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Convergence Sublayer Analysis and Implementation on Medium Access Control Layer using The Embedded Configurable Operating System

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Abstract

This study explores the implementation of the Convergence Sublayer (CS) defined in IEEE Std 802.16TM-2004. The CS, situated atop the Medium Access Control (MAC) Layer, plays a crucial role in mapping and classifying MAC Service Data Units (MSDU) to specific connections identified by Connection Identifiers (CID). Using the Embedded Configurable Operating System (eCos), an Open-Source Real-Time Operating System, this research successfully demonstrates the implementation of MAC CS over a particular hardware platform. The findings indicate that eCos facilitates the efficient execution of MAC CS's mapping and classification functions.

Keywords: IEEE Std 802.16TM-2004, Medium Access Control Layer, MAC Service Data Unit (MSDU)

Abstrak

Penelitian ini menggali implementasi Convergence Sublayer (CS) yang didefinisikan dalam standar IEEE Std 802.16TM-2004. CS, yang berada di atas Medium Access Control (MAC) Layer, memainkan peran penting dalam mengklasifikasikan dan memetakan MAC Service Data Unit (MSDU) ke sambungan-sambungan tertentu yang diidentifikasi oleh Connection Identifier (CID). Penggunaan Embedded Configurable Operating System (eCos) yang merupakan Sistem Operasi Waktu Nyata yang bersifat open source, penelitian ini berhasil menunjukkan implementasi MAC CS pada platform perangkat keras tertentu. Temuan ini menunjukkan bahwa eCos memfasilitasi pelaksanaan yang efisien dari fungsi klasifikasi dan pemetaan MAC CS.

Kata Kunci: IEEE Std 802.16TM-2004, Medium Access Control Layer, MAC Service Data Unit (MSDU)

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I. Introduction

Convergence Sublayer (CS) is the top sublayer on Medium Access Control (MAC) which performs basic functions in Quality of Service (QoS) management [1]. The main function of MAC CS is to perform the classification and mapping of incoming packets from the layer above it into a connection according to the desired QoS parameters.

The classification and mapping process is carried out by receiving the MAC Service Data Unit (MSDU) that enters the MAC CS entity, then the MSDU is connected to the connection defined by the Connection Identifier (CID). MAC CS which is responsible for classifying and mapping the MSDU to the appropriate CID.

MAC CS as the top sublayer of the MAC layer has the following functions [1]. The first function performs the process of classifying the higher layer PDU into the proper connection. Payload Header Suppression (PHS) suppresses the information contained in the payload header with the aim of reducing the amount of data that will be sent over the air. PHS is an optional function. The next function delivers the CS PDU to the SAP MAC to be transported until it reaches the MAC SAP peer. In addition, another function is to receive CS PDU originating from MAC SAP peer. The last function is to reshape the suppressed payload header information in the PHS process. This function is optional.

The use of Information technology (IT) covers a wide range of fields from communications to energy. Scientific work [2] uses computer networks for inter-village communication. The use of computer program for efficient data transmission is discussed in [3][4]. Network analysis for communications on the battlefield is discussed in [5]. computer programs can be used to perform weather analysis [6]. The use of computer networks for underwater communication can be seen in [7]. Seismic wave modeling using mathematical equations and optimization algorithms can be seen in [8]. In addition, deep learning is used for network traffic estimation [9], [10]. From these papers, it can be concluded that IT plays an important role in human life.

The process of classification and mapping in MAC CS involves two main concepts, namely: Connection and Service Flow. Connection is a connection in the MAC that is formed between the BS with the SS or vice versa. The connection formed is unidirectional (one way), namely downlink stream (from BS to SS) or uplink stream (from SS to BS). The formation of a connection between the BS and the SS is indicated by the provision of a CID for the connection. CID is a unique identity assigned to each connection that is formed at the MAC level [1]. The values defined by the CID have specific meanings. In the classification and mapping process carried out by MAC CS, the CID used is the CID transport type [11]. Transport CID has a value in the range 2m+1 – 0xFE9F [11], where the value of m is determined by the BS.

A service flow defines the QoS parameters used to exchange data packets over the air in an established connection [11]. Like the connection, the service flow that is formed is also identified using the Service Flow Identifier (SFID). The relationship between CID and SFID is singular where a CID is associated 1-1 with an SFID.

II. Method

A. Mapping and Classification

The process of classification and mapping is the main function of MAC CS. Through the classification and mapping process, each MSDU that enters MAC CS is mapped into a connection defined by the CID. The process of classification and mapping involves an entity called a classifier. Classifier is a collection of matching criteria called rules [11].The rule contains information about the MSDU specifications that enter MAC CS. If the MSDU that enters the MAC CS has specifications that match the rules, the MAC SDU will be mapped into a connection defined by the CID according to the required service flow characteristics.

