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# DATA AND ENERGY USAGE REDUCTION FOR LIVE STREAMING ON SMART PHONE USING FUZZY LOGIC

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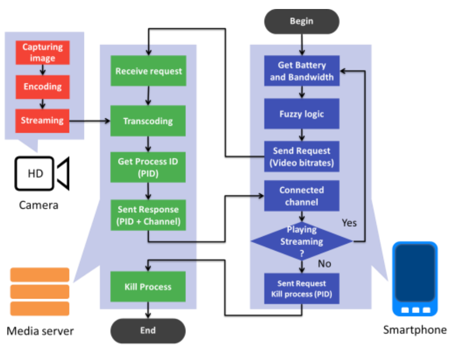
## Graphical abstract




## Abstract

Currently, the live-streaming application running with real-time messaging protocol (RTMP) plays an important role in mobile smart devices. However, two main problems in running such application in the smart devices are the high bandwidth and large amount of energy requirements. In this paper, the available bandwidth and amount of energy in the battery are used simultaneously as input parameters for suitably selecting the video quality in the live-streaming application using Fuzzy logic. It is found that the developed system can select the appropriate video streaming quality accordingly. Using such system, a significant improvement is achieved; that is, the bandwidth and battery usages are reduced by 23 and 24 percent, respectively.

*Keywords*: RTMP; fuzzy logic; android; FFMpeg; live streaming; transcoding



## 1.0 INTRODUCTION

Live-streaming application is now widely used in smart phones; for examples, the online radio or television applications. This application has to be run over the internet with a speed of 4G/3G/Edge/GPRS or WiFi. It means that having this kind of application running on a smart phone, the bandwidth usage is increased considerably. Additionally, the amount of energy use is then increased significantly because of the decoding process on the central processing unit (CPU) and the graphic processing unit (GPU) of the smart phone.

Most of the streaming media system is functioned on RTP/RTCP (Real-time Transport Protocol/Real-time Transport Control Protocol) using UDP (User Datagram Protocol) on Transport level protocol [1, 2]. With this system, there can be a loss of information in transmitting data over the internet resulting in a poor QoS (Quality of Service)[3]. To lessen such problem, currently RTMP with TCP (Transfer Control Protocol) has been adopted since TCP is suited for smoothly transmitting the streaming audio, video, and data over the internet using FMS (Flash Media Server) [4]. There are three types of broadcasting; that is, one-to-one, one-to-many, and many-to-many. These can serve many users; however, it will be a problem if the number of users is higher than the limit that can be served by the server; resulting in a slow service or server shut-down.

A system using NBS (Network-Bandwidth-aware streaming version Switcher) controlled by Fuzzy logic has been proposed in [5]. The system can select a proper video streaming quality according to the available bandwidth. However, such system might not be suitable to current smart-phone users since the more bandwidth usage, the more cost the user has to afford. In a smart-phone video streaming application, the bandwidth usage should be optimized so that the application can run effectively. Also, in a smart-phone application, battery usage is another important parameter. Certainly, if the smart-phone is running with full bandwidth available [6], the battery usage will increase significantly. This will then lead to a short period of time in using a smart phone. At this point, it is seen that there should be a system that takes into account the availability of the network bandwidth and the battery percentage left of the smart phone, simultaneously. The video quality can be obtained from the resulting bit-rate determined from FPS (frames per second) and quality of the streaming according to the speed of the internet and the battery percentage.

In this paper, a system considering both factors (that is, the available network bandwidth and the smart phone battery percentage) is proposed. Fuzzy logic is adopted as a tool for selecting the video quality accordingly. Having the proposed system running in a smart phone for a streaming application, the bandwidth and battery usages will be reduced; hence, the cost of internet service is reduced with a longer time period in viewing the video streaming.

The organization of this paper is done as follows. The related technology is shown in Section 2. The system design is given in Section 3. In Section 4, the results of having the proposed system running is shown and discussed. And, finally, in Section 5, the work in this paper is summarized.

