An Investigation on the Performance of TCP Queue Based Computer Wireless Network

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Abstract— This work aims at investigating the performance of TCP queue based Computer Wireless Network. The TCP queue based computer wireless network has been known to be connection orientated with good level of reliability in information packets transfers. However, it suffers from time delay or slow packet delivery which may result to loss of data packets due to eventual traffic congestion. The objectives of this work are to measure the TCP queue data transfer traffic in an internet enabled computer network, to analyze the data traffic and to examine the performance of the TCP based network. The method applied here is the data traffic capturing using wireshark application software and data analysis using MATLAB. The results show that the least TCP queue network recorded least time of 0.6076seconds and the maximum time of 1.0821 seconds. It was concluded that the lowest TCP time is high and it may not support most networks that require faster data transfer, hence it needs to be improved upon. It was also concluded that the TCP time increased as the number of the sources increased which may cause traffic congestion and eventually loss of data.

Index Terms— TCP; AQM; Wireless Network; Network Congestion; Packets; Time Delay; Data Loss

1 Introduction

THE tremendous growth of the Internet and the continuous increase in the number internet enabled network devices has increasingly resulted to high network traffic congestion problem. Network traffic congestion at routers may be caused by too many computer network sources trying to send an excessive amount of data with a rate that is too high for the network to handle. Network traffic congestion results in long time delays for data transmission and frequently makes the queue length in the buffer of the intermediate router overflow, and can even lead to network collapse [1], [2]. One important feature that has helped to reduce the congestion issue is the buffer management which plays an important role in congestion control for Internet routers. The high speed internet network achieved recently requires a reliable transport protocol such as the Transmission control protocol (TCP) which is a connection-oriented transport layer protocol of the Internet.

TCP is a network communication protocol designed to send data packets over the Internet through the International Standard Organization (OSI) layer. TCP is a transport layer protocol in the OSI layer and it is used to create a connection between remote computers by transporting and ensuring the delivery of messages over wireless networks such as the Internet. Transmission Control Protocol manages most of the information exchange because of its reliable scheme. TCP provides a scheme whereby a sender has authority to set its transmission rate using a window flow-control mechanism. The message sender continuously probes or queries the network's available bandwidth and increases its window size to garner maximum share of network resource after every successful transmission. For every successful end-to-end packet transmission, TCP increases the sender's window size. Conversely, TCP is designed to cut down the window size in half whenever a sender's packet does not reach the receiver and this causes packet loss. Such packet losses can affect network performance and reliability by decreasing the sender's effective transmission rate and increasing delay due to packet retransmission. Some of the problems of this scheme include flow-synchronization [3] and performance degradation due to the excessive time-outs and restarts arising when the trailing end of a sequence of data packets is dropped [4].

The congestion control was considered to enhance the TCP network because, in the absence of congestions there is high level of successful massage transfer and there will be no cut down of the window size. Hence there will be no packet losses. The purpose of congestion control with Active Queue Management (AQM) is to communicate each other more effectively because AQM has local information in the mechanism of computer networks and can manage computer networks.

This work aims to investigate the performance of the current TCP based computer wireless network. This was achieved by monitoring the TCP based computer wireless network traffic using an internet enabled computer system with a wireshark application system which can capture and analyze the internet traffic based on different transport protocols and application protocols.

2 LITERATURE REVIEW

In recent times, communication through the internet has developed to carry data, voice and video traffic and due to the rate of rise in the traffic there has been researches aimed at improving the functionality of the communication systems in order to maintain optimal performance of the system even in the future. Internet congestion occurs when the aggregated demand for a resource (e.g., link bandwidth) exceeds the available capacity of the resource [5]. Resulting effects from such congestion include long delays in data delivery, waste of resources due to lost or dropped packets, and even possible congestion collapse [6]. Therefore it is very necessary to avoid or control network congestion. Internet congestion control has two parts: 1) the end-to-end protocol TCP and 2) the active queue management (AQM) scheme implemented in routers [7]. AQM can maintain smaller queuing delay and higher throughput by purposefully dropping packets at intermediate nodes.

Over a past few years, problems have arisen with regard to Quality of Service (QoS) issues in Internet traffic congestion control [8]. AQM mechanism, which supports the end-to-end congestion control mechanism of Transmission Control Protocol, has been actively studied by many researchers in order to improve the performance of TCP. AQM mechanism controls the queue length of a router by actively dropping packets.

