

Model and Method of Evaluating Performance of Transport Protocols (TCP and UDP) on a LAN Using OPNET Simulation

K. G. Gaya ¹; D. T. Ogbaka¹; and A. Na'imu²

¹Department of Pure and Applied Physics Adamawa State University, Mubi, Nigeria. ²Department of Physics, Collage of Health Technology, Michika, Nigeria.

Corresponding author: kennedygaya1@gmail.com

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Abstract

The fundamental aim of network providers is to provide service to the end users of the network without losing any meaning information. This can be achieved through efficient transport layer supported by different protocols. However, research on TCP and UDP performance is comprehensive but often overlooks modern LAN environments with varied traffic patterns and applications, with insufficient attention to protocol-specific parameters like TCP and UDP packet. In this work, performance of transport layer protocols in transmission control protocol (TCP) and user datagram protocol (UDP) is compared in terms of the traffic sent (packets/sec), traffic received (packets/sec) and packets dropped. The result shows that TCP ensures packets delivery than UDP. However, UDP does not guarantee packets delivery but it sent higher traffic. Finally, it was found that TCP performs 99% and UDP performs 86%. The result also shows that UDP sent more HTTP, E-mail, Database and File transfer traffic than TCP by 15.08886, 8.2711, 16.0731, 2.8358 packets respectively. However, TCP receives more HTTP, E-mail, Database and File transfer traffic than UDP by 3.4933, 0.9157, 0.2456 and 10.9522 packets respectively. OPNET simulations of TCP and UDP on LANs reveal optimal protocol configurations for applications like file transfers, these insights will guide efficient LAN design, QoS policies, and cost-effective virtual testing. The understanding of TCP and UDP dynamics in LANs through detailed simulation-based comparisons will enriches network performance models with new evidence. The findings may drive new theoretical models for protocol performance in emerging SDN and IoT-driven LAN environments.

Keywords: Performance, TCP, UDP, Packets Delivery, Protocols, OPNET, Simulation.

Introduction

The transport layer is very essential in Open Systems Interconnection model (OSI). It provides communication between the data and the session to ensure successful delivery of packets. Usually, transport layers provide efficient and reliable services to the end users of communication networks including wireless and wired networks. Without transport layer, it is impossible to achieve communication from source to destination. They are two types of protocols that makes communication of the transport layer possible. That is, transmission control protocol (TCP) and user datagram protocol (UDP) (Ketulkumar et al.,

2018). TCP and UDP performance in LAN use several models and methods in revealing the performance of TCP against UDP in terms of speed (Yuan-Cheng et al., 2019). The practical performance of UDP and TCP is also explored based on their characteristic's features (Hemant and Abhay, 2011). TCP establishes connection between two pairs of network users before packets can be transferred (end-to-end connection) (Karam et al., 2015) while UDP provides unreliable connection between two processes. UDP does not have their mechanism for retrieval of information and also data is lost randomly (Joseph, 2020). This confirms that, the protocol does not guarantee packets delivery. However, UDP is faster than TCP (Fahad et al., 2018). In addition, TCP and UDP use internet protocol (IP) at the lower layer as best effort delivery services. In fact, IP encapsulate both TCP and UDP in separate occasions to deliver information across router connected on the network. A reviewed studies demonstrate that TCP and UDP have distinct strengths and weaknesses in LAN environments when evaluated using OPNET simulations (IEEE, 2024; Abdelmoniem and Bensaou, 2024; Watanabe and Hasegawa, 2024; Mali and Misra, 2024). TCP excels in reliability and congestion control, making it suitable for applications like FTP and data transfers requiring guaranteed delivery (IEEE, 2024; Abdelmoniem et al., 2024). UDP, however, offers lower potential, benefiting real-time applications like multimedia streaming but at the cost of reliability (Mali et al., 2024; Watanabe et al., 2024). These findings emphasize the need for context-specific protocol selection and potential hybrid solutions to optimize LAN performance (Watanabe et al., 2024; Mali et al., 2024). In LAN environments, where high-speed connections and diverse traffic patterns are common, evaluating their performance is critical. (Friday et al, 2011) conducted a performance analysis of TCP in a reliable connection's environment with UDP flows using OPNET Simulator.

