Simulation of simple hop scenario

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***Abstract*—In this paper, we present a measurement study of the simple multi-hop behavior of the new IEEE 802.11g standard. Furthermore, we show using ns-3 simulation to measure unidirectional throughput for user datagram protocol (UDP) and transmission control protocol (TCP) connection. Both end systems are over Ethernet (IEE 802.3 - 100 Mbps) connected to a wireless router. the connection between the wireless access point (wireless router) must be sent through a total of three radio links. Parameter for this simulation are variance distance between wireless routers, using radio protocol IEEE 802.11g, using routing protocol optimized link state protocol (OLSR), and TCP/UDP transport protocol**

Keywords—Multi-hop, 802.11g, OLSR, TCP/UDP, ns3

I. INTRODUCTION

IEEE 802.11 technology is the most widely implemented Wireless LAN (WLAN) standard to date, and the development of mesh-network technology (an integral part of the WLAN network) shows that this technology standard is very necessary and people are very dependent on this technology, which is generally used on fixed-broadband network technology. Theoretically with a speed of 54 Mbps (802.11g) is a good thing, of course, this is a theory (at layer 1) which we will prove later using mathematical analysis in the next chapter, and has a gap due to aggregation and timing to communicate on the layer above (OSI layer).

However, over the past year, the arriving of the new standard of 802.11 technology has become an industry, manufacturer, media and consumer discussion and debate. Many examples and cases where the best technology is not the latest one for indoor or outdoor environment installation [1]. Wireless LAN network (WLAN) with IEEE 802.11g-2003 or 802.11g standard is one most-widely deployed as its high speed and proven techniques. This technology operates in the 2.4GHz ISM (Industrial, Scientific, and Medical) radio spectrum with signal bandwidth 20MHz that extended maximum raw data throughput to up 54 Mbit/s, although this translates to a real maximum throughput of just over 24 Mbit/s [2].

IEEE 802.11g gives the specifications about 802.11g's MAC layer and Physical Layer (PHY) [3]. In the MAC Layer (Layer 2 of TCP/IP Layer) uses carrier sense multiple access with collision avoidance (CSMA/CA) as a technique, supporting data rates from 1 to 54Mbps. IEEE 802.11g network occupies a bandwidth of about 20MHz and the available channels are defined with 5 MHz separation between consecutive carriers. Theoretically, there are only three non-overlapping channels (channels 1, 6, 11) in 2.4GHz frequency.

Multihop is a condition that is common today, where the sender and recipient are not in an adjacent location and must go through several tracks or devices so that it has several disadvantages, such as bandwidth degradation, radio interference, and network latency. For example, with each hop in the network, throughput can be declined by as much as 50% per hop, with degradation quickly compounding over multiple hops, resulting in severe performance degradation across the network [4].

Throughput is the most important parameter in network performance. Throughput is defined as the amount of data that can be processed in a given amount of time. Many factors can affect throughput, and we will investigate some of them in this task. Generally speaking, throughput performance evaluation of wireless networks is essential for troubleshooting, improvement or even testing before their deployment. Distance has a major impact on throughput performance in wireless networks.

This task, I will present the measurement of the multi-hop of the 802.11g standard using network simulator (ns3). The goal of this task is to do simulations based on 3(three) hop of a wireless access point and analyze and present the results of throughput to give an understanding of what can realistically be expected from a Wireless multi-hop Network. We analyze the throughput behavior and its dependence on path length,

The rest of this document is structured as follows: In Section II, we give the basic theory of 802.11g and all supporting theory due to a multi-hop scenario. Afterward, the methodology of this simulation is examined further in Section III. Section IV describes the result and analysis using ns3 simulation (www.nsnam.org). Finally, in Section V, we summarize our conclusion and provide ideas for possible future research.

Figure 1: Prinzipieller Simulationsaufbau

Figure (1) : Multi-hop task.

II. BACKGROUND & RELATED WORK

A. IEEE 802.11

IEEE802.11 is a series of medium and physical layer access control specifications for implementing wireless local area network computer communications at frequencies 2.4, 3.6, 5 and 60 GHz. They were created and operated by the Institute of Electrical and Electronics Engineers. The basic version was released in 1997 and has gone through a series of updates and provides the basis for Wi-Fi wireless network products. Wi-Fi computer communication in various frequencies including but not limited to 2.4, 5, and 60 Ghy frequency bands. They are the world's most widely used wireless computer networking standards, used in most home and office networks to talk to each other and access the internet without connecting wires (wireless). The base versions of the standard were released in 1997 and have had subsequent amendments. 802.11b was the first widely accepted one, followed by 802.11a, 802.11g, 802.11n, 802.11ac.

