a* and *802.11g* WLAN standards. It runs on Microsoft Windows operating systems from Windows 2000 to Windows XP. The program is commonly used for: wardriving, verifying network configurations, finding locations with poor coverage in a WLAN, detecting causes of wireless interference, detecting unauthorized (rogue) access points, aiming directional antennas for long-haul WLAN links [18].
- **inSSIDer** like *NetStumbler* uses active scanning techniques, and all found the information on access points shown in the table [7].
- **Wi-Fi SiStr** works steadily and is compatible with other software. It is particularly suitable for our experiments [17].
- **Wi-Fi Hopper** can display details like SSID, network mode, encryption type, RSSI, frequency and channel, amongst numerous others, for a complete picture of the environment. It is easy to filter out classes of networks by using the network filters. Additionally, a GPS device can be used for reviewing the approximate locations of the detected access points [9].

From all the programs listed above, only *Wi-Fi SiStr* works stably in conjunction with the software (*Videolan* [21], *Wireshark* [16]). Other programs use active monitoring of the network and do not allow parallel operation of other applications, namely, to invalidate a connection to a wireless network.

Wireshark software was used for analysis of packet loss. This allows the user to view all the network traffic in a real-time regime. *Wireshark* distinguishes between the structures of different network protocols, and therefore allows us to parse the network packet, showing the value of each protocol field at any level. For our experiments, the use of a built-in *Wireshark* RTP flow analyzer was important to show the percentage of packet loss.

On a laptop connected to a wireless network, two programs were installed for network monitoring:

- **iperf** for information about the quality of the connection (j, p, B) [8],
- **Wi-Fi SiStr** for measuring the signal strength (I),
- **Wireshark** for measuring the percentage of packet loss,
- **Videolan** for organizing the RTP stream.

With the utility *iperf* installed on the server we are able to create the required network loading with different hosts. On the server side, the *iperf* utility was run with the following options:

iperf -s -u -i.

On the laptop side (client), it starts with the following options:

iperf -c node2 -u -b 2m,

where *node2* is IP address of the server, *m* is the required switch loading. The scheme was originally used by testing *iperf*, as shown in Fig. 2. In order to change the signal levels, the distance between the laptop and switch is changed. In the experiment, we investigated wireless switches produced by *3COM (Model 7760)* and *D-Link (DAP-1150)*.

Because we were limited in time, only two equipment types of two different manufacturers, *D-Link* and *3 COM*, have been tested. In the near future different wireless equipment manufactured *Cisco* and *Juniper* is planned for testing.

A further feature of the utility *iperf* became clear during the experiment. During measurement, it seeks to minimize the packet loss by reducing the connection speed. Therefore, the characteristics of the equipment are the dependence of the data transfer rate of signal power and given value B. The experimental setup was upgraded to detect packet loss (see Fig. 3).

The measurements were performed with RTP/UDP streams [19].For our purposes, it is sufficient to measure only the percentage of lost packets in the stream. Since inside the RTP/UDP stream packets are numbered, then packet loss is easy to fix at constant speed of transmission. It should be noted that this study does not address the quality of the percept video [10], [2], as well as different types of encryption.

Video was selected and encoded for transmission on the network at different speeds (500, 1000, 2000, 5000, 10 000 *Kbps*). Streaming was implemented using the *Videolan* server (vlc) and the receiving stream data was recorded using the network analyzer *Wireshark*. The RTP streams analyzer integrated into this software package shows automatically the percentage of packet loss, which varies depending on the signal I.

IV. The results of measurements

For RTP streams we obtained three values p, I, B, where I is measured by *Wi-Fi SiStr*, B is wondered how the flow rate of during video. The data were processed in accordance with the algorithms given in Section II, and the data are summarized in Table I.

Parameters α and β were calculated as a result of testing with different loads of equipment and signal levels. They characterize the quality of wireless equipment and satisfy Eqns. (5) and (6).

For a wireless switch produced by *3COM (model 7760)*, measuring the level of the signal network shows that the maximum power I_{max} does not exceed -25 *dBm*. When the

