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An Experimental Performance Evaluation of the Wireless Network for Mobile Users

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Introduction

Wireless networks with standard 802.11.g. are most widespread today. We use such networks in our houses, universities, at workplaces and so on. But the problem is that we can't use such network when we are moving from one point to another, for example when we are driving by car, or traveling by train. The reason is that wireless networks with protocol 802.11.g. have not wide covering zone. It is about 150-200 from the router or access point that provides wireless connection.

But there is one way to increase the coverage of wireless network. You can read about the simple way how to make it in our previous publication [1].The answer on this problem you can find in this article too. In this work you can find how the mobile wireless network with protocol 802.11.g. was developed and installed.

Of course people can use networks that are already created such as GSM or UMTS. But these mobile networks couldn't provide necessary throughput. Wireless networks based on 802.11.g. protocol can provide throughput that is better in ten times or even more.

In the network that is presented in this work were used three wireless routers. These routers were connected between themselves using wireless distribution system technology. The range of signal in this wireless network was about half of kilometer.

Basic descriptions of the wireless networks and simple principles and methods of network development and installation are presented in this work. After network creation an experimental performance evaluation with mobile users was made. The network throughput was taken to estimate the quality of the connection between routers and mobile station. The IxChariot program (version 5.4) was used to find the wireless network throughput. The main tasks of the experiment were:

- wireless network construction with three access points using WDS technology
- wireless network throughput detection on different speed
- comparative graph development depending from the distance

Wireless Distribution System Technology

Access points can expand the wireless network range using WDS (Wireless Distribution System). In IEEE 802.11 terminology a "Distribution System" is system that interconnects so-called Basic Service Sets (BSS). A BSS is best compared to a "cell", driven by a single Access Point. So a "Distribution System" connects cells in order to build a premise wide network which allows users of mobile equipment to roam and stay connected to the available network resources. A distribution system can Wired (typically Ethernet), or Wireless.

Access points can set wireless connection not only with wireless network clients, but also between themselves. The main advantage of such networks is that access points don't use wires for connection. The mobile station that is connected to the network built on WDS technology can change access points without loosing connection.

LAN devices (including wireless LAN devices) communicate which each other by using MAC addresses (which are hardware addresses uniquely assigned in the factory to each device). Each Wireless PC Card therefore has a unique MAC address that is used by the system to send data frames to it. If a LAN device transmits data, it will add its own MAC address to the frame as well in order to indicate to the recipient where the frame came from. In short all data frames transmitted over a LAN will contain a Destination and a Source MAC address as part of the frame header. If a data frame is transmitted over an Ethernet cable just those two MAC addresses are required. When data frames are to be transmitted between LAN end-stations, that are not connected to the same LAN segment, an intermediate device is required to "bridge" the frame from one segment to another. An access point is such a device also known as a bridge, which has the capability to relay traffic from one segment to another. It performs this task with the use of a "bridge learn table", where MAC