B. 802.11g

802.11g operates in the 2.4 GHz frequency band and has compatibility with previous technologies, namely 802.11a and 802.11b. In theory, the 802.11g technology standard has a transfer speed of 54 Mbps (at layer 1) and has a decrease of around 50% in the real scenario. In this standard, a speed decrease according to the signal quality. The same problem between IEEE 802.11g and 80211b and other 2.4 GHz frequencies is a matter of frequency. IEEE 802.11g may seem to be the competence of 802.11a, but it delivers the bandwidth advantages of 802.11a without the range and reliability limitations of 5 GHz technology [1].

C. Transmission control protocol (TCP)

Transmission control protocol (TCP) is a network model used for data communication in the process of exchanging information on the internet. TCP is at the network layer (fourth layer), and TCP will run through the internet network protocol (IP). Major internet applications such as email, file transfer rely on TCP. Otherwise, connectionless provided by User Datagram Protocol.

D. User Datagram Protocol (TCP)

User datagram protocol (UDP) is often confused with the unreliable Transport Protocol because UDP does not provide any IP services except process-to-process and host-to-host communications and little error checking. UDP is a very simple protocol with minimum overhead if a process needs to send a message that is relatively small and does not attach much importance to reliability, it is appropriate to use UDP. Small message sending using UDP requires less interaction between sender and recipient than when using TCP. UDP just sends the packets, which means it has much lower bandwidth. With UDP packets may take different paths between the sender and receiver and as a result, some packet may be lost or received out of order.

E. Mathematical Analysis

Wide coverage of wireless signals is one consideration of WLAN network deployment. The following formula is normally used to obtain coverage when doing network planning [5].

$$Pr = Pt - Lct + Gt + Gt - Lcr >> Rx\ min \qquad (1)$$

In formula (1), Pr and Pt are the Power of receiver (Pr) and the power of transmitter, Lct and Lcr are the feeder loss respectively transmitting and receiving medium, Gr and Gt are the gains of the receiver antenna and the transmitting antenna. Effective Isotropic Radiated Power (EIRP) or Equivalent Isotropic Radiated Power is the value of the power emitted by directional antennas to produce peak power observed in the direction of maximum radiation antenna gain, including gains that the antenna provides and losses from the antenna cable are often used to describe the power limitations for wireless LANs. In Europe (Germany), the FCC defines the transmitting power limitations for wireless LANs for ISM Bands. The FCC declares the EIRP to be 20 dBm or 0,1 watt (100 milliwatts)[5]. Here, in our simulation using ns3, we set parameter Pt, Gt, Gr 1 dBm or 1.26 milliwatts. Then we choose the following model referred to as the path loss model:

$$LFS\ (dBm) = 20*\log(d)+20*\log(f)+32.4 \qquad (2)$$

$$Pr = Rx = Pt - LFS \qquad (3)$$

These equations can be worked out where d is the distance with the units coming out in kilometer, and f is the frequency with the units of megahertz [6]. From figure (1), the two end hosts are connected to the routers with 100 Mbit/s, so we can guarantee the throughput is not limited by transmission’s data rate. In an 802.11g channel, there is a capacity of 24 Mbit/2 available[7], which is the max capacity for a unidirectional transmission, can be utilized in transmitting data. Transmitting data is done in one way, and that means the max throughput is 24 Mbit/s. From equations (1), (2), (3) LFS (Free space loss) depends on transmitting power, antenna gains, frequency and distance (variances that we will measure).

From the task, Pt, Gt, and Gr set 1 dBm or 1,26 milliwatts. Since 802.11g uses an operating frequency of 2.4 GHz, throughput can be calculated. From the authors [2] IEEE 802.11g states that the maximum distance is 125 ft or 38 meters. Therefore in this simulation, we use distance variables as a simulation analysis material. The distance we are set is 3m, 6m, 12m, 25m, and 50m (tolerance of a little of 38m).

IEEE802.11g Througput Calculation			
Distance (m)	LFS (dBm)	RxLev (dBm)	Data Rate (Mbit/s)
3	49.546	-48.546	54
6	55.567	-54.567	54
12	61.588	-60.588	54
25	67.963	-66.963	54
38	71.6	-70.6	54
50	73.983	-72.983	54

Table (1) 802.11g Distance – Throughput Calculation

This table means that throughput will be 24 Mbit/s utilizing the entire capacity of the channel. However, in the next section, we provide other approaches that significantly differ in results.