## 2.0 RELATED TECHNOLOGY OVERVIEW

Nowadays, most of electronics devices have to be able to connect to the internet and become much intelligent. This was defined in [7] as the Internet of Things (IoT). Smart phone is one of the electronics devices that is normally used in our daily life. There are many platforms or operating systems (OS) available for smart phones. In this work, Android OS is selected since it is the most popular OS used currently and it is an open-source OS. Additionally, in this work, technology about Media Streaming Server and Fuzzy logic are adopted. These topics are overviewed in this section.

### 2.1 Android OS

Android OS is functioned on Linux Kernel, which was developed by Google Inc. It was designed to work with any touchscreen devices. In Android OS, Android SDK (Software Development Kit) is included. Android SDK is a tool in developing an Android application program using Java language. Another tool is called Android NDK (Native Development Kit), which is a tool for developing an Android application program using C/C++ language. The video decoder supporting RTMP [8] is not included in Android OS; however, using Android NDK, such video encoder is allowed to be added.

### 2.2 Media Streaming Server

The media streaming server is responsible for receiving and transmitting streaming media between the broadcasting site and the audience over the internet using RTMP. One of the major functions of the media streaming server is to transform the streaming file from one encoding protocol to another protocol. This function is called transcoding, which is done under FFMpeg framework [6]. This allows the devices, which do not support the old encoding protocol, to be able to display the streaming media. Also, this function helps reducing the file size by adopting various data compression algorithms [9]; for example, H.264/MPEG-4 AVC, H.265, VP9, and so on.

### 2.3 Fuzzy Logic

Fuzzy logic [10, 11] is the logic that helps us decide a particular problem under an uncertainty of the data. This kind of logic is similar to the complicated deciding system adopted in human. The major difference between Boolean and Fuzzy logics is that in Fuzzy logic, partial truth ranging between completely true and completely false is allowed. The components in Fuzzy logic are listed below.

- Fuzzy set: A set that its boundary is not strictly defined. The membership value of any particular element can be ranged from 0 to 1.
- Membership function: A function that is used to define the membership value of the input parameter.
- Fuzzy set operation: The operation with fuzzy set is identical to the operation with normal set; for example, union, intersection, and compliment operations.
- Fuzzy rules: IF-THEN rule is adopted in Fuzzy logic in order to determine the membership value of a particular element in the set.

In Fuzzy logic, there are three main processes. The first process is called Fuzzification. Under this process, the input data is assigned a membership value, which is in the Fuzzy set. The second process is dealing with Inference engine. The output is determined here depending on the membership value of the input and the rule base used in Fuzzy rule. And, the last process is called Defuzzification, which is the process of transforming the output obtained from the previous process into the value that can be practically used in the application.

## 3.0 METHODOLOGY

The technology and theory presented in the previous section are adopted in this part. The proposed system is divided into three parts; that is, encoding, media server, and decoding parts, as shown in Figure 1.

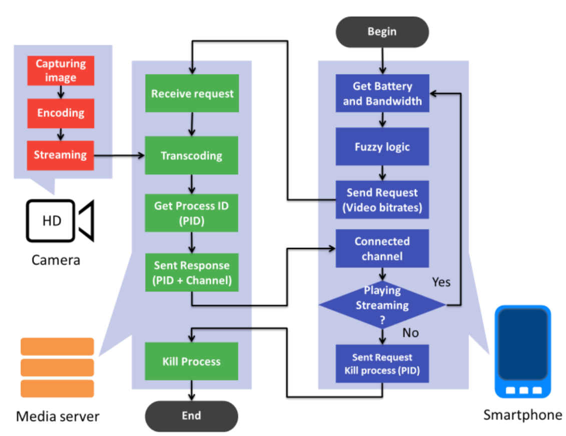



**Figure 1** The proposed system diagram

### 3.1 Encoding Part

In this part, the video is captured by a camera and is sent to the encoding part. The video is encoded into a pre-assigned format. Then, it is sent to the media server over a streaming process, as seen from Figure 1. In this work, Adobe Flash Media Live Encoder is used in order to send a streaming media from the camera to the media server. The pre-assigned encoding formats are given: Input size is 1280×720; Frame rate is 30.00 frames per second; H.264 [12] compression technique is used for video signal; and MP3 compression technique is used for audio signal.