There are two stages of mapping (mapping) to get the CID value in the MAC CS classification and mapping process [2], namely:

1) *IP-SFID mapping*: The incoming MSDU is a packet that has a header. The header has a certain format that contains information about the MAC source address, MAC destination address, IP source address, IP

destination address, and others. From this information, a classification process is carried out based on the rules so that the SFID value is obtained.

2) *SFID-CID mapping*: the SFID value obtained from the IP-SFID mapping process is reused to get the CID value. From the CID value, it can be seen the characteristics of the connection and the service flow used.

B. MAC CS Implementation

MAC CS implementation is a manifestation of MAC CS functions based on the design that has been done. There are two main MAC CS processes implemented, namely:

1) *MAC CS Transmission Process*. It is a process carried out by MAC CS when it receives an MSDU originating from the Upper Layer Entity to be forwarded to the next layer, namely MAC CPS. The process of classification and mapping occurs in this section. Through the process of classification and mapping, the CID value for the MSDU is obtained.
2) *MAC CS Receive Process*. Is a process that is carried out when MAC CS receives a PDU originating from MAC CPS (Lower Entity) to be forwarded to the Upper Layer Entity. The received PDU is forwarded based on the mapping of the CID value on the PDU.

C. eCos Configuration

Embedded Configurable Operating System(eCos) is an open source operating system that can be configured according to the user's goals [12]. The purpose of using eCos is as a platform to be able to implement embedded systems on certain hardware platforms.

The implementation of MAC CS is carried out on the eCos platform and uses the features of eCos as a configurable RTOS. MAC CS implementation is done on a hardware platform called SPARC. SPARC is a type of processor architecture. By using eCos, MAC CS can be implemented on top of the SPARC processor architecture.

D. Reference

The use of features owned by eCos is adjusted based on the needs needed at the time of implementation. These adjustments can be made by configuring the eCos platform that was formed.

The MAC CS implementation uses the following eCos template configuration defaults:

1) Net template, contains supporting packages for the implementation of the OpenBSD Networking stack. This template produces a library of network protocols such as IP and Ethernet that are needed in the classification process in MAC CS.
2) The SPARC_LEON3 target, the created ecos.ecc file has a hardware target that uses a processor architecture platform in the form of SPARC.

For an understanding of eCos and its features, refer to the reference entitled Embedded Software Development with Ecos [11].

III. Result and Discussion

A. MAC CS Testing

In the intricate realm of MAC CS testing, a meticulous process unfolds, one that involves the continuous influx of data packets into both the MAC CS Transmission and MAC CS Receive processes. Within the intricate tapestry of the MAC CS Transmission process, a diverse array of data packets takes center stage, each with its unique purpose and composition. From the seamless flow of video streaming packets represented as TCP segments of reassembled PDU, to the precise choreography of text packets maneuvered through port programming, the spectrum encompasses the complexities of Address Resolution Protocol (ARP) packets, echoing queries like "Who has 192.168.1.173? tell 192.168.1.6." Meanwhile, web page requests materialize in the form of HTTP queries, such as the ubiquitous "GET /firefox/headlines.xml HTTP/1.1\r\n," while the echo of Ping packets (ICMP) reverberates in the digital expanse. Network Time Protocol packets broadcast temporal precision, while the playful cadence of Yahoo Messenger YMSG packets asserts their presence with a default ping status. Lastly, the heartbeat of the system finds its voice through Stream Control Transmission Protocol (SCTP) packets, underscoring the vitality of this intricate dance within the heart of technological innovation.

The following are the test results from the MAC CS Transmission process. In the realm of network communication, an intriguing assortment of data packets takes flight, each meticulously defined by its distinctive attributes. First in line, the Video streaming packet, a TCP segment of reassembled PDU, emerges with CID 65181 (0xFE9D) and is scheduled under nrTPS, exemplifying its seamless integration into the network's multimedia landscape. Meanwhile, Text packets, steered through port programming and assigned CID 65180 (0xFE9C), find their rhythm within the BE schedule, harmonizing text-based exchanges in the digital ether. Address Resolution Protocol (ARP) packets, with their purposeful query "Who has 192.168.1.173? tell 192.168.1.6," bear the mark of CID 65179 (0xFE9B) and gracefully align with the BE schedule, ensuring efficient network address resolution. Venturing further, the Request web page packet, eloquently stating "GET /firefox/headlines.xml HTTP/1.1\r\n," possesses CID 65178 (0xFE9A) and is accorded the distinguished status of UGS, promising unhindered access to web content. Ping packets in the form of ICMP Echo Requests, bearing CID 65177 (0xFE99), echo across the network's expanse, effortlessly blending into the BE schedule. Simultaneously, the Network Time Protocol packet, a bearer of temporal precision, graces the network with its presence through CID 65176 (0xFE98), finding its niche within the BE schedule. Yahoo Messenger YMSG packets, where the ping status reigns supreme, are distinguished by CID 65175 (0xFE97) and elegantly merge into the BE schedule, ensuring seamless communication within the messaging realm. Lastly, the Stream Control Transmission Protocol (SCTP) packet, marked by its essential 'HEARTBEAT,' represents the pulse of the network, although devoid of a specific CID, emphasizing the intrinsic vitality of its function within this intricate tapestry of digital communication.

