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# ENERGY CONSUMPTION OPTIMIZATION BY INCREASING THE PROCESSOR SPEED OF MOBILE COMMUNICATION DEVICES IN TRANSPORT LAYER PROTOCOL

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***Abstract*** – The energy efficiency of mobile devices becomes very important, considering the development of mobile device technology starting to lead to smaller dimensions and with the higher processor speed of these mobile devices. Various studies have been conducted to grow energy-aware in hardware, middleware and application software. The step of optimizing energy consumption can be done at various layers of mobile communication network architecture. This study focuses on examining the energy consumption of mobile devices in the transport layer protocol, where the processor speed of the mobile devices used in this experiment is higher than the processor speed used in similar studies. The mobile device processor in this study has a speed of 1.5 GHz with 1 GHz RAM capacity. While in similar studies that have been carried out, mobile device processors have a speed of 369 MHz with a RAM capacity of less than 0.5 GHz. This study conducted an experiment in transmitting mobile data using TCP and UDP protocols. Because the video requires intensive delivery, so the video is the traffic that is being reviewed. Energy consumption is measured based on the amount of energy per transmission and the amount of energy per package. To complete the analysis, it can be seen the strengths and weaknesses of each protocol in the transport layer protocol, in this case the TCP and UDP protocols, also evaluated the network performance parameters such as delay and packet loss. The results showed that the UDP protocol consumes less energy and transmission delay compared to the TCP protocol. However, only about 22% of data packages can be transmitted. Therefore, the UDP protocol is only effective if the bit rate of data transmitted is close to the network speed. Conversely, despite consuming more energy and delay, the TCP protocol is able to transmit nearly 96% of data packets. On the other hand, when compared to mobile devices that have lower processor speeds, the mobile devices in this study consume more energy to transmit video data. However, transmission delay and packet loss can be suppressed. Thus, mobile devices that have higher processor speeds are able to optimize the energy consumed to improve transmission quality.

***Key words: energy consumption, processor, delay, packet loss, transport layer protocol.***

## I. INTRODUCTION

Mobile communication devices in this case hand phones have been commonly used by the public. According to data from the Global System for Mobile Communications Association (GSMA), an association of world mobile operators, the number of mobile communication device users worldwide reaches almost 2.53 billion users in 2018. The number will continue to increase from year to year. For 2020, it is predicted to increase to 2.87 billion users, equivalent to almost 40% of the world's population in that year[1].

Along with the increasing surge in mobile communication device users, more and more demand for processor components. Processor or often called the CPU (Central Processor Unit) is always a mandatory even very important part in every mobile communication device, because it is the center or the brain of all the performance that is operated on the mobile communication device. Many mobile communication device manufacturers highlight the processor on the products they have released, so that the product output is in great demand by gadget lovers, especially mobile communication devices.

On the other hand, from the survey results in many developed countries, energy consumption in the information and communication industry ranges from 1 to 2 percent of national energy consumption[2]. This amount will be increase rapidly in line with the increasing surge in mobile communication device users. With the high energy consumption, the contribution of the information and communication industry is also high in increasing the amount of $CO_2$ in the air. In many countries, including Indonesia, energy costs have been a large contributor to the magnitude of the operating expenditure (OPEX) of a telecommunications company. Energy costs can range anywhere from 20 to 40 percent of a company's OPEX. This is the reason why many telecommunications companies in the world have declared themselves to be green companies through various methods such as the use of renewable energy sources and energy savings and efficiency.

Various studies have been conducted to grow energy-aware in hardware, middleware and application software[3]. Energy efficiency efficiency steps can be carried out at various layers of mobile communication network architecture[4], such as:

- Physical layer, which includes radio frequency (RF) circuits, modulation techniques, multiplexing and channel coding.
- Data link layer, in terms of error control, framing, and security.
- Network layer, including routing, addressing, and mobility management techniques.
- Transport layer, including reliable connection oriented services and end to end connections.
- Application layer, consisting of applications and services both related to the user, as well as interfacing and representing data.

