Effect of electromagnetic wave interference against computer network quality of service

I N B Hartawan¹*, P P Santika², I B A I Iswara² and I G M N Desnanjaya¹

¹ Computer System Department, STMIK STIKOM Indonesia, Denpasar, Bali, Indonesia
² Informatics Department, STMIK STIKOM Indonesia, Denpasar, Bali, Indonesia

* buda.hartawan@stiki-indonesia.ac.id

Abstract. The need for power grids and computer networks is a critical thing to note. Placement of cables in the building will affect the quality of services provided, especially on computer networks. The computer network transmits digital data that is very susceptible to interference of electromagnetic waves. The electrical cable is one of the media that can produce electromagnetic waves. In this study measurement of electromagnetic waves on electrical wiring, for the quality of computer network services. The type of power cable tested is the power cable used in the NYYHY and NYM cables, while for the computer network cables tested are UTP and STP computer network cables with categories 5e (Cat 5e). The Quality of Service parameters tested in the study this is Throughput, Jitter, Delay, and Packet Loss. Tool used to measure electromagnetic wave radiation is the Electromagnetic Radiation Detector DT-1130. The results of this study indicate that the electromagnetic interference generated by the power cable affects the quality of service computer network. Decreasing network performance on UTP is greater than STP.

1. Introduction

The use of computer networks is widely used today. Companies and individuals use computer networks in their daily lives. Many people use computer networks for many things, namely browsing, chatting, social media, e-commerce, file transfer, sharing devices, etc. Computer networks sometimes have interference that causes access to be slow. If there are problems with computer network performance, usually the lack of bandwidth is called the cause. The decline in computer network performance is not only caused by bandwidth, but also by interference from the device or problems in the installation.

The need for good quality network services is very important in the use of computer networks. The factor that most influences the quality of network services is the transmission media used. In computer networks there are 2 (two) transmission media, namely wireless transmission media and cable transmission media. Wireless transmission media is more susceptible to interference than cable transmission media. Research related to the quality of network services on wireless transmission media is widely carried out [1-5]. This shows that interference with the network with wireless transmission media is very high. However, cable transmission media can also experience interference [6,7].

Companies generally build computer network infrastructure to support their activities using both wireless and wired transmission media. However, in the installation of cable transmission network with the media, there are still companies that combine the power cord and network cable channels, even tied
together. Can be seen in Figure 1. The power cable is the media that generates electromagnetic waves [8]. Electromagnetic waves can affect network performance when transmitting data [8].

Figure 1. Electrical and network cable installation in buildings.

The purpose of this study was to measure the effect of electromagnetic waves produced by electrical wires, on the quality of network services on cable transmission media. The power cable used in this study is NYYHY and NYM type electrical cables, because this type of cable is commonly used in electrical installations in buildings. Whereas the network cable used in this study is a network cable type Unshielded Twisted Pair (UTP) and Shielded Twisted Pair (STP) category 5e (Cat 5e). The research was carried out by conducting experiments in the laboratory by tying the power cable and network cable into one during the process of sending packet data.

The research was carried out by conducting experiments in the laboratory by tying the power cable and network cable into one during the process of sending packet data. The network topology used in this study is point-to-point with the concept of client server. The server is enabled as a File Transfer Protocol (FTP) service provider with FTP Server installed. While the client computer is installed FTP client, which functions to download files on FTP Server. The size of the file that the client will download from the server is 100MB. The process during the download of the file takes place recorded by Wireshark to obtain the value of Throughput, Jitter, Delay, and Packet Loss generated during the packet data transmission process. Throughput, Jitter, Delay, and Packet Loss values are Quality of Service parameters that affect network performance [9].

2. Literature review

Research conducted by Robert et al namely UTP Cabling and the Effects of Electromagnetic Interference (EMI) [7]. In his research, UTP cable endurance testing of electromagnetic wave interference derived from various sources. To demonstrate the sensitivity of UTP cabling to the common sources of EMI, several channels were set-up to run a shared IEEE 802.3u 100BASE-TX Ethernet operating system and exposed to various sources of noise. Signal packets and network traffic were monitored for errors using a commercially available local area network (LAN) software program analyzer. Sensitivity is determined by evaluating the number of packet errors detected under peak operating network utilization.

Similar studies were also carried out by Sarma et al [6]. In his research, Sarma tested the Unshielded Twisted Pair (UTP) network cable. The UTP cable used is Cat 5e and Cat 6. This type of cable is commonly used in installing network infrastructure. From the test results showed that UTP cable is susceptible to electromagnetic radiation produced by AC power.

