Analysis of UDP Multicast Quality of Service in Communication Systems for Wheeled Soccer Robots

Heru Wijanarko[1], Wahidah Izmi Addinah[2], Wanda Eka Kurniawan[3], Hendawan Soebhakti[4], Senanjung Prayoga[5], and Rifqi Amalya Fatekha[6]

wijanarko@polibatam.ac.id[1], wahidahizadh@gmail.com[2], scoeg12@gmail.com[3], hendawan@polibatam.ac.id[4], senanjung@polibatam.ac.id[5], rifqi@polibatam.ac.id[6]

Mechatronics Engineering Study Program Politeknik Negeri Batam[1,2],
Robotics Engineering Study Program Politeknik Negeri Batam[3,4,5,6],
The Institution of Engineers Indonesia (Persatuan Insinyur Indonesia (PII)), Batam, Indonesia[1]

Abstract. In this research, we discuss the Quality of Service (QoS) analysis of UDP Multicast used in the communication between the computer controller or base station and the wheeled soccer robot. In the Indonesian Robot Competition (Kontes Robot Indonesia), the wheeled soccer robot must run autonomously, whether finding the ball, dribbling, or kicking it. Therefore, UDP Multicast communication needs to be tested to determine the quality of the network used between the base station and the wheeled soccer robot using QoS methods that have four parameters: throughput, delay, jitter, and packet loss, based on the TIPHON (Telecommunications and Internet Protocol Harmonization Over Networks) standards issued by the European Telecommunications Standards Institute (ETSI). Network communication testing was carried out using the Wireshark application, so the data obtained can show the throughput value or data transfer speed of 23,765 bps, with a delay of 19.64 ms and jitter of 19.64 ms, as well as 0% packet loss. From these data, it can be concluded that the UDP Multicast communication network is very good for implementing communication between the base station and the robot.

Keywords: QoS, TIPHON, UDP multicast, wheeled soccer robot, wireshark.

1 Introduction

In the current era of technological advancement, significant progress has been made in Internet network capabilities, enabling seamless communication among computers. This goes beyond information sharing, extending to collaborative computing, allowing users to control computers or other devices collectively. Among the various computer communication applications, one notable use is in the Indonesian Robot Contest (KRI) context, particularly in the Wheeled Soccer Robot division (KRSBI).

The Indonesian Robot Contest (KRI) is a design and engineering competition in robotics organized by the National Achievement Center, Ministry of Education and Culture of the Republic of Indonesia. The current Wheeled Soccer Robot competition implementation

ICAE 2023, November 07, Batam, Indonesia

DOI 10.4108/eai.7-11-2023.2342927

involves two attacking robots that are remotely started using Wi-Fi within a network. The setup includes a computer controller (base station) and two robots of wheeled soccer robots. Once initiated, the robots must operate autonomously in tasks such as locating the ball, dribbling, and kicking.

In wheeled soccer robot competitions, various factors are crucial in making a robot the best. One of these factors is the algorithm, such as Particle Filter for localization [1], goal detection, opponent avoidance [2], [3], and even the use of AI for Steering Motion [4]. Another essential factor is motion, as discussed in [5], focusing on odometry and rotary encoder methods. However, the communication system of wheeled soccer robots is equally important, an aspect that has not been extensively explored. In [6], a study on the communication of wheeled soccer robots using esp8266 and Wi-Fi communication was conducted. This research utilized a game software controller, examining Quality of Service (QoS) parameters like communication time, time difference, distance, and signal interference. The results of this study need further development, possibly referencing specific standards like TIPHON (Telecommunications and Internet Protocol Harmonization Over Networks) or others. Additionally, it is essential to continue examining QoS in implementing a particular protocol.

Because of the above, this research focuses on the QoS analysis of communication between the base station and wheeled soccer robots using UDP (User Datagram Protocol) Multicast. QoS is a measurement method used to define a network service's characteristics, assessing the network's quality in delivering that service. QoS encompasses a network's ability to provide reasonable bandwidth, overcome delay and jitter, eliminate packet loss, and reduce failures in data packet delivery [7].