The motivation for study arises from the critical role these protocols play in modern networks and the need to understand their behavior under various network conditions in terms of speed and reliability when it comes to packets delivery. (Friday et al, 2011; Muhammad, 2009). Study on TCP and UDP performance is wide but lacks focus on modern LAN environments with diverse traffic patterns applications and lacks insufficient study of protocol-specific parameters (TCP and UDP) packet loss. To actualize this work, the following objectives is employed:

- To develop a simulation model of a LAN environment using OPNET and use it as a test bed for evaluating transport protocols.
- To compare the performance of TCP and UDP based on HTTP, E-mail, Database and File transfer traffic
- To provide insights and recommendations on protocol selection and configuration for improved network efficiency and reliability in LAN environment.

Methodology

The use of OPNET, packet size and traffic types in evaluating TCP and UDP performance on LANs is justified by OPNET's robust simulation capabilities, the critical role of packet size

in determining network efficiency, and the need to model diverse traffic types to reflect real-world scenarios (IEEE, 2024; Abdelmoniem et al., 2024). These elements collectively enable comprehensive analysis of protocol behavior, offering valuable insights for optimizing network performance (Watanabe et al., 2024; Mali et al., 2024; IEEE, 2024). To developed network topology, set up and configuration in OPNET, the application configuration, task configuration, server, IP cloud and work station modules are added to the network environment as shown in figure 1. The following metrics parameters were used:1800(sec) simulation time, 1024bytes packets dimension, 2,264 maximum segment size (bytes), receiver buffer size (8,760) bytes and persist timeout at 1.0sec respectively to ensure the validity and reliability of TCP and UDP performance evaluation.

A. Transport Protocols for Local Area Network

The services of transport protocols feature some transport layers in local area network which include TCP and UDP. The transport protocols for each particular application have its importance and feature under specific environment as presented in table 2 and 3 for different types of packages.

B. Overview of Transport Protocols

For this study, two transport protocols were considered. That is, the TCP and the UDP to determine the application traffics of HTTP, Database traffic, E-mail traffic and File transfer traffic.

i. Transmission Control Protocol (TCP)

TCP of internet protocol is a standard for the majority of internet application and services such as HTTP, E-mail. Database and File transfer packets. TCP has a strong ability to established a strong end-to-end connection between two applications running on nodes of an IP-based network concepts of a reliable ordered stream of bytes. It ensures that the receiving end can build a stream of data as communicated by the first sender. The ability to managed flow control by avoiding transmitting of data application faster other than the receiving endpoint that can consume the transmitted data, control congestion and enable fairness and friendliness that avoids congestion.

ii. User Datagram Protocol (UDP)

UDP is a transport layer protocol that operates without a connection. Because there is no acknowledgment in the data transfer, it is untrustworthy. Therefore, an application software that uses UDP should handle specifically the end-to-end communication problems that would have been handled by a connection-oriented protocol. These problems could include congestion control, packetization and reassembly, flow control, transmission for consistent delivery, etc. It is quick because no phase of link setup and dismantling. For modest applications that don't require a dependable connection, it is therefore ideal. One of the importance of UDP is found in the services of DNS. UDP is a transport layer protocol that is used to obtain the IP address for a requested URL from DNS. However, because of

the losing packets, time-sensitive and real-time applications like speech and video traffic uses UDP better than ones that are delayed.

iii. Developing Network Topology and Simulation Model.

A simulation network topology is first developed using a setup wizard, the required components are then dragged in to the simulation environment as shown in figure 1.