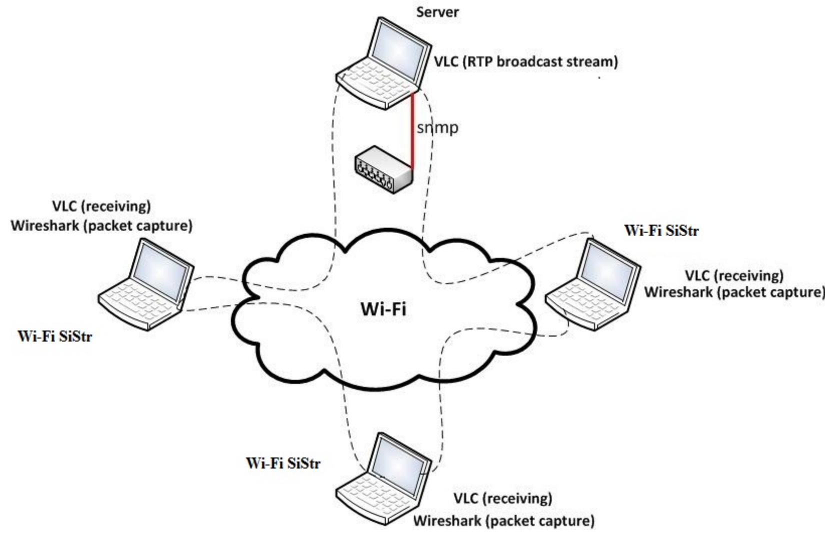

Fig. 3. Scheme of experiment with RTP/UDP stream

TABLE I
BASIC PARAMETERS OF ANALYTIC MODEL

Switch	I_{max}, dBm	I_{min}, dBm	B_{max}, Mbps	α, dBm^{-1}	β, Kbps^{-1}
3COM	-30	-80	25	$(1.0 \pm 0.3) \times 10^{-3}$	$(1.0 \pm 0.6) \times 10^{-6}$
D-Link	-15	-70	25	$(2.2 \pm 1.2) \times 10^{-3}$	$(2.0 \pm 1.6) \times 10^{-6}$

signal level I_{min} = -80 *dBm*, connection terminates. Maximum load B_{max} does not exceed 25 *Mbps*. The quality of communication depends largely on the power of the received signal and not on the speed of RTP streams.

The *D-Link* wireless switch *(model DAP-1150)* shows greater signal power I_{max} = -15 than the *3COM*. Other values do not differ greatly from the *3COM* switch. Measurements for the wireless routers produced by *D-Link* and *3COM* are given in Table I.

Values of α and β coefficients represent the slope angle of the line in the planes (p, I) and (p, B). Comparison of α and β coefficients on the working area indicates that the signal power defines the communication quality by 80 percent. In general, the equipment *3COM* showed that its performance in more than two times better than the competitor *D-Link*.

It should be noted that the network configuration of *IEEE 802.11n* is optimized to reduce the percentage of packet loss. When reducing the power of the received signal, the baud rate automatically drops to a value at which packets are no longer lost. The real network load is reduced by 3-4 times compared with that given by the utility *iperf* option *m*. Thus, the communication quality at comparable settings when using the *D-Link* router is almost an order of magnitude lower.

The TCP/IP connection is considered to be good if packet loss does not exceed 0.5% [2], [14]. The obtained result is at least an order lower than the good level.

In operating the model, experience of networks of standard *IEEE 802.11g* was used for the network connections, which are characterized by a significant percentage of packet loss. The *IEEE 802.11n* standard, however, is characterized by a small percentage of errors, so the model presented here does not describe the quality of the network connection well and needs modification.

The experimental setup is shown in Fig. 3, during the experiment to evaluate the bandwidth used by the utility *iperf*. The essence of the experiment is that for a given bandwidth is a real load is considerably less, depending on the capacity of the wireless signal. Experiments have shown that much better equipment can be described by the following relationship:

- B_{real} is a real value bandwidth using the utility *iperf*;
- B_{iperf} is a value indicating the key m in the utility *iperf*;
- I *Wi-Fi Sistr* is received signal strength.

The experimental results are presented in graphical form depending on the achieved bandwidth of the signal power are shown in Fig. 4. For example, when using *iperf* with bandwidth B_{iperf}=20 *Mbps* and signal level I = -70 *Dbm*, the real speed of data transmission in a wireless network will be

- for **3COM** B_{real}^{3COM} = 6,8 *Mbps*

and

- for **D-Link** B_{real}^{D-Link} = 800 *Kbps* (see Fig. 4).

From this we can conclude that the quality of communication at comparable parameters when using a *D-Link* router is of a lower order.

V. CONCLUSION

In this paper, a simple analytical model is constructed to compare the quality of wireless networks. Several parameters are selected for quantitative comparison of the investigated

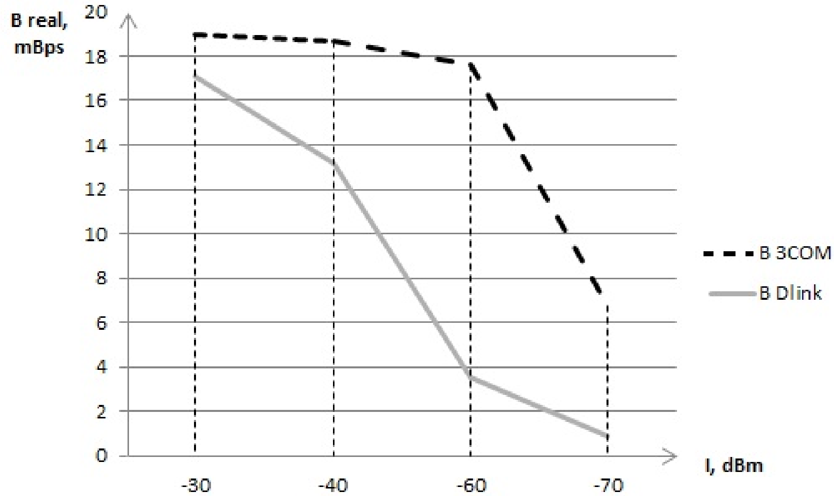

Fig. 4. Real iperf bandwidth

equipment. These options allow us to objectively describe the quality of the wireless standard *IEEE802.11b/g/n*. The experiments have confirmed the suitability of the model for assessing the quality of wireless equipment. Also, the study revealed the superiority of the *3COM* wireless device over the *D-Link* equipment. However, our model needs to be clarified, as *IEEE 802.11n* networks are characterized by a low percentage of losses that can be achieved by reducing the data rate.

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