Meanwhile, the MAC CS test results for the receive process can be seen in Figure I.

Return		CS_SPEC_IPV4_OVER_ETHERNET		CS_SPEC_ETHERNET	CS_SPEC_IPV4_OVER_ETHERNET				CS_CID_NOT_FOUND
CID	Dec	65181	65180	65179	65178	65177	65176	65175	65174
	Hex	0xFE9D	0xFE9C	0xFE9B	0xFE9A	0xFE99	0xFE98	0xFE97	0xFE96

Figure I. Results Of The CSRXCLASSIFY Function Classification Process

B. MAC CS Functionality Analysis

The parameter that is measured to determine the performance of MAC CS is the amount of latency generated. The amount of latency obtained will be compared with the time required by the MAC layer to form a frame (frame duration) which is 2.5 ms. Latency generated by the MAC CS Transmission process is shown in Figure II.

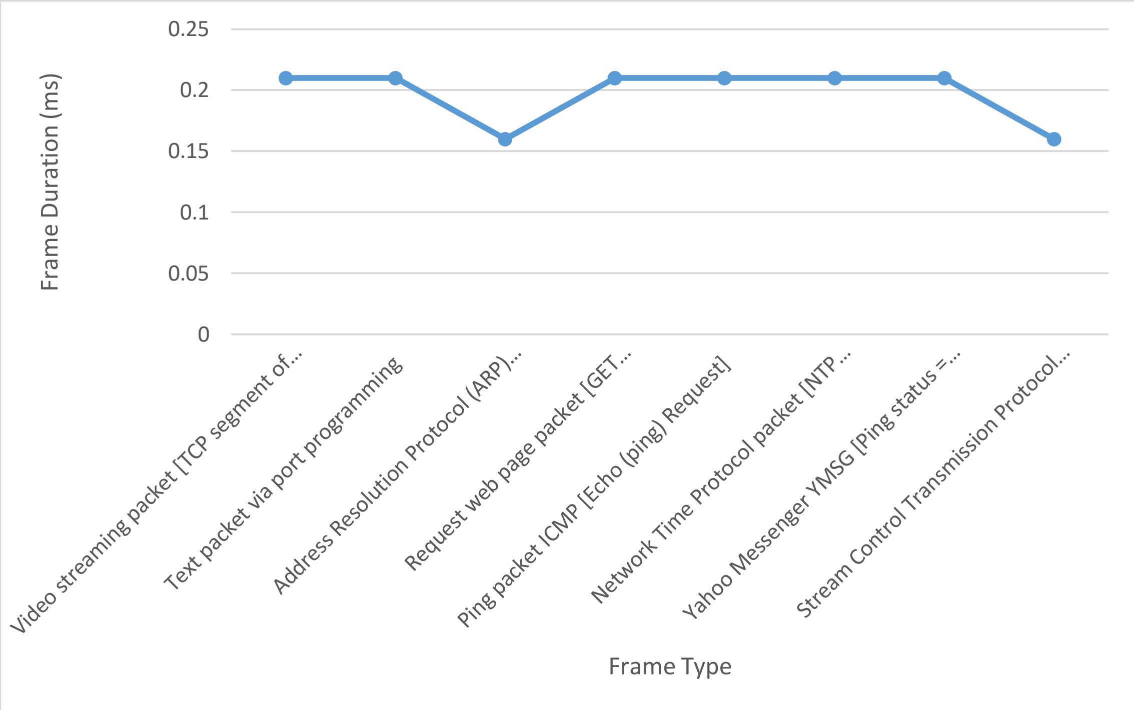

Figure II. Cstxclassify Function Latency Value Calculation

The average time it takes to execute the eight types of packages is:

$$x = \frac{\sum simulated\_time}{8} \quad (1)$$

$$x = \frac{(0.21 + 0.21 + 0.16 + 0.21 + 0.21 + 0.21 + 0.21 + 0.16)ms}{8} \quad (2)$$

$$ratio = \frac{0.2\ ms}{2.5} \times 100\% = 8\% \quad (3)$$

IV. Conclusion

The conclusion of this research is as follows. MAC CS that is implemented can carry out the classification and mapping process correctly. The use of eCos for MAC CS implementation on the SPARC platform can be carried out up to the testing level. The implemented csTxClassify function has an average latency value of 0.20 ms. in carrying out the classification and mapping process which is the main function of MAC CS.The csRxClassify function implemented in this study has an average latency value of 0.01 ms.Suggestions that can be made for further research are as follows. Further research can develop MAC CS functions, especially the Payload Header Suppression (PHS) function. Further research can implement the IP Version 6 protocol specification on MAC CS.

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