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Analysis of ATM Adaptation Layers and Service Classes in Providing Quality of Service in a Distributed Systems

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Abstract

There has been an increase in the need for multimedia content on the internet deviating from the initial intention of the web as proposed by Tim Berner Lee. This therefore calls for a robust and reliable network infrastructure that will provide an increased in bandwidth, low latency and high availability of the network resources, hence the introduction of the ATM network. An ATM network was invented to support different application with divergent Quality of service (QoS) requirement. To support the QoS requirement of different applications running in the network, the ATM forum has outlined the service class category tailored for such applications. An evaluation of the performance of the distributed network was conducted through a simulation using the riverbed academic edition 14.5 simulator. In each of the experiment, there were two (2) scenarios, in which various multimedia applications deployed were configured to have the AAL2 and AAL5 on each category of the service classes. The study has found out that, some applications do have a high performance when configured on certain classes and AALs. Multimedia applications such as voice, audio and video which requires a tight constraint on delay should be configured on either CBR, nrt VBR and rt VBR for QoS and higher performance. Whiles text-based applications like email, ftp and http have a high performance when configured on UBR and ABR service classes. For database application, it was realized that, they have an optimized system performance and achieving QoS when configured on ABR service class.

Keywords: asynchronous transfer mode, services class category, simulation, quality of service

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INTRODUCTION

The pervasiveness of the computers in our society nowadays and the richness of the information on the internet has called for a more holistic approach to the management and deployment of our network infrastructure (Vedantham, 1997). There has been an increase in the need for multimedia content on the internet deviating from the initial intention of the web as proposed by Tim Berner Lee. This therefore calls for a robust and reliable network infrastructure that will provide an increased in bandwidth, low latency and high availability of the network resources, hence the introduction of the ATM network. The ATM network support multimedia content ranging from voice, data, image and video traffic (Model, 2008; Muller, n.d.). ATM is the backbone for Wide Area Network (WAN) and promotes inter carrier and inter vendor interoperability(Z. Bin Ali et al., 2011).

An ATM network was invented to support different application with divergent Quality of service (QoS) requirement. To support the QoS requirement of different applications running in the network, the ATM forum has outlined the service category tailored for such applications. Each of the service category has different QoS requirement. (Bernet, 2000; Xiao & Ni, 2009) defined QoS as the level of satisfaction derived from the communication service systems by the users. To the authors, they argued, that if computed, it is easily conveyed in terms of the level of disaffection expressed by the user. This disaffection may stem from "call blocking and dropping, packet loss, transmission delay and delay jitter and transmission error".

Data traffic is of a great concern to traffic management in ATM networks. The data traffic is defined by the authors as "having an absence of tight time delay restriction or the ability of this traffic to adapt its transmission rate to the available network resources." The loose requirement of the data traffic has inspired the ATM forum to develop the various service class category to cater for the different applications running in the distributed system. The service class categories have different objectives ranging from high network efficiency, fairness and interoperability of different network mechanism and offer different QoS. The theory of OSI model stated by (Uiphanit et al., 2019) provides standardization in computer network, as the ATM forum also provides standardization for transmission of multimedia content through the distributed system (Hieder et al., 2020).

ATM network technology is designed to support high speed multimedia applications in a networked environment. There has been an upsurge in the use of multimedia applications recently in the internet domain. These applications are accommodated on the ATM network by using the various service classes. These applications are required to exhibit their QoS and traffic requirement erstwhile to connection setup. On an ATM network, it is assumed that the required bandwidth requested by an application prior to connection will be made available during the entire duration of network connection and that the QoS will be affected negatively if the required bandwidth is not achieved (Vedantham, 1997). According to (Asante et al., 2021), despite "ATM Adaptation Layer is optimized for a specific type of traffic, there is no stipulation in the standards that AALs designed for one class of traffic cannot be used for another." There is a limited research or knowledge gap as to the effect of all the service classes and the various adaptation layers of the ATM on the performance of the distributed system. This paper is therefore seeking to bridge that gap in research by examining the impact of all the ATM adaptation layers and the influence of the service classes on system performance.

Research Objective

The aim of the paper is to examine the impact of the various ATM adaptation layers and service classes on the performance of an ATM network. The specific objectives are

- To examine the effect of all the ATM adaptation layers and service classes on network performance
- Assess the QoS requirement of the different multimedia application running on the network infrastructure
- Assess how much virtual path bandwidth will be needed to guarantee QoS and data throughput in an ATM network.