The QoS parameters assessed in this study pertain to the reliability and speed performance in delivering various types of data during communication. These parameters include throughput, delay, jitter, and packet loss based on the TIPHON standard. TIPHON is a QoS parameter evaluation standard issued by the international standards body ETSI (European Telecommunications Standards Institute). ETSI, within the European Standards Organization (ESO), holds recognized regional standards in telecommunications, broadcasting, networks, and other electronic communication services [8].

The key contributions of this study are: i) Obtaining measurable outcomes from experiments conducted in the actual setup at Barelang Robotics and Artificial Intelligence Lab (BRAIL); ii) Concluding these experiments that can serve as a reference for wheeled soccer robot teams; and iii) Identifying relevant aspects of UDP Multicast and QoS in the applicable topology.

The structure of the paper is as follows: Section 2 (Protocols) outlines the main features of the components based on this experimental study. Section 3 (Scenarios and Experimental Resources) describes the topology and interface system. Section 4 (Test Results) presents the quantitative data obtained from the QoS of TIPHON. Finally, Section 5 discusses the main conclusions derived from this research.

2 Protocols

The research team examined the behavior of the communication system in the network nodes for wheeled soccer robots, focusing on throughput, delay, jitter, and packet loss. The aim was to evaluate the effectiveness of using the UDP protocol in IP Multicast. Lacking sufficient understanding of this subject may result in oversimplified conclusions, misinterpretations, planning mistakes, and inaccurate simulations, leading to instability in the infrastructure. The following section briefly overviews the key features of the protocols employed.

2.1 User Datagram Protocol (UDP)

User Datagram Protocol (UDP), a connectionless or unreliable transport protocol, operates without establishing a connection but is considered less reliable. UDP does not add much to the IP service except for facilitating process-to-process communication rather than host-to-host communication. Additionally, UDP has limitations regarding error-checking functions [9].

UDP sends messages called datagrams, as illustrated in Figure 1. It is considered a best-effort communication mode, meaning the service cannot guarantee that data will be delivered or provide specific features for resending lost or damaged messages. UDP offers two services not provided at the IP layer. It only assigns port numbers to help distinguish user requests and provides a function to check the file's authenticity (checksum) to verify that the data arrives intact.

2.2 IP Multicast

IP Multicast is a data delivery technique employed to send a packet or message from one server to multiple recipient (client) computers connected in a group known as a Multicast Group. In this way, multicast only delivers to interested connected recipients, and this method is known as the one-to-many approach.

IP Multicast operates by specifying a single multicast address as the destination address for the transmitted datagram. This address is not a host multicast address but is intended to reach those who have joined the same group.

Header 8 bytes		*Data*
Source port number 16 bits	*Destination port number* 16 bits	
Total length 16 bits	*Checksum* 16 bits	

Fig. 1. User Datagram format

3 Scenarios and Experimental Resources

The research conducted an experimental design to test the wheeled soccer robot's communication system and network quality. The stages of the research involve creating a communication program using UDP based on multicast. Subsequently, the communication program will be tested on two units robot of wheeled soccer striker robots. The study includes an analysis of QoS based on THIPON standards and an examination of observation results and statistical data. During the testing phase, when Robots One and Two establish a connection, they connect to the base station. Once connected, both robots wait for data, and the base station then sends data to the robots. After receiving the data, Robots 1 and 2 execute strategies and commands instructed by the base station. This comprehensive approach aims to evaluate the effectiveness of the UDP Multicast-based communication system in the context of wheeled soccer robots.

Figure 2 illustrates the communication system topology utilized by wheeled soccer robots. This communication system operates through an internet-connected Wi-Fi router. The communication between the referee box and the base station utilizes the Transmission Control Protocol (TCP), while the communication between the base station and the robots employs the UDP in multicast mode. The robot communication system comprises a referee box serving as the server for the base station, with the base station acting as the client for Robot 1 and Robot 2. At the beginning of the match, the Referee Box (shown in Fig 3. (a)) issues instructions to manage the game, such as start, kick-off, and stop commands. Subsequently, the data is transmitted to the base station (shown in Fig 3. (b)) via the Wi-Fi router. The base station then sends the data to the robots. The base station connects to an access point and directs commands to Robot 1 and Robot 2, each having its respective IP address.