2.1 Congestion Control Technique

The TCP/AQM network is a physical system which suffers from varied forms of uncertainties due to the fact that it must be modeled for technological development and design improvement. The closed loop congestion control technique generates an error signal which needs to be continuously compensated in order to produce desired results. This is because the error signal changes with time. Secondly, In the process of modeling and linearizing the system there exist some level of discrepancies between the real system and its model. This discrepancy is cancelled or addressed by the application of a robust controller. The theory of control is very important in the development and improvement of systems and it has been applied in many fields of technology to realize better working systems. Congestion control refers to the techniques used to control or prevent congestion. Figure 1 shows the basic congestion control techniques. Congestion control techniques can be broadly classified into two categories [12]:

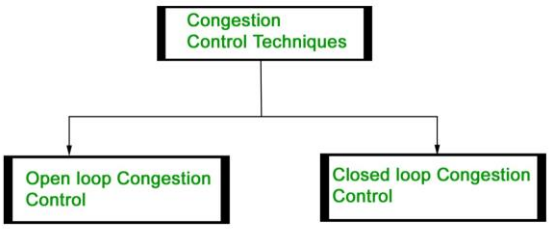

Figure 1: Basic congestion control techniques [12]

A. Open Loop Congestion Control

Basically, open loop control technique does not involve the feedback principle. This means that the output of the system or the congestion is not monitored and therefore, cannot be controlled when congestion occurs. Open loop congestion control policies or laws are applied to prevent congestion before it happens because output is not monitored. The congestion control in a network is handled either by the source or the receiver or destination before it occurs. In this case, optimization of the performance becomes very difficult to achieve. **Policies adopted by open loop congestion control [12]:**

1. **Retransmission Policy:**
   This is the policy in which retransmission of the packets are taken care when the sender notices that a sent packet is lost or corrupted, the packet needs to be retransmitted. This transmission may increase the congestion in the network.
   To prevent congestion, retransmission timers must be designed to prevent congestion and also able to optimize efficiency.

2. **Window Policy:**
   The type of window or window size at the sender side may affect the congestion in the network. Several packets in the Go-back-n window are resent, though some packets of information may be received successfully at the receiver side. When such duplication occurs, it may increase the congestion in the network and making it worse.
   Thus, selective repeat window should be implemented as it sends the specific packet that may have been lost in the network.

3. **Discarding Policy:**
   A good discarding policy adopted by the routers is that the routers may prevent congestion and at the same time partially discards the corrupted or less sensitive package and also able to maintain the quality of a message.
   In case of audio file transmission, routers can discard less sensitive packets to prevent congestion and also maintain the quality of the audio file.

4. **Acknowledgment Policy:**
   Since acknowledgement are also the part of the load in network, the acknowledgment policy imposed by the receiver may also affect congestion. Several approaches can be used to prevent congestion related to acknowledgment.
   The receiver should send acknowledgement for N packets rather than sending acknowledgement for a single packet. The receiver should send a acknowledgment only if it has to sent a packet or a timer expires.

5. **Admission Policy:**
   In admission policy a mechanism should be used to prevent congestion. Switches in a flow should first check the resource requirement of a network flow before transmitting it further. If there is a chance of a congestion or there is a congestion in the network, router should deny establishing a virtual network connection to prevent further congestion.

The above open loop control policies are adopted to prevent congestion before it happens in the network. Hence, such control law is limited and cannot address the problem of congestion when it eventually occurs.

B. Closed Loop Congestion Control

The close loop control technique is basically a feedback system which measures or monitors the output and compares it with the desired output or the reference input to generate an error signal which is continuously compensated for an enhanced output. Closed loop congestion control technique is used to treat or alleviate congestion after it happens. Several techniques are used by different protocols; some of them are [12]:

1. **Backpressure:**
   Backpressure as shown in figure 2 is a technique in which a congested node stop receiving packet from upstream node. This may cause the upstream node or nodes to become congested and rejects receiving data from above nodes. Backpressure is a node-to-node congestion control technique that propagate in the opposite direction of data flow. The backpressure technique can be applied only to virtual circuit where each node has information of its above upstream node.

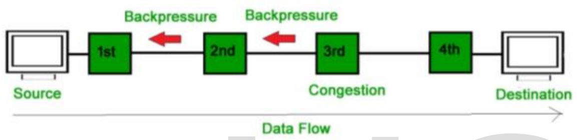

Figure 2: Backpressure technique [12]

   In above diagram the third node is congested and stops receiving packets as a result second node may get congested due to slowing down of the output data flow. Similarly first node may get congested and informs the source to slow down.