Research Questions

Based on the problem statement, the following research questions (RQs) will be investigated through experiment (simulations).

RQ1: What is the impact of all ATM adaptation layers and service classes on network performance?

RQ2: What is the QoS requirement of the multimedia applications on the network infrastructure?

RQ3: How much bandwidth is needed to ensure QoS in an ATM network environment?

Research Hypotheses

H1: ATM adaptation layers significantly impact on network performance

H2: Service classes positively impact on network performance

H3: QoS requirement of multimedia application significantly impact on network performance

Contribution of the paper

The research work is conducted to fill in the knowledge gap done by the earlier researchers in the area of ATM adaptation layers and service classes. The specific contribution of this work includes

- Examining the impact of all the ATM adaptation layers and service classes on network performance.
- Assess the QoS requirement of different applications running on the ATM network.
- Assess the total bandwidth needed to guarantee QoS in an ATM network.

LITERATURE REVIEW

Asynchronous Transfer Mode (ATM) is a standard that have been developed to allow the simultaneous transfer of voice and data services (Horvath et al., 2020). To the authors, the ATM is based on cells as a transmission unit which is used to overcome the challenges encountered in the packet and circuit switched based network. The data traffics are enveloped into a single cell-based data stream for transmission. The ATM provides higher bandwidth and support different multimedia applications, better network security and simplified network management and operational services. To (Ibrahim Ali & Diyeb, 2017), ATM and Frame Relay are the two most widely used technologies or protocols with high speed and accuracy for interconnecting or multiplexing many wide area network (WAN). To the authors, the two technologies are connection oriented and support switching and multiplexing of different data traffic onto a single line and offers a dynamic bandwidth allocation.

According to (Zemrane et al., n.d.), the working principle of the ATM network is based on cell transmission and switching involving the virtual connections and multiplexing of the data traffic on to more than one transmission medium. To (Pavlou & Psaras, 2018), " the design principle behind the ATM was the reservation of network resources per micro-flow, i.e. application-to-application flow, through end-to-end network signaling." (Onyishi, 2014), describe the ATM networks as "a multi-service network to integrate different services like voice, music, telephony and video over a single network". According to the author, such multi service nature of the ATM is achieved by deploying network resource allocation which offered high QoS.

Multiplexing according to (Oluwatoyin et al., 2019), is the "simultaneous transmission of different messages over the communication network through a partitioning of the available bandwidth or other resources". According to the authors, application running on the network takes only small portion of the available bandwidth of the transmission channel and by multiplexing, small different applications can share the same channel often in opposite direction achieving full channel utilization. ATM is a protocol that accepts multiple streams of multimedia data, convert them into packets and statistically multiplexed them into cells using virtual circuit (VC). To (Oluwatoyin et al., 2019), the VC are logical connection which are setup in the network used for packet transmission and automatically torn down when not needed. A path as defined by (Oki et al., 2017) is a bundle of circuit with large capacity and offers cost effective transmission per bit as compared to a circuit which has a smaller channel capacity. The authors expound that, a path is configured based on traffic demand prediction and there is low traffic utilization in path as compared to circuit. In an ATM network, circuits are replaced by virtual circuit (VC) and multiple VC are lodged into a Virtual Path (VP) which are multiplexed into a single channel connecting the terminal nodes. (Shatnawi, 2019) explain that, a network is a connection between multiple sources and destinations which are connected through VC. Virtual Path (VP) has been introduced to simplify the network resource management which reduces the processing function and processing load at the intermediate node.

According to (Aguodoh,2018), the ATM network employs a dedicated signaling channel which is use to set up and tear down connection between two nodes. These signaling are; User Network Interface (UNI) and the Network Interface (NNI). When a host node wants to set up a connection, the UNI entity on the host machine sends a setup message to the network which is a collection of ATM switches. The network then uses NNI to build a route between the host and destination node. The destination node then uses the UNI to complete the connection setup between them.

The unit of data transmission in the ATM network is small fixed sized packet or a cell of 53 bytes. To (Odii, 2017), cells in ATM network are identified as part of a group of logical connection identified by VCI which is labelled in header of the cell. The cell is 53 bytes long including 5 bytes' header. (Aju & Olajide, 2020) argues that the ATM network uses a zero routing and a special dedicated ATM switches to link the terminals in an end-to-end point connection allowing a direct flow of data traffic from the source node to the destination node. The authors contend that the ATM network uses a fixed sized cell to encode the data for transmission and each cell is processed at its own time, with the next cell in line processed afterwards. With the no routing and fixed sized cells, there is better utilization of the bandwidth in an ATM network according to the authors. The multiplexing and the integration of switching functions in an ATM network makes it ideal and suitable for bursty traffic.