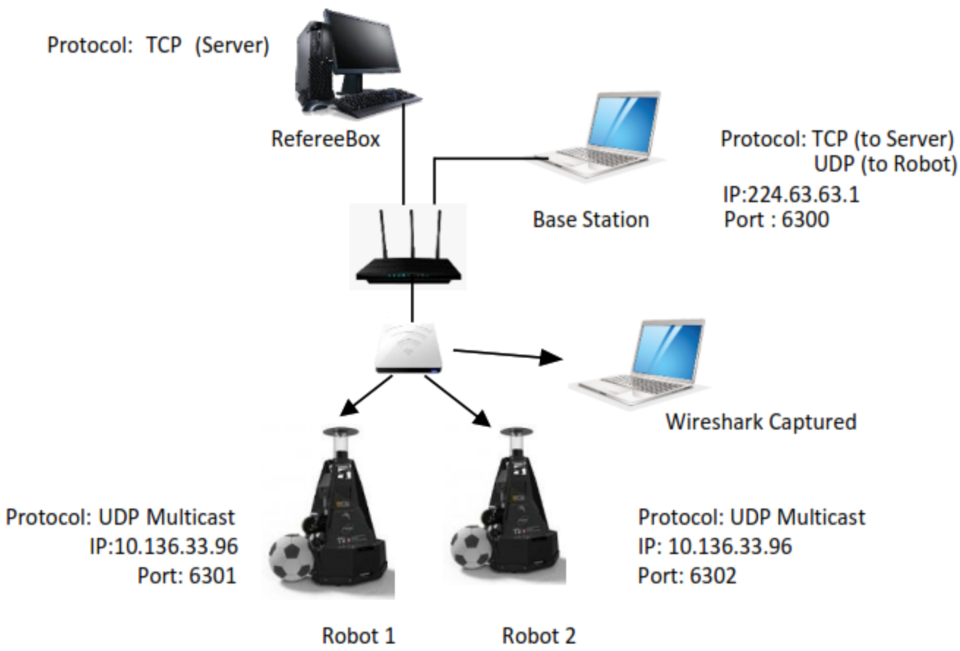

Fig. 2. Topology of communication system in robotic settings.

(a)

(b)

Fig. 3. Interface of (a) Referee Box and (b) Base Station

This study employs the Wireshark application to test the UDP Multicast communication system network between the base station and wheeled soccer robots. Wireshark is a network application utilized for understanding and analyzing network performance, featuring a GUI (Graphical User Interface) interface. It monitors data traffic, such as the sending and receiving activities between the base station and wheeled soccer robots.

The testing procedure is divided into two parts:

1. Communication Testing

   Communication testing involves using the Wireshark application in the same network as Robot 1 and Robot 2, specifying the source and destination IP addresses and the protocol used. This testing aims to determine the transmission time required for sending and receiving data and to validate that the communication system adheres to the rules of the Wheeled Soccer Robot Competition (KRSBI-Beroda) [10].

2. Network Testing

   Network testing assesses the success rate and quality of UDP Multicast communication between the base station and robots in executing strategies and coordinating among wheeled soccer robots.

This network testing employs the QoS method based on the TIPHON standard, with four parameters:

a. Throughput, as defined by TIPHON, represents the data transfer speed and is categorized according to the standards outlined in Table 1.

   Throughput calculation is presented in equation (1),

$$Throughput = \frac{Total\ Data\ Sent}{Data\ Transmission\ Time} \quad (1)$$

b. In network communication, delay refers to the time data travels from the source to the destination. Various factors, such as the physical distance, congestion, or lengthy processing times, can influence delay. According to TIPHON standards, the delay categories are outlined in Table 2.

   Delay calculation presented in equation (2),

$$Delay = \frac{Total\ Delay}{Total\ Received\ Packets} \quad (2)$$

c. On the other hand, jitter represents the delay variation caused by queue length fluctuations during data processing over time. Queue delays in routers and switches can contribute to jitter. According to TIPHON, the jitter categories are detailed in Table 3.

   Jitter calculation is presented in equation (3),

$$Jitter = \frac{Total\ Variation\ in\ Delay}{Total\ Received\ Packets - 1} \quad (3)$$

d. Finally, packet loss indicates the number of packets that fail to reach their intended destination. The categories of packet loss, according to TIPHON, are presented in Table 4.