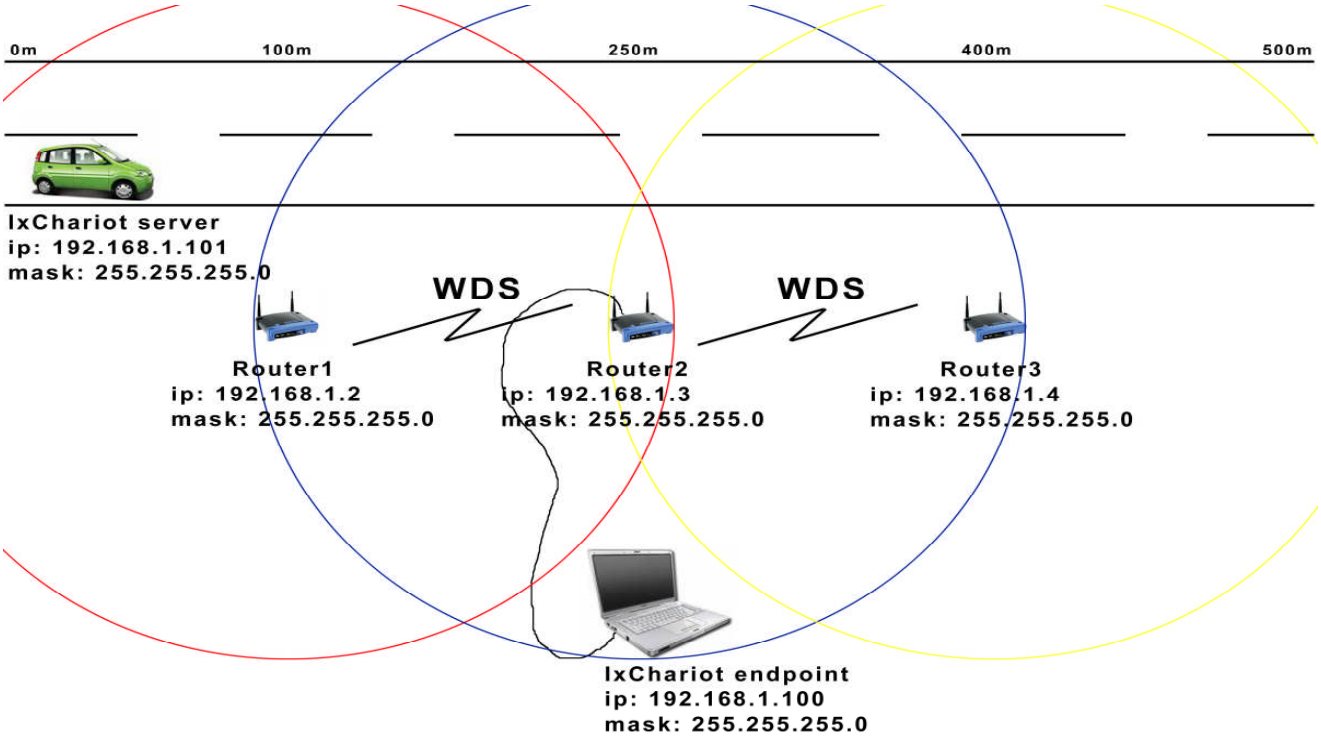

Fig. 1. Configuration of the experimental wireless network with three routers

addresses are stored in association with the LAN segment (or physical interface) where they reside (from the perspective of the bridge).

Traffic between wireless LAN devices that conform to the IEEE 802.11 standard requires 4 MAC addresses instead of 2. When a wireless device is associated to an access point it will always direct its traffic to the access point by using the MAC address of the PC card in the access point as its direct destination address. The MAC address of the end station to which the frame was to be sent to is also included in the frame header, so that the PC card in the access point can determine where to relay the frame to. Finally the sending station's own MAC address is in the frame as the source address. So a total of three addresses is used. When a WDS link is set up between two access points, all four available address fields in the MAC header are used:

- the MAC address of the sender,
- the MAC address of the final destination,
- the MAC address of the sending PC card in the access point,
- MAC address of the receiving PC card in the other access point.

There are two modes of wireless connections between access points where Wireless Distribution System can be used:

- wireless bridge mode – access points can work only with other access points, but not with clients wireless adapters,
- wireless repeater mode - access points can with other access points and with clients wireless adapters.

Description ot the Experiment

For the experiment were taken three Linksys routers (model WRT54GL v1.1). On routers was installed Tomato Firmware v1.19.1463. This firmware can be downloaded on this site http://www.polarcloud.com/tomato/. This firmware has WDS support. All three routers where connected with WDS technology. The distance between them was 150 meters. Middle router had direct cable connection with the notebook where "netiq" endpoint was installed. This endpoint is necessary for connection creation. The experiment was made on the opened territory with good weather conditions. Fig. 1 shows the configuration of the experimental network. Three BACK-UPS CS 500 from APC company where used for providing the power supply to routers. Notebook with IxChariot server was set in the car [2].

The experiment was divided on two stages:

- measuring of wireless network throughput with three routers depending from distance to the mobile wireless client in the stationary mode
- measuring of wireless network throughput depending from speed of the mobile wireless client in dynamic mode

Stationary mode

Measurements in stationary mode were made with IxCariot program in different points of our route (0m – start point, 100m – near the first router, 175m – between first and second routers, 250m – near the second router, 400m – near the third router). How we can understand

witch router provide wireless connection to the mobile station while the experiment? That was the main problem in this stage. For answer on this question NetStumbler program version 0.4.0 was used. This program can show all wireless routers ranges and active router (router that is used at this moment). Better throughput was on the second router, because the endpoint was connected with it (using cable).

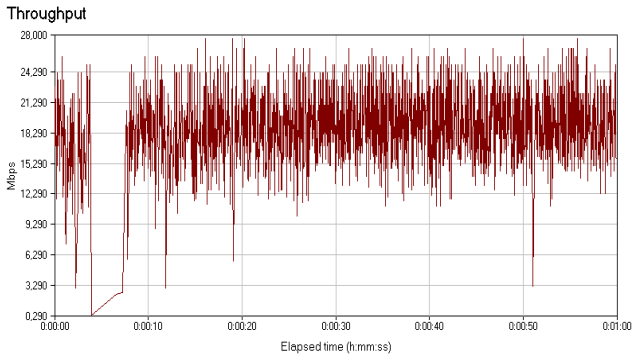

Fig. 2. Network throughput in stationary mode near the second router (the result of IxChariot program)

Fig. 2 shows the result of measure with chariot program near the second router (250 meters from the start) and mobile station is connected to the second router. Here you can see that average throughput is 21.2 Mb/sec.