At the transport layer protocol, energy efficiency efforts focus on the division of TCP and UDP protocols, both through splitting[5] and multipath[6]. The transport layer has two main functions, namely managing the data flow between two hosts and the reliability function[7]. There are two protocols at the transport layer protocol namely Transport Control Protocol (TCP) and User Datagram Protocol (UDP).

- TCP (Transport Control Protocol)
  This protocol performs connection-oriented functions, that is, before exchanging data, two TCP user applications must make a connection (handshake). Next, TCP performs the reliability function by implementing the packet error detection process and sending it back. The last function performed is a byte stream service, i.e. the data packets sent will arrive at their destination in sequence.
- UDP (User Datagram Protocol)
  This protocol performs unreliable and connection less functions. UDP protocol cannot guarantee that the datagram sent will arrive at its destination. The protocol only sends packets to the recipient without any confirmation if a problem occurs. The sender and recipient of IP packets do not enter into an agreement (handshake) in advance. In the UDP protocol there is no acknowledgment so the number of traffic is lower. This protocol also does not have a mechanism to replace lost packets or packets that experience errors.

Meanwhile, just like the processor on a computer, the processor in a mobile communication device is a chip-shaped component whose job is to control all the components in the device. It could also say the processor is the central controller of a device. Another factor that affects the performance of mobile communication devices is memory capacity. The specifications of processor and memory capacity of a mobile communication device will be influence the performance of the device.

Mobile communication device processors are designed to stay cool and use small electric power to save battery. The small electricity usage requires the communication device processor to use a low clock speed, but still able to run tasks such as browsing the internet, watching videos, sending messages, and editing photos properly because those tasks do not really require very fast processor capabilities. Currently, by the development of technology, there are processors in mobile communication devices that have 2 cores (dual core) and some also have 4 cores (quad core) to 8 core (octa core) with clock speeds ranging from 1 GHz to 2.3 GHz. In addition, mobile communication devices are equipped with 512 MB to 2 GB of memory and limited storage capacity of around 8 GB to 64 GB.

A mobile communication device that has a CPU speed of 369 MHz and RAM capacity of less than 0.5 GB, consumes an average energy of 0.0173 Joules per packet for UDP, and 0.285 Joules per packet for TCP in transmitting data packets in the form of video streaming[8]. Then, how about the energy consumption of mobile communication devices that have greater processor speed and RAM capacity?

For this reason, this study will analyze the effect of the speed of the mobile communication device processor on energy consumption with video streaming traffic on the transport layer protocol. Energy consumption is measured based on the amount of energy per transmission and the amount of energy per package. To complete the analysis, it can be seen the strengths and weaknesses of each protocol in the transport layer protocol, in this case the TCP and UDP protocols, also evaluated the network performance parameters such as delay and packet loss.

The amount of energy per transmission is the amount of energy consumption per transmission in Joules per transmission, where in UDP the number of packets per transmission is 1 packet, while TCP uses a sliding window, that is, the transmission is made if the number of packets meets the sliding window size quota. The amount of energy per packet is the amount of energy needed to send each packet in Joules per package. Delay is the accumulation of queue processing and queue processing on the router. Delay will produce intermittent speech sounds and broken video images. The packet loss is a packet of data that was lost during transmission. When data goes through the network, passing through the buffer and queue on the router there may be one or more of the buffer is full and reject data. So that data will be discarded and become a packet loss (packet loss)[9].

This research is expected to be useful as an initial identification in planning the energy-aware transport layer protocol in order to minimize the use of batteries in mobile communication devices, so that longer durability is obtained. Furthermore, the results of this study are expected to provide information on whether mobile communication devices that have high-speed processors will increase the optimization of energy consumption in the transport layer protocol.