   Packet loss calculation is presented in equation (4),

$$Packet\ Loss = \frac{Total\ Sent\ Packets - Total\ Received\ Packets}{Total\ Sent\ Packets} \times 100\% \quad (4)$$

Table 1. TIPHON's throughput standard

Category	Throughput (bps)	Index
Very Good	100	4
Good	75	3
Fair	50	2
Poor	<25	1

Table 2. TIPHON's delay standard

Category	Delay (ms)	Index
Very Good	<150	4
Good	150 – 300	3
Fair	300 – 450	2
Poor	>450	1

Table 3. TIPHON's jitter standard

Category	Jitter (ms)	Index
Very Good	0	4
Good	75	3
Fair	125	2
Poor	225	1

Table 4. TIPHON's packet loss standard

Category	Packet Loss (%)	Index
Very Good	0	4
Good	3	3
Fair	15	2
Poor	25	1

Table 5. Standard categories for QoS values by TIPHON

Index	Percentage (%)	Category
3.8 – 4	95 – 100	Very Good
3 – 3.79	75 – 94.75	Good
2 – 2.99	50 – 74.75	Fair
1 – 1.99	25 – 49.75	Poor

In the QoS framework, which is based on TIPHON standards, four types of indices and categories are used to determine QoS parameters: very good, good, fair, and poor, as illustrated in Table 5.

4 Test Results

After executing the scenarios and experiments in this research, this section explains the test results. In Figure 4, the graph illustrates the data transfer speed or throughput in bits per second (bits/sec). The graph shows that the communication data transfer speed between the base station and the robot lasted 53.36 seconds, with 2717 packets sent. In the initial phase, the data transfer speed was approximately 24000 bits/sec, but later, the data speed appeared unstable and ultimately settled at around 22300 bits/sec.

Furthermore, Figure 5 displays the statistical data retrieval of communication between the Base Station and the robot using the Wireshark application. It reveals that the data transmission amounted to 158501 Bytes, with 2717 packets sent within 53.36 seconds at 23 kbits/s. Additionally, it is noteworthy that all the data packets were successfully sent and received at a rate of 100%.

Based on the data collected during the communication test, throughput can be calculated using equation (1), delay and delay variation using equation (2), jitter using equation (3), and packet loss using equation (4). The results indicate a throughput value of 23,765 bits/sec, falling into the "very good" category. The delay value is 19.64 ms, also categorized as "very good," with a

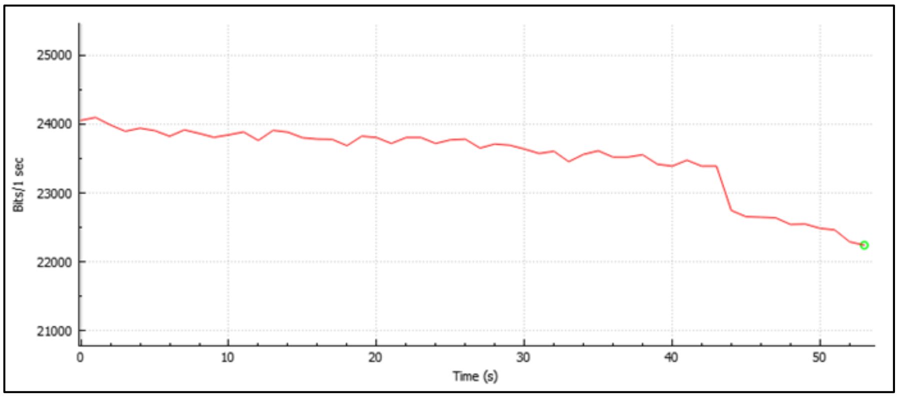

Fig. 4. Throughput graph

Statistics

Measurement	Captured	Displayed	Marked
Packets	2717	2717 (100.0%)	—
Time span, s	53.356	53.356	—
Average pps	50.9	50.9	—
Average packet size, B	58	58	—
Bytes	158501	158501 (100.0%)	0
Average bytes/s	2970	2970	—
Average bits/s	23 k	23 k	—

Fig. 5. Statistical data in Wireshark

delay variation of 53,336.63 ms. The jitter value is 19.64 ms, falling into the "very good" category, and the packet loss is 0%, classified as "very good" as well. The summarized results are presented in Table 6, where the obtained values lead to an average index calculation of 3.97 with a percentage of 99.25%, categorizing it as "very good." Therefore, the analysis suggests that the communication between the base station and wheeled soccer robots using the UDP Multicast protocol achieves an excellent index and category, making it suitable for implementation and development in the Indonesian Robot Contest (KRI), specifically in the Wheeled Soccer Robot category.