2. **Choke Packet Technique:**
   Choke packet technique as shown in figure 3 is applied in many network types such as virtual and datagram subnets. A choke packet is an information packet sent by a node to the source to inform the source of congestion. Each router in a network monitors its own resources and the utilization of its resource at each of its output lines. Whenever the resource utilization gets beyond the threshold value which is set by the network administrator, the router in such network directly sends a choke packet to the source giving it a feedback to reduce or regulate the traffic. The intermediate nodes in the network through which the information packets have traveled are not warned or informed about congestion.

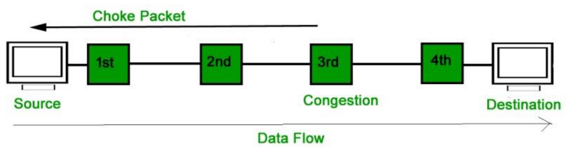

Figure 3: Choke Packet technique [12]

3. **Implicit Signaling:**
   In implicit signaling, there is no communication between the congested nodes and the source. The source guesses that there is congestion in a network. For example when sender sends several packets and there is no acknowledgment for a while, one assumption is that there is congestion.

4. **Explicit Signaling:**
   In explicit signaling, if a node experiences congestion it can explicitly sends a packet to the source or destination to inform about congestion. The difference between choke packet and explicit signaling is that the signal is included in the packets that carry data rather than creating different packet as in case of choke packet technique.
   Explicit signaling can occur in either forward or backward direction.

   1. **Forward Signaling:** In forward signaling signal is sent in the direction of the congestion. The destination is warned about congestion. The receiver in this case adopts policies to prevent further congestion.

   2. **Backward Signaling:** In backward signaling signal is sent in the opposite direction of the congestion. The source is warned about congestion and it needs to slow down.

2.2 Related Works

Network anomaly estimation for TCP/AQM networks using an observer was carried out in [13] where they stated that Network anomaly detection is an active research area in network community. It was stated also that researchers have approached such problem using various techniques such as artificial intelligence, machine learning, state machine modeling, and statistical approaches. The purpose of the work is to design an observer for network anomaly estimation for TCP/AQM networks using time delay system approach. It was presented that collaborating an observer with an AQM, constant anomalies considered as perturbations for the network can be detected. Figure 4 illustrates a network topology consisting of N TCP sources, with the same propagation delay connected to a destination node through a router and the bottleneck link is shared by N flows.

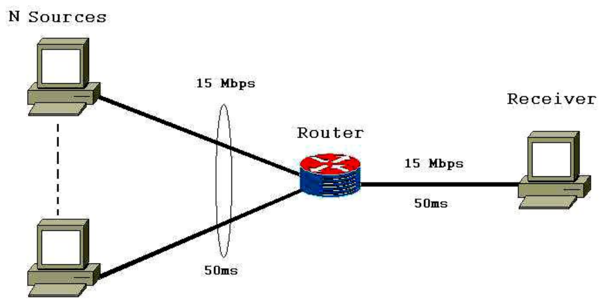

Figure 4: Network topology [13]

Addressing performance degradations in end-to-end congestion control has been one of the most active research areas in the last decade [14]. Active queue management (AQM) aims to improve the overall network throughput, while providing lower delay and reduce packet loss and improving network. The basic idea is to actively trigger packet dropping (or marking provided by explicit congestion notification (ECN)) before buffer overflow. As proposed in [14], Radial Bias function (RBF)-based AQM controller is suitable as an AQM scheme to control congestion in TCP communication networks since it is nonlinear. Particle swarm optimization (PSO) algorithm was also employed in their work to derive RBF parameters such that the integrated-absolute error (IAE) is minimized. Furthermore, in order to improve the robustness of RBF controller, an error-integral term is added to RBF equation. The results of the comparison with Drop Tail, adaptive random early detection (ARED), random exponential marking (REM), and proportional integral (PI) controllers were presented. Integral-RBF has better performance not only in comparison with RBF but also with ARED, REM and PI controllers in the case of link utilization while packet loss rate was small.