## II. METHODOLOGY

Generally, the steps in this research are implementing the transport layer protocol on mobile communication devices and measuring its energy consumption. Measuring the battery consumption of mobile communication devices requires a controller that measures the current and voltage that enters the mobile device, calculates the energy absorbed and converts it to an energy unit, Joule. While the transmission process is realized by programming socket on a mobile device using Java mobile edition software.

Materials and equipment used in this study are:

a. Handphone Sony Xperia E4g,which has the following specification:
   OS Ver : Android KitKat
   CPU : Quad-core
   Kecepatan CPU : 1,5 GHz
   RAM : 1 GB
b. BatteryLi-polymer 3,7 V
c. Resistor 0,22 ohm
d. Arduino UNO Board
e. Connection cable
f. Soldering and tin
g. Downloader cable
h. Laptop
i. Java Programming J2ME 2.0.1
j. Arduino software
k. Video foreman_cif.yuv
l. Wireless Ad-hoc Connectify network
m. Netbeans IDE 8.0.
*n.* Wireless Tool kit 2.5.2
*o.* Java Development Kit JDK 8u20 windows i586

The specifications of the transmitted video are as shown in Table I where the file used is video foreman, in the basic format (raw file) YUV, the number of images per second (frames per second, fps) 30, group images (Group of Pictures, GoP ) 30 and the number of pictures/frames 300.

TABEL I
Characteristic of video traffic

| Parameter | Value |
|---|---|
| Video sequence | foreman_cif.yuv |
| Frame rate | 30fps |
| Frame type | IPP |
| Video codec | MPEG4 |
| Packet size | 1024 bytes |
| Group of Pictures | 30 |

This research activity was carried out through 2 stages, namely preliminary research and main research. Preliminary research conducted by conducting surveys and literature studies to identify problems so that the resulting problem formulation and objectives to be obtained from this research. While the main research there are 2 jobs carried out before testing and measurement to get the results to be analyzed. Both of these jobs are designing energy measurement systems for mobile communication devices and designing video data transmission systems.The design of the energy consumption measurement system can be seen as shown in Figure 1 below.

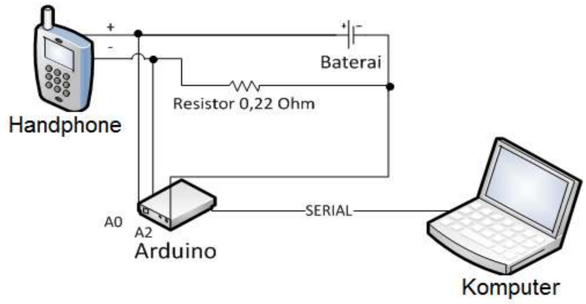



Fig. 1 Design of The Energy Consumption Measurement System

The design of a measurement system for the consumption of mobile communication devices is carried out on the hardware of a measurement device that connects the handphone, battery and Arduino in a serial connection. When the arduino controller is activated, the sensor will measure the current and voltage entering the moving device in analog form, then change it in digital form through the ADC (Analog Digital Converter). The data is then sent to the laptop via a serial interface. On laptops, Arduino software is run to convert current and voltage data into energy data and write them as data loggers. Resistor of 0.22 Ohm functions as a current meter, where the value is obtained from the distribution of voltage between the resistor leg and the resistor value. The voltage that enters the mobile device is measured directly through the measuring terminal directly connected to the mobile device. The product of the voltage, current and duration of the measurement sample produces a unit of energy.

In the next step, software programming on an arduino device uses the arduino programming language. The use of ports, measurements, calculations and data recording is realized through Arduino software. Parameter initialization, including voltage and current validation, and time validation are done at the beginning of the program. Then the measurement looping is done for the desired measurement period.