In this study measurement of electromagnetic waves on electrical wiring, for the quality of computer network services. The type of power cable tested is the power cable used in the NYYHY and NYM cables, while for the computer network cables tested are Unshielded Twisted Pair (UTP) and Shielded Twisted Pair (STP) computer network cables with categories 5e (Cat 5e). The Quality of Service parameters tested in the study this is Throughput, Jitter, Delay, and Packet Loss. Tool used to measure electromagnetic wave radiation is the Electromagnetic Radiation Detector DT-1130.

3. Research method

This research was carried out in the laboratory by conducting experiments in accordance with the conditions of the network cable installation in the building. Network cable installation in a building is
still done by tying the network cable to the installation of the power cable that has been installed previously. This is done to facilitate the installation of a network cable so that there is no need to install a new channel, just tie it to an existing power cable. In experiments conducted in the laboratory, the network cable was tied to an electrical cable that had previously been given a computer load. The testing environment used in this study can be seen in Table 1.

### Table 1. Testing environment.

| No | Descriptions                              | Specifications            |
|----|-------------------------------------------|---------------------------|
| 1  | NYYHY                                     | 2 meters                  |
| 2  | NYM                                       | 2 meters                  |
| 3  | UTP                                       | 2 meters                  |
| 4  | STP                                       | 2 meters                  |
| 5  | Electromagnetic Radiation Detector        | DT – 1130                 |
| 6  | File Server                               | FileZilla Client-Server   |
| 7  | File Size                                 | 100 MB                    |
| 8  | Capture Packets                           | WireShark                 |
| 9  | Topology Model                            | Point-to-point            |
| 10 | Media transmission                        | Wired                     |
| 11 | Network Interface Card                    | Fast Ethernet (100 Mbps)  |
| 12 | Distance between Cable                    | 0 cm                      |

In the table above can be seen testing environment used during the study. The electrical cables used are NYYHY and NYM types, where these cables are generally used in installing electrical wiring in buildings. Whereas the network cable used is the Unshielded Twisted Pair (UTP) type and Shielded Twisted Pair (STP) category 5e (Cat 5e). This type of network cable is also commonly used in network cable installations on local area networks (LANs) in buildings. The length of each cable used is 2 meters. The power cable and network cable are tied together during the testing process.

![Electromagnetic radiation detector DT-1130](image)

**Figure 2.** Electromagnetic radiation detector DT-1130.

The electromagnetic radiation measuring instrument used is the Electromagnetic Radiation Detector DT-1130 and has a CE logo. CE is an abbreviation of Conformité Européenne (French) which means "European Conformity" or the product has fulfilled the security qualifications in Europe. Picture of DT-1130 Electromagnetic Radiation Detector measuring instrument can be seen in the Figure 2.

The network topology used in this study is a point-to-point topology, using the Fast Ethernet network interface card (NIC). The bandwidth used is the default value of fast Ethernet, which is 100Mbps. The network model used is client-server. The server used is FTP Server that is installed using Filezilla Server, while the client uses Filezilla client. During the process of downloading data by the client from the server, data capture is done using the Wireshark application. Wireshark application is an application to
analyze network performance that is often used in research [10-12]. The topology used to this study can be seen in Figure 3.

![Figure 3. Network topology.](image)

The client downloads 100MB of files from the server using Filezilla Client. During the file download process, data capture is done using the Wireshark application. This is done to measure the Quality of Service produced during the download of the file by testing the parameters Throughput, Jitter, Delay, and Packet Loss. The testing scenarios used in this study are as follows:

- Connect the client and server using a UTP cable, then the client downloads the file from the server for 100MB. During the file download process, data traffic is recorded using Wireshark. This condition is repeated 5 times in a row.
- The NYYHY type electric cable was given a charge to turn on a computer. Furthermore, measured the level of radiation produced by NYYHY electric cable using DT-1130 Electromagnetic Radiation Detector. The UTP cable is fastened to the power cable and ensures that the entire surface of the UTP cable attaches well to the surface of the NYYHY electrical cable. Then the client downloads the file from the server for 100MB. During the file download process, data traffic is recorded using Wireshark. This condition is repeated 5 times in a row.
- NYM-type power cables are charged to turn on a computer. Furthermore, measured the level of radiation produced by NYM power cable using DT-1130 Electromagnetic Radiation Detector. The UTP cable is fastened to the power cable and ensures that the entire surface of the UTP cable attaches well to the surface of the NYM power cable. Then the client downloads the file from the server for 100MB. During the file download process, data traffic is recorded using Wireshark. This condition is repeated 5 times in a row.
- This condition is repeated 5 times in a row. Connect the client and server using an STP cable, then the client downloads the file from the server for 100MB. During the file download process, data traffic is recorded using Wireshark. This condition is repeated 5 times in a row.
- The NYYHY type electric cable was given a charge to turn on a computer. Furthermore, measured the level of radiation produced by NYYHY electric cable using DT-1130 Electromagnetic Radiation Detector. The STP cable is fastened to the power cable and ensures that the entire surface of the STP cable is firmly attached to the surface of the NYYHY power cable. Then the client downloads the file from the server for 100MB. During the file download process, data traffic is recorded using Wireshark. This condition is repeated 5 times in a row.
- NYM-type power cables are charged to turn on a computer. Furthermore, measured the level of radiation produced by NYM power cable using DT-1130 Electromagnetic Radiation Detector. The STP cable is fastened to the power cable and ensures that the entire surface of the STP cable attaches well to the surface of the NYM power cable. Then the client downloads the file from the server for 100MB. During the file download process, data traffic is recorded using Wireshark. This condition is repeated 5 times in a row.
Figure 4 shows the measurement model used in this study. All trial scenarios used were repeated five times each. This aims to obtain a more accurate average value. Radiation measurements were carried out using DT-1130 Electromagnetic Radiation Detector in each trial scenario to determine the difference in radiation produced in each trial.

During the process of sending data, capture data is done using the Wireshark application. The Figure 5 shows the results of packet capture data that occurs during packet data transmission. The packet data capture results are carried out, then processed to obtain the Quality of Service parameter values namely Throughput, Jitter, Delay, and Packet Loss.

The following are formulas for Throughput, Jitter, Delay, and Packet Loss.

3.1. Throughput
The throughput value is the total number of packet data received per second. The unit used is bit-per-second (bps). The greater the throughput value, the better. The throughput value is calculated using a formula [13][14]:

$$Throughput = \frac{\sum{received\_packet\_size}}{(Stop\_time-Start\_time)}$$  \hspace{1cm} (1)

3.2. Jitter
Jitter is the variation of the delay. Jitter is affected by variations in traffic load and the amount of collisions between packets (congestion) on the network. Jitter influence on network performance should be considered in conjunction delay. When large jitter delay is small but the performance of the
network cannot be said to be bad because of the amount of jitter can be compensated with a small delay value. Jitter will degrade the performance of the network when the value is great and also the value of delay is too large [9].

\[ Jitter = \frac{\sum \text{variation delay}}{\sum \text{packet received}} \]  
(2)

3.3. Delay
Delay or Latency is the time delay caused by transmission from one point to another which is the destination [15].

\[ Delay = \frac{\text{packet length (bit)}}{\text{Link bandwidth (bit/s)}} \]  
(3)

3.4. Packet loss
Packet loss is the failure of sending data packets from the source to the destination caused by various things [9].

\[ \text{Packet loss} = \frac{\text{packet sent} - \text{packet received}}{\text{packet sent}} \times 100\% \]  
(4)

4. Results and discussion
Test results conducted on Quality of Service on networks with cable transmission media, in this section are presented in tables and graphs.

Table 2. Quality of service on UTP cable.

| Parameter       | UTP-None | UTP-NYYHY | UTP-NYM  |
|-----------------|----------|-----------|----------|
| Throughput (Mbps)| 98,892   | 95,829    | 95,6702  |
| Packet Loss (%) | 0,4962   | 3,4506    | 3,4876   |
| Delay (s)       | 8,8468   | 8,8676    | 8,8786   |
| Jitter (µs)     | 0,0012   | 0,0012    | 0,0014   |

The Table 2 shows the results of measurements of network cables with Unshielded Twisted Pair (UTP) types of NYYHY and NYM type electrical cables.