In most recent works, control theory methods have been applied in congestion control problem especially the feedback method due to its ability to measure the output of the system and compare it with the desired or set input for continuous improvement of the final output of the system for performance optimization. These approaches can control the router queue length as a plant variable and balance between link utilization and queuing delay [15]. Figure 5 illustrates the schematic of control closed-loop system and its components such as the AQM, the queue time delay which represents the process and the feedback subsystem which measures the actual output of the control system and feed it back to the system to be compared with the reference input variable to generate an error signal which is fed in to the controller for compensation and improvement of the system output performance. In this figure 2, Q represents the instantaneous queue length, Q_{ref} represents the reference queue length value or the reference input and the process represents a combination of subsystems such as TCP sources, TCP receivers, routers and *etc*.

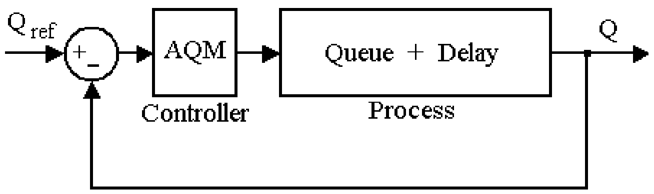

Figure 5: TCP based Congestion Control with an AQM Algorithm [15]

Many works have been proposed and implemented on the TCP queue congestion control but the TCP delay time or slow nature has continued to be its major problem. The TCP time investigation in this work aims at examining the current situation in the TCP performance based on the time used to complete message transfers in the network.

3 METHODOLOGY

Considering the TCP/AQM system in a real environment in figure 6, with uncertainties such as disturbances and noise, the inputs to the system becomes the reference input r, and uncertainty inputs: the disturbance D, and measurement noise N [16].

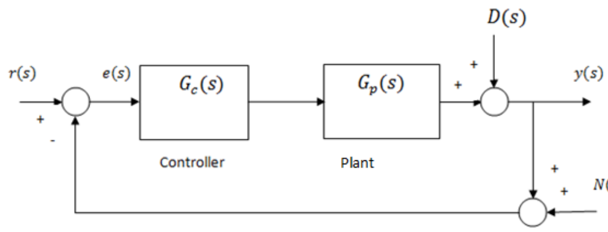

Figure 6: TCP/AQM with disturbance and noise inputs in real environment [16]

The general transfer function of the feedback TCP/AQM system is represented as follows (Agbaraji et al, 2020):

$$Y(s) = \frac{G_c(s)G_p(s)}{1+G_c(s)G_p(s)}(R(s) - N(s)) + \frac{1}{1+G_c(s)G_p(s)}D(s) \quad (1)$$

$$Y(s) = \frac{G_c(s)G_p(s)}{1+G_c(s)G_p(s)}R(s) - \frac{G_c(s)G_p(s)}{1+G_c(s)G_p(s)}N(s) + \frac{1}{1+G_c(s)G_p(s)}D(s) \quad (2)$$

$$E(s) = \frac{1}{1+G_c(s)G_p(s)}(R(s) - D(s) + N(s)) \quad (3)$$

$$E(s) = \frac{1}{1+G_c(s)G_p(s)}R(s) - \frac{1}{1+G_c(s)G_p(s)}D(s) + \frac{1}{1+G_c(s)G_p(s)}N(s) \quad (4)$$

Where R(s) is the reference input, Gp(s) is the TCP queue, Gc(s) is the AQM, D(s) is the disturbance input, N(s) is the measurement noise and Y(s) is the actual output of the TCP/AQM system.

Equation 4 shows that the error in the information transfer in the TCP based wireless network is influenced by the disturbances in the system and the measurement noise as a result of the AQM feedback technique.

3.1 TCP Performance Investigation

Internet service performance monitoring and data collection was carried out in a Local Government Area in Imo State using a computer server system connected to the internet through a router. The server system with Linux operating system and wireshark application system was connected to the internet for internet service monitoring and management. This means that the server system was used to manage the internet resources and monitor the network traffic. The Wireshark application system provides a platform or environment where most protocols such as the transport protocols e.g., TCP etc., are monitored for performance and congestion. In this case the performance is based on the TCP time which the protocol uses to resolve data transfer issues. TCP delta time measures how much time elapsed between the prior and current packet in the conversation or system to system information transfer session. When the time increases, the possibility of traffic congestion increases and it has been established already that the occurrence of traffic congestion causes failure in the information transfer between some senders or sources and the receivers and this automatically causes cut down of the window size which results to loss of packets or data.

The software monitors and records the network performance and the captured data analyses were carried out using MATLAB application system. This investigation of the TCP data transfer time will help to ascertain the performance of the TCP in the recent fast computer wireless networks.