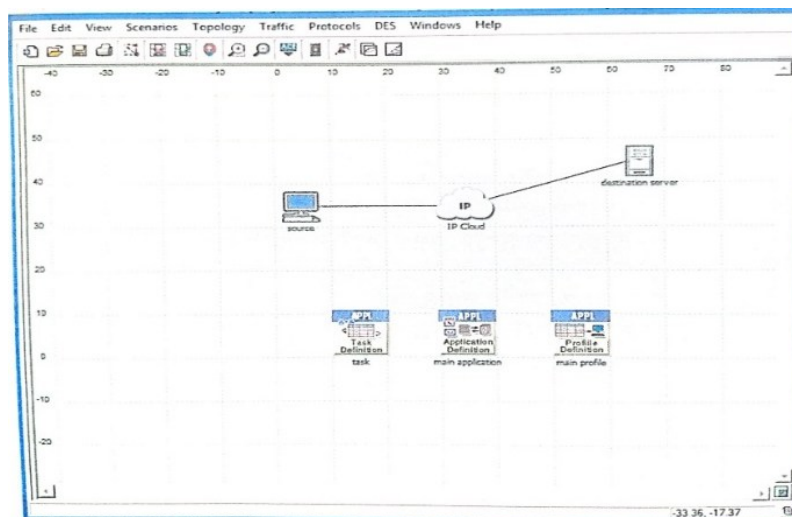


Figure 1. Network topology of the simulation

The component fields are set to perform their function, this includes the client host, PPP server, IP cloud, task configuration, Application configuration and profile configuration. Table 1 shows the parameter metrics.

Table 1: Metrics Parameters

Nodes	Simulations
Technology	PPP
Traffic monitored	HTTP, E-mail. Database, File transfer
Application configuration	Create Application
Profile configuration	Support profile
Task configuration	Create characteristics
Server	Support profile
Client	Support server
Links	100-Base T
Packets dimension	1024bytes
Simulation	1800 (sec)

III. Model Evaluation

The percentage performance and packet dropped for both TCP and UDP is determine using equation 1 and 2 respectively.

$$\text{Performance percentage (\%)} = \frac{\text{total traffic received}}{\text{total traffic sent}} \times 100 \quad (1)$$

$$\text{TCP/UDP dropped} = \frac{\text{packets dropped}}{\text{packets dimension}} \times 100 \quad (2)$$

$$\text{TCP/UDP Delay} = \text{Sending time} - \text{Receiving time}, \quad (3)$$

while the average delay will be determine using equation 4 as

$$\text{Mean delay} = \frac{\text{Total delay}}{N} \quad (4)$$

Where N represent the total number of packets received.

Results and Discussion

In this work, four simulation parameters were considered for simulation. The results of the simulation are presented in table 2 to 4 respectively.

Table 2: Overall TCP simulated results

Traffic monitored	Traffic sent	Traffic Received	Drop	Percentage (%)	Drop (%)
HTTP	98.3246	97.5734	0.7512	99.2%	0.075%
E-Mail	97.5104	96.9679	1.5425	99.4%	0.05%
Database	98.9486	97.2515	1.6971	98.3%	0.2%
File transfer	98.7821	97.7486	1.0335	99.0%	0.1%
Total	393.5657	389.5414	5.0243	99.0%	1.02%

Table 3: Overall UDP simulated results

Traffic monitored	Traffic sent	Traffic Received	Drop	Percentage (%)	Drop (%)
HTTP	113.4132	94.0801	19.3331	83.0%	2.0%
E-Mail	105.7815	96.0522	9.7293	91.0%	0.97%
Database	115.0217	97.0059	18.0158	84.3%	1.8%
File transfer	101.8343	86.7964	15.0379	85.2%	1.5%
Total	436.0507	373.9346	62.1161	86.0%	14.25%

Table 4: Comparison between TCP and UDP

Packets	TCP	UDP	Differences
Traffic sent	393.5657	436.0507	±42.485
Traffic received	389.5414	373.9346	±15.6068
Traffic dropped	5.0243	62.1161	±57.0918
Dropped (%)	0.4%	6.2%	±5.8%
Performances (%)	99%	86%	±13

V. TCP/UDP Graphical Relationship

The graphs in figure 2-9 show the relationship between both TCP and UDP protocols for each of the application traffic (HTTP, E-Mail, Database and File transfer) in terms of traffic sent and traffic received.