Table 3. Quality of service on STP cables.

| Parameter       | STP-None | STP-NYYHY | STP-NYM  |
|-----------------|----------|-----------|----------|
| Throughput (Mbps)| 99,1518  | 98,9214   | 98,1920  |
| Packet Loss (%) | 0,2402   | 0,4792    | 1,1482   |
| Delay (s)       | 8,8470   | 8,8476    | 8,8468   |
| Jitter (µs)     | 0,0001   | 0,0013    | 0,0023   |

The table above shows the results of measurements for network cables with Shielded Twisted Pair (STP) type on NYYHY and NYM type electrical cables. To facilitate reading, measurement results are presented in graphical form as follows.
The Figure 6 is the result of measurement of throughput parameters on UTP and STP network cables. In the picture it can be seen that the throughput value has decreased. When the measurement is done on UTP cable only (UTP-None), the results of the study show that the resulting throughput is 98.889 Mbps. When measuring the UTP cable tied to the charged NYYHY power cable (UTP-NYYHY), it was found that there was a decrease in throughput value of 95.829 Mbps. Subsequent measurements of the UTP cable tied to NYM (UTP-NYM) type power cables also decreased but were not significant at 95.6702 Mbps.

Subsequent measurements of the UTP cable tied to NYM (UTP-NYM) type power cables also decreased but were not significant at 95.6702 Mbps. The measurement results of the STP type network cable only (STP-None) results in a throughput of 99.1518 Mbps approaching the bandwidth value of 100Mbps. In the measurement of STP type cable network that is tied with NYYHY type electrical cable, the measurement of throughput value is 98.9214 Mbps. While the measurement of STP type network cable that is tied with NYM type electrical cable shows the results of throughput value of 98.192 Mbps.

The measurement of the value though the input on the UTP and STP type network cables has experienced a decrease when fastened to the charged NYYHY and NYM power cables. This shows that electromagnetic radiation which is piloted by charged electrical wires gives an effect on the throughput value of Quality of Service. But the decrease in throughput value that occurs in STP type network cables is smaller than the UTP type network cable. This is due to the additional isolation of the STP network cable that can reduce interference produced by other devices, so that it can be said that STP cable is more susceptible to interference than UTP cable.

The Figure 7 shows the results of measurements of Quality of Service on the network with cable transmission in the jitter parameter. Jitter is a delay variation that occurs during packet data transmission. The higher the jitter value, the worse the Quality of Service on the network. Measurement of jitter parameters on UTP type network cable only (UTP-None) shows a value of 0.0012 µs. When the UTP
type network cable tied to the NYYHY (UTP-NYYHY) type power cable shows a fixed jitter value of 0.0012 µs. Measurement of jitter parameters on UTP type network cables that are tied to NYM (UTP-NYM) type power cables shows that the increase in jitter value reaches 0.0014 µs.

Measurement of STP type network cable only (STP-None) shows 0.0001 µs jitter value. When the STP type network cable is tied with NYYHY power cable (STP-NYYHY) and measurements of jitter parameters are obtained, there is an increase in the jitter value of 0.0013 µs. Measurement of jitter parameters when the STP type network cable is tied to NYM type power cable (STP-NYM) shows that there is an increase in the jitter value to 0.0023 µs.

The measurement results of jitter parameters in this study indicate that, electromagnetic radiation produced by electrical wires has an effect on the quality of service on the network. But the resulting effect on the jitter parameter is not significant both on the UTP type network cable, and the STP type.

![Delay Parameter Value](image)

**Figure 8.** Delay parameter value.

The picture above shows the results of measurements of Quality of Service on delay parameters. Measuring only the UTP cable (UTP-None) shows the total delay value of 8.8468 s. When the UTP type network cable was tied with NYYHY (UTP-NYYHY) type power cable, there was an increase in the delay value to 8.8676 s. The same thing also happens when the UTP type network cable is fastened to the NYM (UTP-NYM) type power cable. Increased value of the resulting delay becomes 8.8786 s.

Measurement of the delay parameter on the STP cable only (STP-None) produces a value of 8.847 s. Whereas when the STP type network cable tied with NYYHY (STP-NYYHY) type electrical cable shows a delay value of 8.8476 s. The value of delay when the STP type network cable is fastened to NYM type power cable (STP-NYM) is 8.8468 s.

The results of the measurement of the delay parameters indicate that there is an increase in the delay value in the UTP type network cable, but the STP type network cable has a fluctuating delay value. Even so, the increase in the delay value that occurs in each UTP and STP type network cable is not significant. This shows that electromagnetic radiation produced by electrical cables has an effect on Quality of Service on the network on delay parameters.
Figure 9. Packet loss parameter value.