III. METHODOLOGY

This task is to analyze the measurement of throughput on the variable distance of the radio link. In this task the parameters are, is the connection with a wireless router using Ethernet on the sender and receiver, the protocol used is 802.11g, using the UDP and TCP transport protocols, using the OLSR routing protocol, and the Wifi-MAC Layer used is Ad-Hoc with the TxGain parameter, RxGain is 1.0 dBm, and the payload size is 1000 Bytes..

A. Software Used

In this task, the author will use the NS3 network simulator. NS3 network simulators will be used to identify throughput performance in accordance with the tasks assigned. NS3 is used to measure UDP and TCP transport protocol performance with different distance variances. In this simulation, the operating system used is Ubuntu 18.04 and 4.18 as the kernel.

B. Network simulator 3

The NS-3 is based on the development of NS-2. It is mainly applied to education and scientific research. Its function is very powerful which can study various networks and protocols. In wireless network scenarios, NS-3 perform better than others. The focus of ns-3 is on the simulation of IP- based networks and good transferability of the simulation models into real implementations. Basics architecture shown by a figure (3).

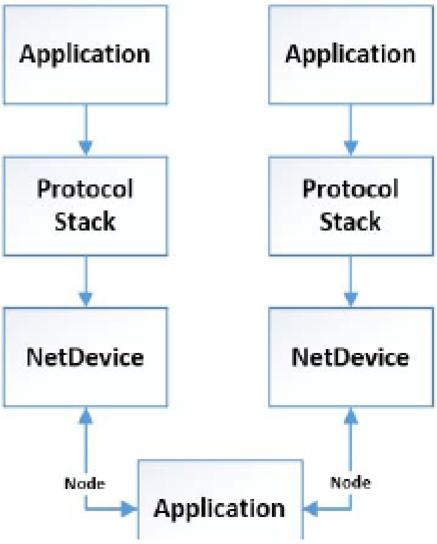

Figure (2) The basics architecture of NS-3

Basic assumptions for this simulation that channel has losses only from free space, hence the loss is a free space loss which depends on distance (meters), frequency (hertz), and antenna gains (dBi). Delay in the channel is assumed to be constant so that, the chosen model is the constant speed propagation delay model. The models of loss and delay in the channel are taken from the propagation module. It is also assumed that nodes are linearly placed with equal distance between each node and the other. For this modeled, the mobility model is used. This task use payload 1000 byte to be application payload. Routing protocol existence is vital for this simulation to work correctly. A routing protocol is needed for this topology and from the task used OLSR (Optimized link state routing protocol)

C. *OLSR (Optimized link state routing) Protocol*

OLSR is a proactive routing protocol proposed for Mobile Ad hoc Network (MANET), OLSR is an optimization of the link state protocol. The key concept in OLSR is MPRs (Multipoint Relays), where each node can maintain a route to all destinations on the network using periodic exchange message protocols such as HELLO and Topology Control (TC). Each node in the network periodically broadcasts HELLO messages to one-hop neighbors. By sending a HELLO message, a node identifies itself and reports a list of its neighbors. Each node chooses from one neighbor's hop a set of Multipoint Relays (MPR). Thus, only nodes are selected as MPRs that can broadcast TC traffic in the network. The use of MPRs reduces the number of messages that will flood the network during the routing update process. In the OLSR routing protocol, there is no mechanism to ensure the integrity of the control package received. So that at in some cases a malicious node can inject invalid topological information and cause the routing table information that is formed to not match the existing network topology

For OLSR to be used in the simulation, the OLSR module which is provided by ns.3 can be used. The Parameter used for the devices is shown in Table 2. One important parameter is the remote station manager used which is in our case Minstrel.

Simulation Parameter	
Parameter	Setting
Radio protocol	IEEE 802.11g
Channel-Width	20 MHz
WiFi Mac-Layer	Ad-hoc
TxGain	1 dBm
RxGain	1 dBm
TxPowerStart	1 dBm
TxPowerEnd	1 dBm
Rate Manager	Minstrel rate Manager

Table (2) Simulation Parameters

D. *Minstrel rate manager*

The need for a rate manager comes from the erratic behaviors that wireless channel does which influence the throughput eventually. A bad wireless channel can limit the available capacity for reliable connections. However, this can be solved by reducing the data rate. Minstrel is a commonly used rate manager that adapts to the channel, so it gives a better and more reliable connection through the channel while maintaining the highest possible operating data rate. The idea behind Minstrel is that is retries transmission at certain rates for specific periods of time, so that if the transmission failed at one rate for a certain amount of time it moves to the lesser rate and tries the transmission again, and so on. The determinant of the rate values in Minstrel is the probability of success for each bit rate and also the throughput [8].