4 RESULTS AND DISCUSSION

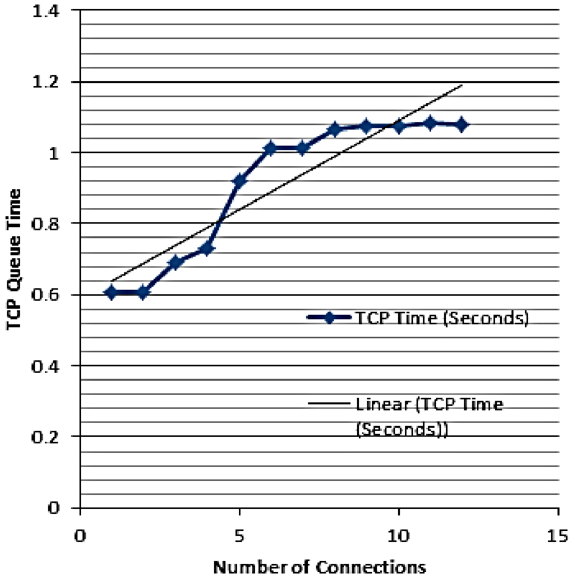

Figure 7: First TCP based Network Performance measurement

$$Y = 0.05X + 0.5881 \quad (5)$$

The results in figure 7 show that the TCP recorded least time of 0.6076 seconds and a maximum TCP time of 1.0821 seconds.

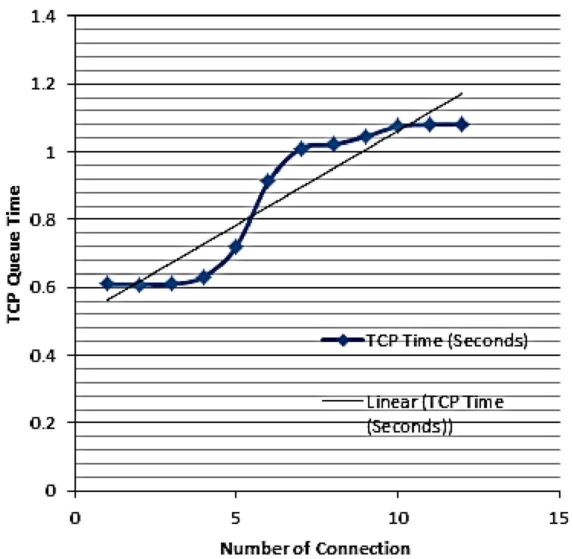

Figure 8: Second TCP based Network Performance measurement

$$Y = 0.0549X + 0.51 \quad (6)$$

The results in figure 8 show that the TCP recorded least time of 0.6101 seconds and the maximum TCP time of 1.0802 seconds.

The results show that the least TCP time is 0.6076 seconds and the maximum TCP time is 1.0821 seconds. This indicates that the lowest TCP time is high and it will not support most networks that require faster data transfer. The result also indicates that the TCP time increased as the number of the sources sending messages increased which will cause traffic congestion and eventually loss of data as the sources increases.

5 CONCLUSION

The TCP/AQM is an important aspect of communication networks especially networks that involve the internet. Due to the huge volume of data that is being communicated through the networks and the physical structure of the system, there exists an increasing amount of congestion which limits the performance of the network. The TCP/AQM has a primary function of controlling network congestion but due to the increase in complexity of the network and the amount of data being communicated, the TCP/AQM technique does not provide adequate congestion control.

From the literature review of the related works, it is very clear that TCP as an important component of modern day communication and which plays a key role in the smooth communication between a sender and the receiver has gained more interest in recent research. This is because, as the number of users is currently increasing tremendously, the communication system develops problems such as congestion due to high communication signal traffic. The wireless network has experienced a lot of improvements and it has been a medium through which most human daily activities recently rely on because of its speed and capability to link across people and nations. It has however, suffered from disturbances especially congestions which eventually result to poor performance or total collapse of the network. As a result, the wireless network seem to be unreliable in some situations especially when highly classified information transfer is involved because of the consistent network congestion which may result to data loss. The TCP is at the center of every wireless network because of its connection oriented nature. The TCP performance investigation was carried out successfully.

The results show that the least TCP time recorded is 0.6076 seconds and the maximum TCP time recorded is 1.0821 seconds. It was concluded that the lowest TCP time is high and it will not support most networks that require faster data transfer, hence it needs to be improved upon. It was also concluded that the TCP time increased as the number of the sources sending messages increased which will cause traffic congestion and eventually loss of data as the sources increases hence the TCP performs poorly when the sources of packets of information increases than when it is low.

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