The picture above shows the results of measurements of packet loss parameters on UTP and STP type network cables. Measurement of packet loss parameters on UTP type network cable only (UTP-None) is 0.4962%. Whereas when the UTP cable is tied with NYYHY (UTP-NYYHY) type power cable, there is an increase in packet loss value of 3.4506%. The same thing is also shown when the UTP type network cable is tied to NYM (UTP-NYM) type power cable with a packet loss value of 3.4876%.

Measurement of packet loss parameters generated on STP type network cable only (STP-None) is 0.2402%. When the STP type network cable is tied with NYYHY (STP-NYYHY) type power cable, the packet loss value increases to 0.4792%. The increase in delay value also occurred when the STP type network cable was tied with NYM type power cable (STP-NYM) to 1.1482%.

The measurement results of packet loss parameters indicate that electromagnetic radiation produced by NYYHY and NYM power cables has an effect on network quality of service on packet loss parameters. Value of packet loss on UTP cable is higher than STP cable. This is due to additional insulation on the STP cable that functions properly when interference occurs.

5. Conclusion
From the research that has been done it can be concluded that:

- Electromagnetic radiation has an interference effect on the Quality of Service network with cable transmission media both Unshielded Twisted Pair (UTP) and Shielded Twisted Pair (STP) Cat 5e.

- Electromagnetic Interference (EMI) waves causes impairment of Throughput, Jitter, Delay, and Packet Loss which varies in amount on each cable.

- The decrease in network performance on Unshielded Twisted Pair (UTP) cable transmission media is greater than that of Shielded Twisted Pair (STP) network cables, this is influenced by the presence of additional insulation that wraps the STP cable so that it is more resistant to interference than UTP cable.

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References
[1] M A Matin and M M Islam 2012 Overview of Wireless Sensor Network Wireless Sensor Networks - Technology and Protocols (InTech)
[2] S Mangold 2002 IEEE 802 11e Wireless LAN for Quality of Service Proceedings of the European
Wireless

[3] Q Ni, L Romdhani and T Turletti 2004 A survey of QoS enhancements for IEEE 802.11 wireless LAN *Wirel. Commun. Mob. Comput.*.

[4] H Zhai, X Chen and Y Fang 2005 How well can the IEEE 802.11 wireless LAN support quality of service? *IEEE Trans. Wirel. Commun.*.

[5] H Zhai, Y Kwon and Y Fang 2004 Performance analysis of IEEE 802.11 MAC protocols in wireless LANs *Wirel. Commun. Mob. Comput.*.

[6] M Sarma and S K Sarma 2013 Effect of AC Power Line on UTP Cable: A Review 2013 4th International Conference on Intelligent Systems, Modelling and Simulation pp 549–552

[7] Robert Y, Faber Jr., RCDD and Valerie A R 1997 UTP Cabling and the Effects of EMI - Siemon The Siemon Company, Watertown, Connecticut [Online] Retrieved from: http://www.siemon.com/us/white_papers/97-10-02-presentation.asp Accessed on: 15-Sep-2018

[8] A Fröbel 2009 Cable Shielding to Minimize Electromagnetic Interference *Int. Conf. Environ. Electr. Eng.* pp 1–3

[9] W Sugeng, J E Istiyanto, K Mustofa and A Ashari 2015 The Impact of QoS Changes towards Network Performance,” *Int. J. Comput. Networks Commun. Secur.* 3 2 pp 48–53

[10] S Wang, D Xu and S Yan 2010 Analysis and application of Wireshark in TCP/IP protocol teaching 2010 International Conference on E-Health Networking, Digital Ecosystems and Technologies, EDT 2010

[11] P T Files 2010 Wireshark Network Analysis The Official Wireshark Network Analyst Study Guide Analysis

[12] A Orebaugh, G Ramirez, J Burke, L Pesce, J Wright and G Morris 2006 *Wireshark & Ethereal Network Protocol Analyzer Toolkit*

[13] I Nyoman, B Hartawan and W Wibisono 2013 Mekanisme Pemilihan MPR dengan Congestion Detection Dalam Olsr Pada Manet 6 2

[14] I B A I Iswara and W Wibisono 2013 Pemilihan Node Tetangga Yang Handal Dengan Memperhitungkan Signal Strength Dan Link Quality Pada Zone Routing Protocol Di Lingkungan Manet J. Ilmu Komput. 6 2

[15] G M 2010 *Impact of Packet Loss on BC/DR Deployments* p 10