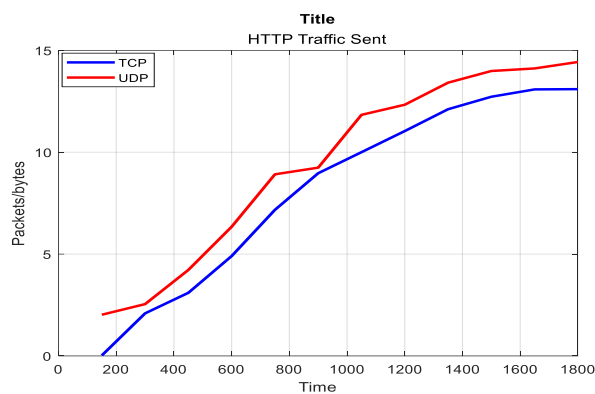


Figure 2. HTTP traffic sent

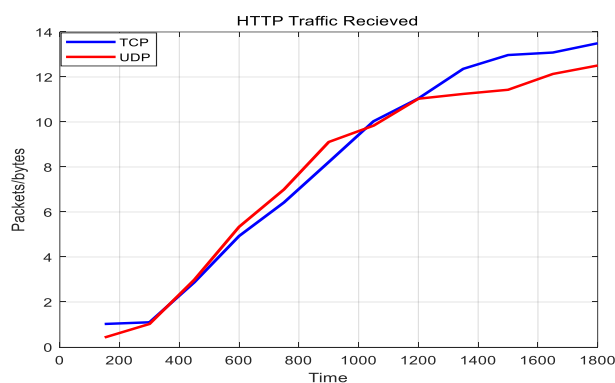


Figure 3. HTTP traffic received

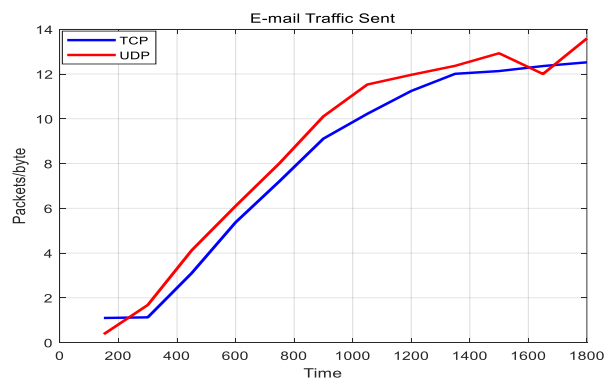


Figure 4. E-Mail traffic sent

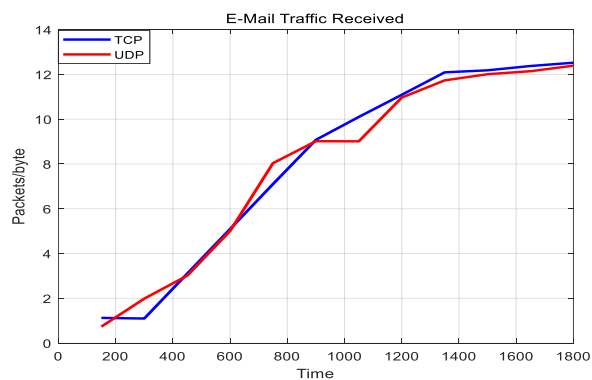


Figure 5. E-Mail traffic received

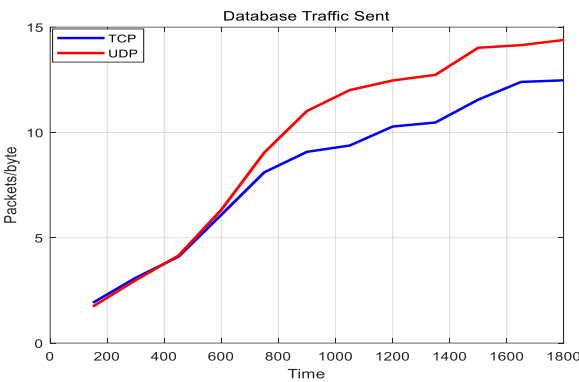


Figure 6. Database traffic sent

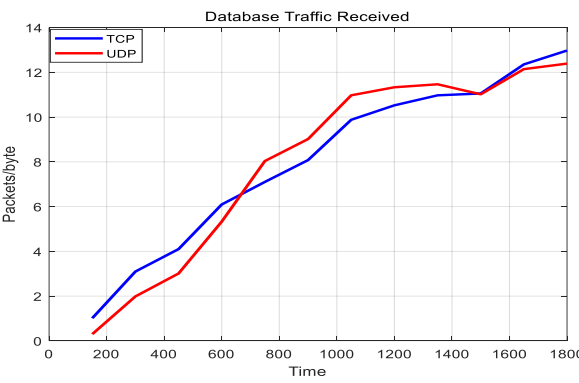


Figure 7. Database traffic received

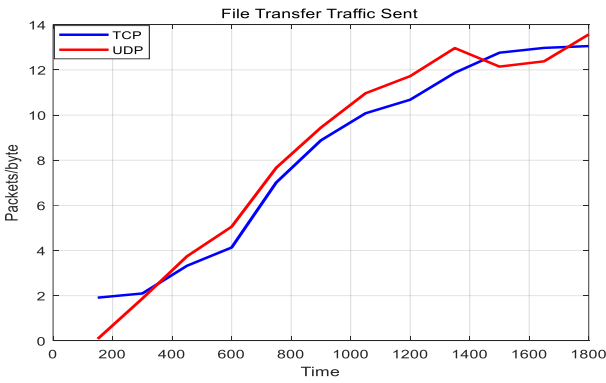


Figure 8. File Transfer traffic sent

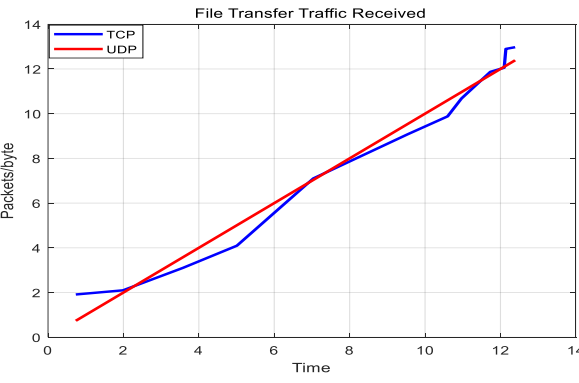


Figure 9. File Transfer Traffic received

Table 2 and 3 present the number of traffic sent and traffic received in TCP and UDP. Traffic sent from the database records the highest number of traffic both in TCP and UDP, followed by file transfer from TCP and HTTP from UDP. E-mail also shows a similarity of level of traffic sent both in TCP and UDP. HTTP has the lowest traffic sent in TCP while file transfer has the lowest traffic sent in UDP. The level of number of traffic received by each packet in TCP and UDP does not correspond with each other packets. However, in TCP, file transfer records the highest number of traffic received, followed by HTTP, Database and E-mail respectively. In UDP, database records the highest number of traffic received, followed by E-mail, HTTP and file transfer accordingly.

Table 4 also show the comparative performance between TCP and UDP. The result of the comparison shows that in TCP, there is a significant drop in database, followed by file transfer, E-mail and HTTP respectively. Where as in the case of UDP, HTTP has a significant drop, followed by database, file transfer and E-mail. The high percentage of drop is due to the high number of traffic sent.