Meanwhile, programming streaming video software uses the java programming language. Video data transmission system starts from the client request (laptop) to the server (mobile device) to access the video file. The server selects the requested video file, processes the video data for the transmission process, and sends data packets using the selected protocol. The transmission process introduces delay and loss. These parameters are analyzed and recorded at the receiver, together with recording energy consumption data. The design of software on mobile devices as a server uses Java for Mobile Edition (J2ME) programming, while client programming on a PC uses the Wireless Tool Kit (WTK) with the Java Development Kit (JDK) engine and the Netbeans Editor.

The video sending software installed on the Sony Xperia E4g handphone, consists of 2 parts: UDP streaming and TCP streaming. Programming procedures include opening socket connections and constructing data delivery threads. To simplify the process of sending videos, the video renderer and video reader are removed. Video data is modeled based on video trace, in this case used video traceraw file foreman_cif.yuv that has not been coded. Video trace is video data information about the sending time and the number of bytes, dummy bytes used to facilitate the evaluation of video data.

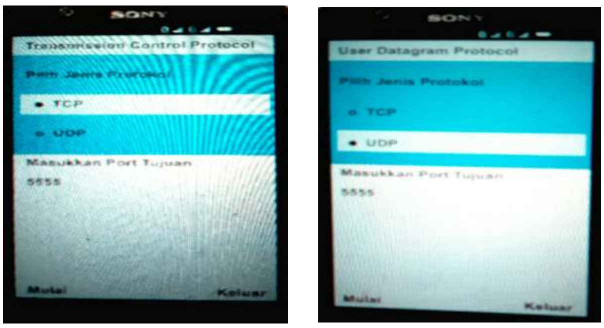
From the receiver side, Netbeans on the laptop activates the video request program, where the cellphone functions as the sender and the laptop as the receiver. This is intended because the power consumption of video senders is more significant than video receivers. Video delivery and energy measurements are carried out simultaneously with a 60 second video duration and a battery voltage value of 3.7 volts. After all the design is done in accordance with the concept, the final step is to carry out measurement experiments when the video delivery process is carried out.

The experiments in this study were carried out by utilizing the 802.11 adhoc network, by activating WiFi facilities on mobile devices and laptops. This network was chosen because of the easier of setting a private IP address. While the use of cellular networks has the disadvantage of needing a live IP that can be accessed publicly. Furthermore it is assumed that the transmission media does not greatly affect the system, due to experiments conducted in close proximity. Due to the availability of channels when data is transmitted, external network interference during the experiment is ignored. Physical layer settings such as transmit power, antenna systems and others are assumed to follow the default settings of the device used.

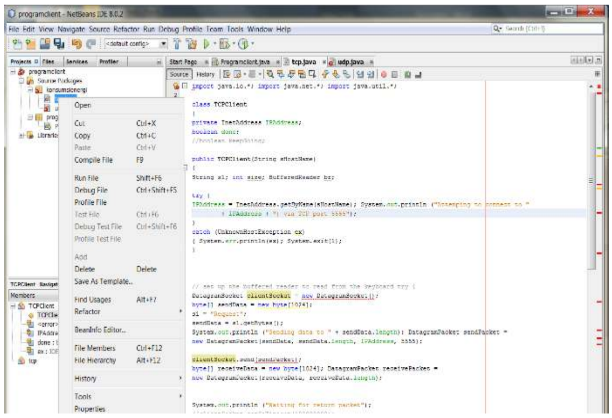
## III. RESULTS AND DISCUSSION

After the design of the energy consumption measurement system is integrated with the design of the video data transmission system, where the mobile communication device functions as a server and laptop as a client, the next step is to process the sending of data by the server using the protocol as requested by the client.

Screen capture of handphone display that functions as a server and receiver program display on a laptop that functions as a client are shown in Figure 2.