### 3.2 Media Server Part

The media server part is also shown in Figure 1. In this part, there are two main functions; i.e., receiving the streaming media from the encoding part and broadcasting the streaming media [13] with a proper bitrate to the requesting smart phone. To be able to broadcast with a proper bitrate, information about the bitrate has to be sent out from the smart phone along with the request. After getting the information about the bitrate, in media server part, a transcoding process [14] will be done using FFMpeg. Then, the streaming channel will be sent to the smart phone for getting the streaming media from the media server.

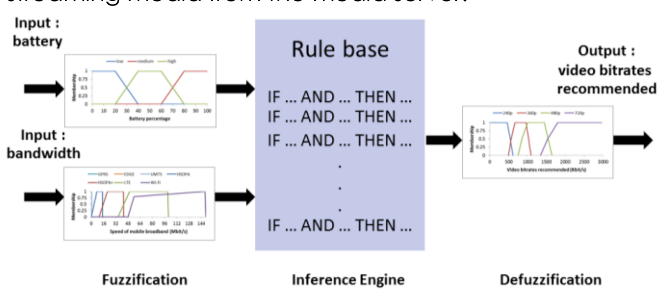



**Figure 2** Fuzzy logic processes for the proposed system

### 3.3 Decoding Part

In this part, Fuzzy logic [15] is adapted in order to decide the proper quality and frame rate of the video streaming depending on the bandwidth of the network and the battery percentage of the smart phone. The Fuzzy logic done in this part is divided into 3 processes, as shown in Figure 2.

In Fuzzification process shown in Figure 2, there are two inputs; that is, battery percentage of the smart phone and the available bandwidth of the network. For the battery percentage, it is divided into 3 ranges; that is, low (1% – 30%), medium (31% - 70%), and high (71% - 100%), as seen in Figure 3. The value of battery percentage shown in the figure is 70%, for example. And, for the bandwidth of the network, as seen in Figure 4, it is ranging from GPRS to WiFi depending on the speed of the network. For example, the speed shown in the figure is 32 Mbps, which is the case of HSDPA+.

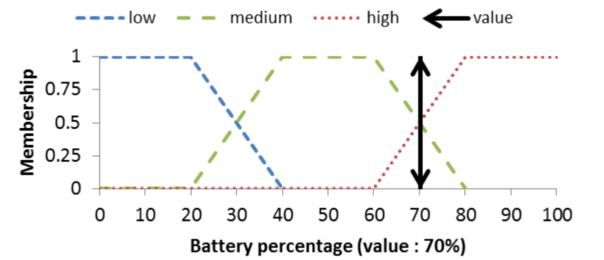



**Figure 3** Membership function for battery percentage of the smart phone

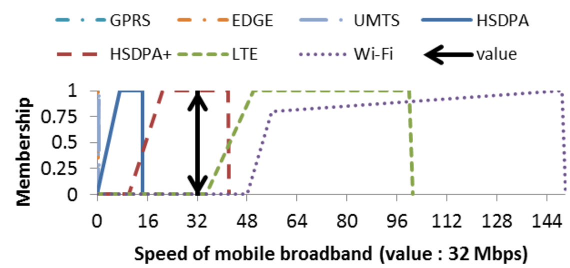



**Figure 4** Membership function for the speed of the network

In the inference engine process, the membership values obtained from the Fuzzification are used in the rule base in order to determine the degree of support. The rule base used in the paper is shown below.

*Rule 1: IF battery IS low THEN selection IS 240p*

*Rule 2: IF battery IS medium AND bandwidth IS UMTS*

*THEN selection IS 360p*

…

*Rule N: IF battery IS high AND bandwidth IS Wi-Fi*

*THEN selection IS 720p*

**Table 1** Output of rule base used in the proposed system

| Speed of network | Battery level | | |
|---|---|---|---|
| | low | Medium | high |
| GPRS | 240p | 240p | 240p |
| EDGE | 240p | 240p | 240p |
| UMTS | 240p | 360p | 360p |
| HSDPA | 240p | 360p | 360p |
| HSDPA+ | 240p | 480p | 480p |
| LTE | 240p | 480p | 720p |
| Wi-Fi | 240p | 720p | 720p |

It is seen that to apply this rule base to the inputs in Fuzzy logic normal logical Booleans; that is, AND, OR, and NOT; have to be used. For example, from Rule 1, it is seen that if the battery level is low, the quality of the video streaming will be set to 240 p. And, from Rule 2, if the battery level is medium and the bandwidth is UMTS, the video streaming will be set to be 360 p. It is seen that two important inputs; that is, the battery level and the bandwidth of the network, are considered in these rules. The result of applying this rule base to different values of inputs is summarized in Table 1.