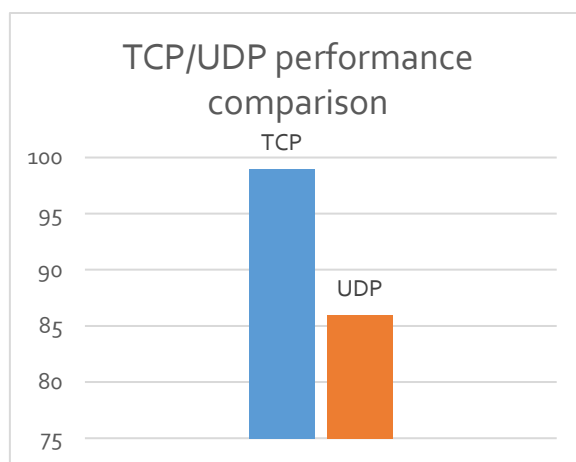


Figure 10: Graphical Performance comparison of TCP and UDP

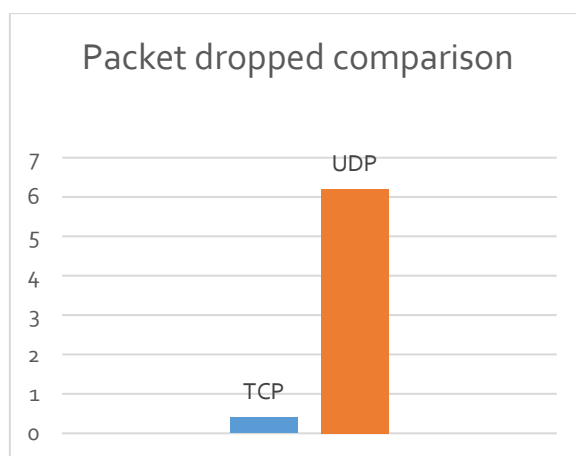


Figure 11: Graphical comparison of Packets dropped by TCP and UDP

As presented in table 4 and figure 10 and 11, a total drop of 1.02% and 14.25% was found in TCP and UDP with drop difference of $\pm 5.8\%$ with percentage LAN performance of 99% and 86% in TCP and UDP with a difference of $\pm 13\%$.

Conclusion

In conclusion, Both TCP and UDP are internet protocol IP and they are transport layer components that provide the connection between the network layer and the application layer. An optimistic Network Engineering Technology (OPNET) was used to monitor four (4) different traffic HTTP, E-mail, Database and File transfer. It was found that TCP performs 99% while UDP performs 86% which indicated that there is a more drops of packet in UDP than TCP. However, the research work focused on only two transport protocols (TCP and UDP) and four traffic types (HTTP, E-mail, Database, and File Transfer), which may not fully represent the diversity of network traffics and the use of OPNET for monitoring performance is a simulation-based approach, which may not fully capture real-world network complexities.

Significance and Application of TCP and UDP in Communication Networks

The research underscores the critical roles of TCP and UDP as transport layer protocols in facilitating communication between the network and application layers within the Internet Protocol (IP) framework. By evaluating their performance across four common traffic types; HTTP, E-mail, Database, and File Transfer using OPNET simulations. The study provides valuable insights into their reliability and efficiency. The findings show TCP's superior LAN performance (99% delivery rate with 1.02% packet drop) compared to UDP (86% delivery rate with 14% packet drop), which highlight TCP's suitability for applications and reliability, such as web browsing and file transfers, and UDP's utility in latency-sensitive applications despite its higher packet loss. These results are significant for network engineers and application developers in selecting appropriate protocols based on specific use case requirements, optimizing network performance, and informing the design of network Quality of Service (QoS) policies.

Recommendations and Further Research

The following recommendations and further research are observed:

- Use TCP for Critical and Reliable Data Transmission because it consistently outperformed UDP across all traffic types with a minimal packet drop rate (1.02%) and high delivery LAN performance (99%).
- Reserve UDP for Real-Time or Latency-Sensitive Applications because it allows faster data transfer without connection overhead, which is suitable where speed is prioritized over reliability.
- Optimize UDP Applications with Error Correction particularly HTTP and Database due to severe losses.

- Avoid Using UDP for High-Reliability Services Like HTTP or Database.
- Implement Network QoS Policies by Prioritize critical TCP traffic during congestion or overload.

Further Research Work can expand traffic type analysis, real world testing beyond OPNET simulations to validate findings under varying conditions, TCP and UDP performance over time under sustained network load.

Competing Interests

Authors wish to declared that no competing interests exist on the research.

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