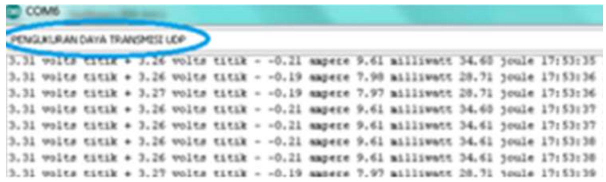

Handphone Display



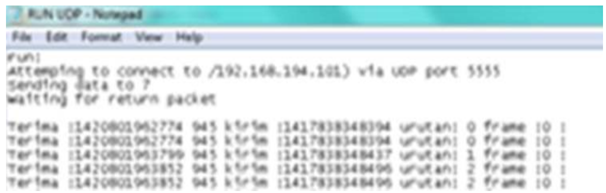
Receiver Program on Laptop Display

Fig. 2 Screen Capture of Handphone Display as a Server and Receiver Program on Laptop as Client

The screen capture of energy measurement data and video data reception is shown in Figure 3.




Data of Energy Consumption

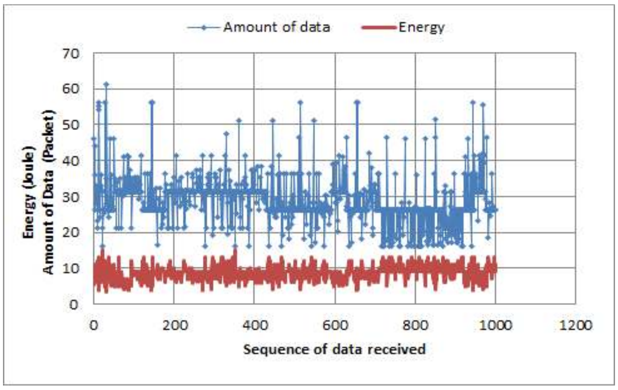



Data Reception

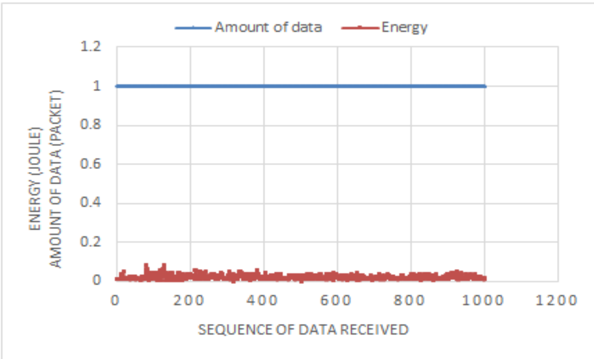
Fig. 3 Screen Capture of Energy Consumption Data and Data Reception

Sending with TCP requires re-transmission and acknowledgment. Transmission on TCP occurs repeatedly and it is done in each segment where not only 1 packet is sent. Thus, TCP needs considerable energy. This is indicated by the total energy consumption for transmitting all video data to 8,799.16 Joules. When viewed from the amount of energy consumed compared with the data that was successfully transmitted, TCP consumes 0.305 Joules of energy per packet. While UDP consumes 0.022 Joules of energy per package. Figure 4 shows the statistics of energy consumption and the number of data packets successfully received in each transmission.

Next, the comparison of the resulting delay between the TCP and UDP protocols is shown in Figure 5. Experiments show that to transmit all data, the TCP protocol takes 286,230.9 milliseconds, while the UDP protocol takes 18,286.42 milliseconds. This means that the TCP protocol has an average transmission delay of 127.27 milliseconds and 8.13 milliseconds for the UDP protocol.