In Defuzzification process shown in Figure 2, many values of degree of support found in the inference engine process are calculated in order to have only one output to be used. The calculation is done by Central of Gravity (COG) method. The output of this process is the defuzzified value, which is the recommended video bitrate, for this case. As shown in Figure 5, the quality of the video is divided into 4 categories; that is, 240, 360, 480, and 720, respectively. The output is the recommended video bitrate. For example, the video bitrate of 1,168.8 kbps is recommended in the figure for the 480p video quality.

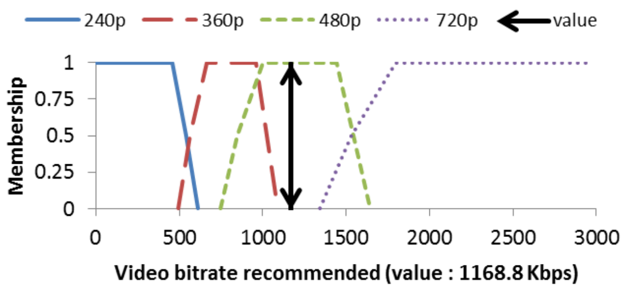



**Figure 5** Recommended video bitrate and membership value for the proposed system

## 4.0 RESULTS AND DISCUSSION

The experiment is done using Virtual Private Server (VPS) with the following specifications: Intel Xeon E3-1240 v3, 3.40 GHz 4-Core CPU, 4-GB RAM, and Gigabit Port Network working on Ubuntu Server 14.04.1 with Nginx and RTMP module installed. The specifications of the smart phone used in the experiment are: Intel Atom Z2560, 1.6-GHz CPU, 2-GB RAM, WLAN 802.11 b/g/n, and EDGE/GPRS/UMTS/HSPA+, and Android 4.4.2 OS. Two cases are performed in the experiment; that is, the streaming with and without the proposed system.

- For the case of without the proposed system, the video streaming media is broadcasted from the media server with the pre-assigned quality and frame rate; that is, 720p and 15 fps.

- For the case of using proposed system, the battery percentage of the smart phone and the speed of the network are sent to Fuzzy logic process every 5 minutes in order to determine the recommended video bitrate. The quality and frame rate that suit the video bitrate will then be obtained. This could be viewed by information in Table 2. The quality and frame rate are then sent to the server in order to transcode the video streaming accordingly.

The experiment is simulated assuming that the streaming media is viewed over WiFi or 3G network at a university library between 2 to 4:30 PM (150 minutes). The available bandwidth or speed is varied depending on the number of users as shown in Figure 6. It is seen that between the 40$^{th}$ and 90$^{th}$ minutes the speed of the network is reduced drastically. And, at that moment, there will be a problem for the smart phone viewing the video streaming without the proposed system. The user will not be able to view the streaming media continuously.

**Table 2** Video Bitrate (in kbps) for different video quality and frame rate

| Frame Rate | Video Quality | | | |
|---|---|---|---|---|
| | 240p | 360p | 480p | 720p |
| 10 fps | 278 | 495 | 746 | 1344 |
| 12 fps | 317 | 564 | 850 | 1532 |
| 15 fps | 373 | 663 | 999 | 1799 |
| 20 fps | 459 | 815 | 1229 | 2213 |
| 25 fps | 539 | 958 | 1443 | 2599 |
| 30 fps | 614 | 1092 | 1645 | 2964 |