Dynamic mode

The difference of measuring in dynamic mode is that we made throughput test while the mobile was moving. The experiments were started at 0 meters and were ended at 500 meters. Experiments were made on different speeds: 20 km/h, 40 km/h, 50 km/h, 60 km/h, 70 km/h and 90 km/h.

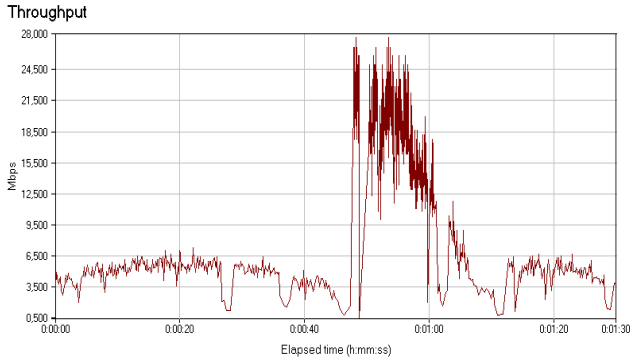

Fig. 3. Network throughput in dynamic mode on speed 20 km/h (the result of IxChariot program)

Fig. 3 shows the result of measure with chariot program near while moving on speed 20 km/h. Average throughput in this experiment was 5.971 Mb/sec. Here you can see that throughput is not so constant as in the stationary experiment. While mobile client is connected to the firs router throughput is about 5 Mb/sec. When mobile client reconnects to the second router throughput became higher (about 21 Mb/sec). When mobile client reconnects to the third router throughput became the same as on the first router. Of course, better throughput was on the second router, because the endpoint was connected with it using cable. Everyone can see that throughput in this experiment was not 0 Mb/sec. There is reason to say that WDS technology provide useful throughput for wireless mobile network.

Analysis of results

Experiments results were analyzed afterwards. Fig. 4 shows dependence of network throughput from speed of mobile station.

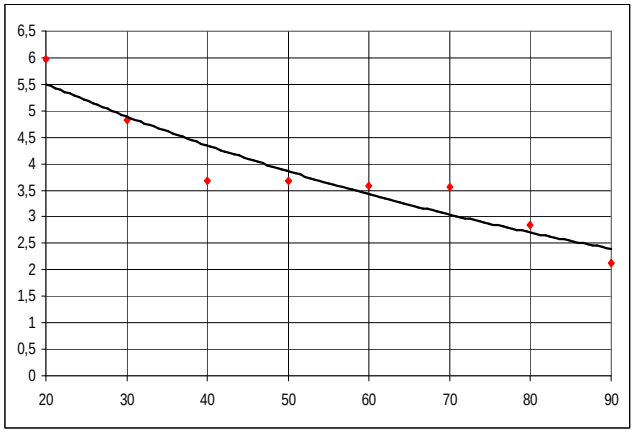

Fig. 4. Network throughput dependence from speed of mobile station and exponential trend line

Fig. 4 shows that throughput of mobile station decrease when speed becomes higher. Average throughput on 20 km/h was 5.971 Mb/sec, but on 90 km/h was 2.133 Mb/sec.

Next step was combining dependences on different speeds together. The problem is that IxChariot program can't use speed and routes. IxChariot X axes show only time of experiment. If the speed of the experiment and the distance are known, there is no problem to find the time of the route. For example speed is 20 km/h= 5.56 m/sec, the distance is 500 meters, so time of the experiment is

$$t = \frac{P}{V} = \frac{500}{5.56} \approx 90\,\text{sec}\,, \qquad (1)$$

Only time from 0 till 90 seconds was taken from IxChariot graph on 20 km/h. The same procedure was made with other graphs. On x axes we have the same distance, that is equal 500 meters, an on y axes there is throughput on different speeds.

All graphs were combined together using program Photoshop CS3. Fig. 5 shows throughput dependence from different speeds. Red point shows static results in different points of the route. This graph shows that this wireless network for mobile users can provide necessary throughput for mobile stations on speed till 50 km/h. When the speed is higher, mobile station drop the signal on the second router and reconnects only on third router.