E. *Procedure*

NS3 for this simulation is 3.29. Starting off with importing the necessary modules :

```
#include "ns3/core-module.h"
#include "ns3/mobility-module.h"
#include "ns3/wifi-module.h"
#include "ns3/internet-module.h"
#include "ns3/applications-module.h"
#include "ns3/olsr-module.h"
#include "ns3/network-module.h"
#include "ns3/flow-monitor-module.h"
#include "ns3/animation-interface.h" //usefor NetAnim
```

Core module which illustrates the use of core module functionality contains time management or a simulator. The Mobility module has a constant position mode, list position, and mobility model. The Wifi module has the physical and MAC models ready to be adjusted and used. Internet module used to create the Internet stack for each node and also to define the IP addresses for them. Application modules provide many application models to be used as the user data generator. In application, it is possible to adjust many parameters as will come next. OLSR module enables users to use the OLSR protocol as it provides a model for it. Same as applications, OLSR parameters can be modified using that module. The Network module has a network node class. The Flow monitor module provides a method to translate raw packet data and objects monitor. Animation interface used to interface to network animator.

The simulation time makes variance also from 60 seconds (1 minute) up to 300 seconds (5 minutes) to make sure OLSR is running. These times were checked to ensure the simulation runs properly. Throughput calculation is done with the flow monitor using a flow monitor module. It is calculated by measuring the amount of data that the destination received successfully in during the time of sending those data. We show the results of the simulation which was done three times for each measurement.

IV. RESULT OF SIMULATION

In tables 3 and 4, it shows throughput measurements in the TCP and UDP transport protocols. In table 3, the measurement of throughput is done by using different distance variables ranging from 3m - 50m using a simulation time of 60 seconds. While in table 4 throughput measurements use different simulation time variables using the same distance, only to see the difference.

Distance (m)	Throughput; t=60m	
	TCP	UDP
3	8.36	17.23
6	8.31	17.1
12	6.33	12.35
25	4.71	8.26
50	3.26	4.35

Table (3) Throughput - Distance

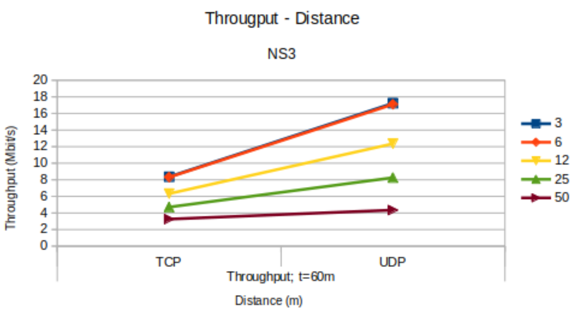

Figure (3) Throughput – Distance

Simulation Time (s)	Throughput; d=12m	
	TCP	UDP
300	6.33	12.35
240	6.32	12.44
180	6.32	12.42
120	6.31	12.38
60	6.31	12.28

Table (4) Throughput – Simulation Time

From the graph in figure 3, and table 3, the distance factor greatly influences throughput, this is possible because the distance factor causes the loss of propagation to be greater or smaller. In addition, we can conclude that the UDP transport protocol is better than TCP in measuring throughput with variables. same distance. The measurement with the simulation is because the UDP protocol does not have a full duplex or handshake features like the TCP protocol which causes a decrease in the speed of work data.

From table 4 (we don't need to show it in graphical form), the simulation time factor does not show a significant effect on throughput, because the simulation results only ensure that the OLSR routing protocol is sure to run.

V. RESULT OF SIMULATION

This simulation was made to see comparisons with mathematical analysis (II.E), and the results showed better things. Where in the mathematical analysis calculations are carried out at layer 1 (physical layer), where the results are ideal, and cannot be used as conclusions and simulation needs to be made to see the layer above (layer two and third). The mathematical analysis does not model various elements in a simulation because it only models free space loss, where there are many obstacles and loss factors in the real condition. Besides that, in the mathematical analysis, it also cannot take into account the different transport protocols, as we will do in the simulation later.

This simulation experiment was made using ns3 [10], modeling experimental elements with code lines. Based on the simulation, the distance factor is a key factor to get higher throughput. This can be seen in the simulation results. In addition, the simulation time factor has no significant effect on the results of throughput. In addition, this simulation shows that the TCP transport protocol does not work well rather than UDP. This simulation is considered not accurate enough, although it is better than modeling using mathematical analysis. Therefore to get better results, it is necessary to do a field test to get a better conclusion because the results in the field test are the actual and reliable results.

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