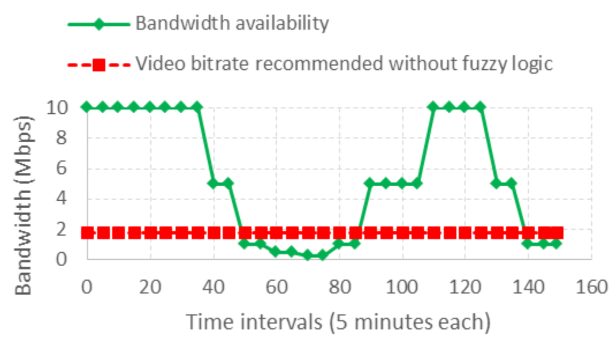



**Figure 6** Available bandwidth and video bitrate used by the smart phone without fuzzy logic from the proposed system

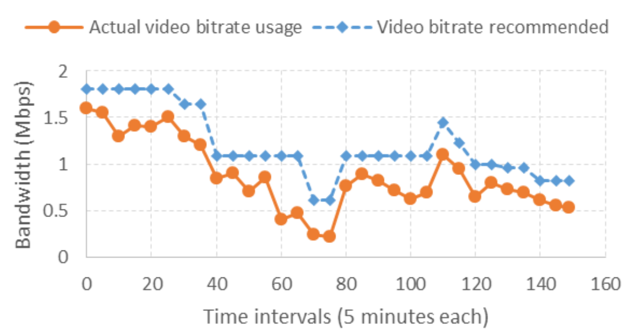



**Figure 7** Actual and recommended video bitrates for the proposed system

Applying the proposed system, the proper quality and frame rate are selected adaptively according to the battery percentage of the smart phone and the available speed of the network. The result of having such system applied in terms of the bitrate usage is shown in Figure 7. It is seen that the video bitrate recommended is changed according to the available bandwidth of the network (as seen in Fig. 6). This means that viewing a video streaming with such proposed system can be done continuously. Additionally, considering the actual video bitrate usage, it is seen that it is slightly below the recommended one. This is from the fact that there is a compression in the broadcasting site. The compression results in a lower video bitrate required.

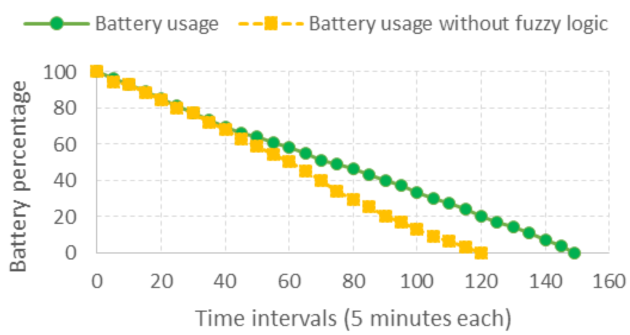



**Figure 8** Battery percentage and usage time of the smart phone

The battery usage is considered and shown in Figure 8. From the figure, it is clearly seen that comparing between the cases of with and without the proposed system, a longer usage time can be obtained from the case of using the proposed system. Approximately 30-minute usage time can be achieved, as seen from the figure. This is the result of having the battery percentage of the smart phone as an input to the Fuzzy logic consideration. Energy consumption in the smart phone is used efficiently.

The comparisons in terms of viewing time and bandwidth usage of the smart phone in a video streaming application for the case of with and without the proposed system is shown in Table III. It is seen that with the proposed system, the battery usage can be increased by 24.16% and the bandwidth usage is reduced by 23.26%.

**Table 3** Comparisons of the viewing time and bandwidth usage for two categories: with and without the proposed system

| | Application without fuzzy logic | Application with fuzzy logic | Difference |
|---|---|---|---|
| Viewing time | 120 minutes | 149 minutes | +24.16 % |
| Bandwidth usage | 1.29 GB | 0.99 GB | -23.26 % |

## 5.0 CONCLUSIONS

A system for selecting a proper video quality for video-streaming application in a smart phone was proposed and explained. The system contains 3 major parts; that is, encoding, media server, and decoding parts. Fuzzy logic is adopted as a tool for adaptively determining the proper video quality according to the battery percentage of the smart phone and the available speed of the internet connection. It has been shown that the energy consumption was reduced resulting in a longer viewing time; that is, an increase of 24.16% was obtained from the experiment. Also, the bandwidth usage was reduced significantly; that is, 23.26% decrease; without affecting the video quality. These improvements were obtained since the video quality was determined adaptively depending on the two important parameters as mentioned. It is clearly seen that adopting the proposed system in the video streaming application with a smart phone, the energy and bandwidth efficiencies can be obtained.

## Acknowledgement

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