5 Conclusions and Future Works

In summary, the testing and discussion of data from network tests using the QoS method to analyze UDP Multicast communication between the base station and wheeled soccer robots revealed promising results. The throughput, or data transfer speed, reached 23,765 bps, with a delay of 19.64 ms, jitter of 19.64 ms, and no packet loss. This suggests that employing the UDP Multicast protocol for communication between the base station and wheeled soccer robots is highly effective for implementing strategies.

For future research, it is recommended to expand the analysis beyond the communication system between the base station and one or two robots, including observing the impact of 2.4 GHz and 5GHz. Exploring scenarios involving more than two robots is crucial to comprehensively understanding the communication dynamics. Additionally, addressing occasional delays observed in UDP Multicast data transmission from the base station to the robot should be a focus for optimizing data delivery speed in future studies.

References

[1] B. Sugandi and A. D. Zain, "Localization of Wheeled Soccer Robots Using Particle Filter Algorithm," in *2019 2nd International Conference on Applied Engineering (ICAE)*,Oct. 2019, pp.1–4.

[2] N. Rinanto, I. Marzuqi, A. Khumaidi, and S. T. Sarena, "Obstacle Avoidance using Fuzzy Logic Controller on Wheeled Soccer Robot," *Jurnal Ilmiah Teknik Elektro Komputer dan Informatika*, vol. 5, no. 1, pp. 26–35, 2019.

[3] B. Sugandi, S. Prayoga, I. A. Riandi, and D. G. Tinambunan, "Goal Detection and Opponent Avoidance Algorithm for Wheeled Robot Soccer using Color Filtering and Contour Extraction," in *2018 International Conference on Applied Engineering (ICAE)*, Oct. 2018, pp. 1–5.

[4] X. Xiong, "Artificial Intelligence Control Algorithm for the Steering Motion of Wheeled Soccer Robot," *Int. J. Patt. Recogn. Artif. Intell.*, vol. 33, no. 10, p. 1959034, Sep. 2019.

[5] M. Taufiqqurohman and N. F. Sari, "Odometry Method and Rotary Encoder for Wheeled Soccer Robot," *IOP Conf. Ser.: Mater. Sci. Eng.*, vol. 407, no. 1, p. 012103, Aug. 2018.

[6] R. A. Pamungkas, A. Maulana, D. P. Sya'ban, R. Ramdani, A. Musafa, and I. Riyanto, "Wi-Fi Data Communication System Design for Wheeled Soccer Robot Controller," *Advanced Science Letters*, vol. 24, no. 11, pp. 8782–8786, Nov. 2018.

[7] T. Mazhar *et al.*, "Quality of Service (QoS) Performance Analysis in a Traffic Engineering Model for Next-Generation Wireless Sensor Networks," *Symmetry*, vol. 15, no. 2, Art. no. 2, Feb. 2023.

[8] "ETSI TS 102 024-2 V4.1.1 (2003-09): Telecommunications and Internet Protocol Harmonization Over Networks (TIPHON) Release 4; End-to-end Quality of Service in TIPHON Systems; Part 2: Definition of Speech Quality of Service (QoS) Classes." ETSI, Sophia Antipolis Cedex - France.

[9] T. O. Aro, S. A. Adekeye, H. B. Akande, and B. O. Funso, "Application of Transmission Control Protocol (TCP) and User Datagram Protocol (UDP) in Teleconference System," *Journal of Computer Science and Control Systems*, vol. 12, no. 2, pp. 15–19, 2019.

[10] Y. Pratama, H. Soebhakti, S. Prayoga, and B. Budiana, "Localization System on Wheel Robot Soccer," in *ICAE 2022: Proceedings of the 5th International Conference on Applied Engineering, ICAE 2022, 5 October 2022, Batam, Indonesia*, European Alliance for Innovation, 2023, p. 127.