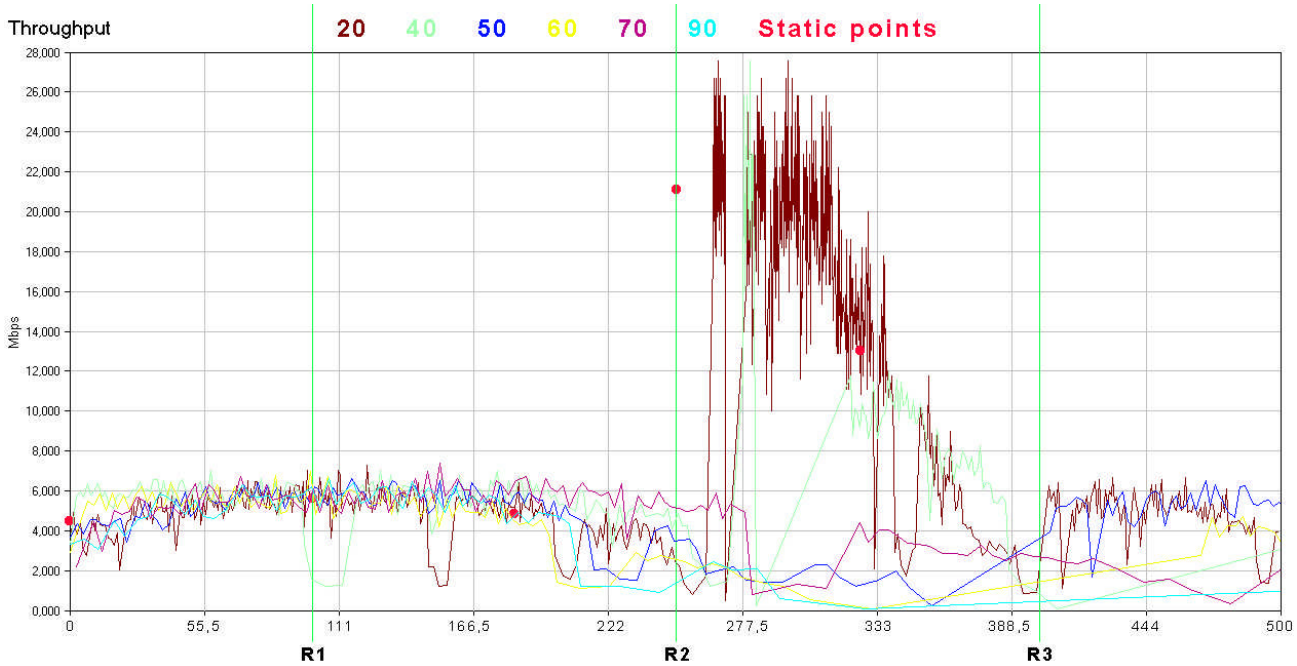

Fig. 5. Throughput dependence from different speeds in wireless network for mobile users

Conclusions

In this work was made an attempt to find dependence of wireless network throughput from speed of mobile workstation that is connected to it. Wireless network with 802.11.g. standard was successfully developed from three routers using wireless distribution system technology. Were made experiments using "IxChariot v5.4" program to find real throughput in mobile wireless network on different speeds. New method of wireless network throughput evaluation was developed. This method can be used in future experiments. This method can be used for future real wireless network with mobile stations throughput evaluation as well. This work shows that wireless networks with 802.11.g. protocol can be really used on the roads.

References

1. **Ipatovs A., Petersons E.** The wireless network installation for mobile users // ECT. – 2008. – P. 13–16.
2. **Haverkort B. R.** Performance of Computer Communication Systems. A Model-Based Approach. – John Wiley & Sons Ltd. – 1999. – P. 495.

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The main idea is the detection of throughput in network with protocol 802.11.g. and WDS technology on different speeds of mobile user. Wireless network for mobile users was developed and described. Experimental performance measurements of the network were made. New method of evaluation of such wireless network was described. Ill. 5, bibl. 2 (In English; summaries in English, Russian and Lithuanian).

А. Ипатов, Э. Петерсон. Экспериментальная оценка производительности беспроводной сети для подвижных пользователей // Электроника и электротехника. – Каунас: Технология, 2009. – № 5(93). – С. 21–24.

Главная идея – определение пропускной способности сети с протоколом 802.11.g. и WDS технологией при разных скоростях приема данных подвижным пользователем. В этой работе была разработана и описана беспроводная сеть для подвижных пользователей. Были проведены эксперименты по измерению пропускной способности данной сети. Описан новый метод оценки эффективности таких сетей. Ил. 5, библ. 2 (на английском языке; рефераты на английском, русском и литовском яз.).

A. Ipatovs, E. Petersons. Eksperimentinis mobiliesiems vartotojams skirtų bevielių tinklų efektyvumo įvertinimas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2009. – Nr. 5(93). – P. 21–24.

Pagrindinė idėja – matuoti tinklo, veikiančio 202.11.g protokolo ir WDS technologijos pagrindu, duomenų pralaidumą, esant skirtingai mobiliųjų vartotojų duomenų priėmimo spartai. Sukurtas ir aprašytas mobiliesiems vartotojams skirtas bevielis tinklas. Atlikti eksperimentiniai tinklo našumo matavimai. Aprašytas naujas tokio bevielio tinklo efektyvumo įvertinimo metodas. Il. 5, bibl. 2 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).