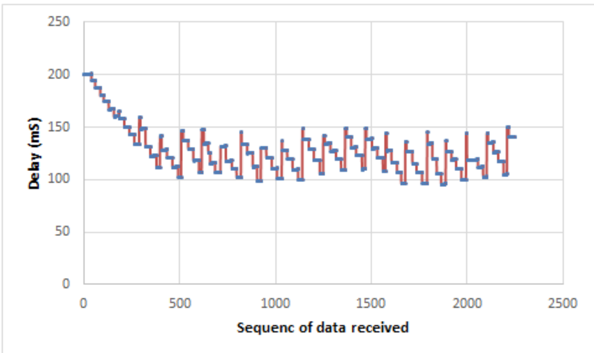



TCP

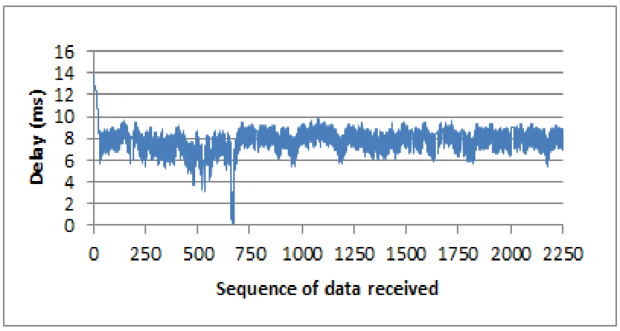



UDP

Fig. 4 Energy Consumption Statistics and Number of Data Packages Received




TCP




UDP

Fig. 5 Statistics of Data Transmission Delay

Although the UDP protocol consumes less energy and transmission delay than the TCP protocol, the UDP protocol can only send 1 data packet per transmission. In contrast, the TCP protocol can transmit 28.88 data packets per transmission on average. This means that the packet loss generated by the UDP protocol is far greater than the TCP protocol. Comparison of the amount of packet loss between the two protocols is shown in Figure 6 below.

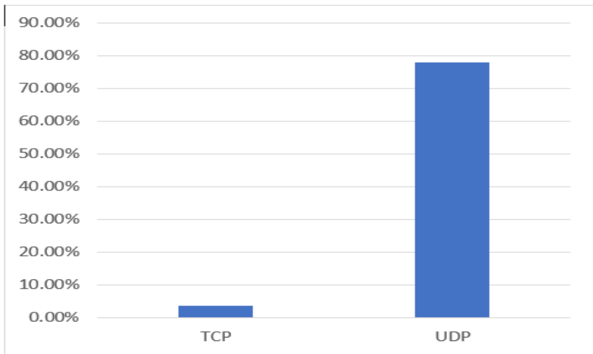



Fig. 6 Comparasion of The Amount of Packet Loss between TCP and UDP Protocol

From the results of the above experiments, we can find out that for real-time communication, UDP is feasible to use, because it has a low delay and low energy consumption. However, for adequate link bandwidth, TCP is more feasible because it can transmit almost of all data.

Now let's compare it with the results of similar studies using mobile devices with lower processor speeds, as shown in Table II below.

Tabel II
Comparison of Energy Consumption Characteristics in Terms of Different Processor Speeds

| Speed of Processor (GHz) | Energy Comsumption (Joule per Packet) | | Average of Transmission Delay (ms) | | Packet Loss (%) | |
|---|---|---|---|---|---|---|
| | TCP | UDP | TCP | UDP | TCP | UDP |
| 1.3 | 0.305 | 0.022 | 127.27 | 8.13 | 96 | 3.7 |
| 0.369 | 0.285 | 0.017 | 200.2 | 13.81 | 92 | 12 |

The characteristics of energy consumption as shown in Table II shows that the energy consumption of mobile communication devices that have higher speed processors consumes more energy compared to the energy consumption of mobile communication devices that have processors with lower speed. But, mobile devices with higher processors produce lower transmission delay and packet loss than mobile devices that have lower processors. This means, a mobile device with a higher processor speed can optimize energy consumption to transmit data in a faster time.

## IV. CONCLUSION

This research proves that the TCP protocol consumes almost 14 times more energy than the UDP protocol. Similarly, the average transmission delay on the UTP protocol is almost 16 times greater than the

UDP protocol. Even so, the TCP protocol managed to send almost 96% of data packets, while the UDP protocol actually lost such a large data packet.

When compared with mobile devices that have a processor speed of 369 MHz, the mobile devices in this study can reduce the average transmission delay by about 40% and packet loss by more than 42%. However, the mobile device in this study consumed 14% more energy.

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