Signaling in data communication and computer network is an act of exchanging user and various network control information between the user and the network, between two users or between two computer networks (Chand et al., 2016). According to the authors, in an ATM term, the ATM signaling forms the connection phase. Signaling establishes the desired link or virtual circuit and deactivates it after the transmission is finished.

There are two types of connection in an ATM network. They include the permanent virtual connection (PVC) which are established offline with a network management procedure and the Switched Virtual Connection (SVC) which is established dynamically in real time using the signaling procedure. In the SVC connection setup, two disparate signaling protocols are used. One of the protocols is used in entirely over the UNI whiles the other is used wholly within an ATM network(van Bosse & Devetak, 2007). The signaling protocol used in an ATM network is known as the signaling protocol Q.2931.

Connection admission control (CAC) is the series of tasks engaged in by a network during the call setup stage which considers whether to accept or reject a connection (Ray & County, 2018). According to the authors, "a connection request for a given call will only be accepted if sufficient network resources are available to establish the end-to-end connection while maintaining the required quality of service (QoS)". To (Ng & Tham, 2000), one of CAC criteria is to allot resources based on the availability of bandwidth necessary to guarantee the negotiated QoS. CAC happens before a client's information or data is admitted in the ATM network. To ensure quality of service is provided to the client, without affecting the quality of services needed for the data allowed for the network, a call is made to see if there are available resources for an end-to-end connection. The source information is examined by the CAC to ascertain its peak and average cells, burstiness, peak length, and the level of service that the source information will require, such as cell transfer delay, cell loss ratio, and burst cell loss. If everything is in order, a connection is created and the customer's data is allowed access to the ATM network. (C.Courcoubetis et al., n.d.), explained that, CAC is performed at every switch in the ATM network, whether there are available resources to accept a call. The authors opined that, the choice to accept or deny a connection is based purposely on the connection's bandwidth requirement and the availability of bandwidth for the chosen service category. (Leong & Zhuang, 2003), admits that, QoS is an important element of the future network systems and as such CAC is the first most critical function to be imposed on a user for QoS. The authors opined that, when a there is a request for new connection, CAC calculates the number (amount) of resources by considering the existing consumers (users) and the pending consumers, then sums up their total demands against the channel capacity. Upon this computation, that, the users request will be given a positive acknowledgement or rejected by the system for connection. As intimated by (Gelenbe & Mang, 1996), CAC is a very critical and sensitive issues in traffic control management in ATM network. They argued that, in meeting the required QoS requirement of any new connection, there should be enough resource in a position to establish the end-to-end interconnection which make best use of network resources in meeting user QoS.

To (Saleh et al., 2003; Shanmugavel et al., 2016), for the required QoS to be guaranteed, the CAC scheme implemented should make a decision based on the traffic descriptors, availability of network resources, number of existing connections and the quality requirement of the new connection before attempting to accept or reject the call for connection. The authors proposed CAC algorithm based on rate adaptation of source coders. In their proposed scheme, the decision to accept a new call into the network is primarily based on whether the call acceptance will guarantee the QoS specified by the user. However, call denied admission into the network have another chance of acceptance if the coders transmit at a lower rate. In this model, a call request has to be made after which the CAC controller determines the requested QoS based on the previous knowledge of the existing connection and resources. The call is admitted only when the requested QoS is met, otherwise, the CAC scheme enters into negotiation with the source for adjusting to a lower rate. The proposed algorithm averts congestion along the communication path as evident in the work of (Saleh et al., 2003). (Sigwele, 2017) opined that, one effective strategy in the avoidance of network congestion and the delivery of QoS request by the user is through an effective CAC scheme. The authors argue that, the CAC main task is deciding precisely the acceptance of a new connection based on fore knowledge of the resource constraints of a network without compromising the QoS requirement of the existing established connections. An experiment conducted by (Hanif et al., 2017) to compare the performance of the ATM network to the Point to Point Protocol (PPP) and Frame Relay shows that the ATM network performed better in response time , for the different applications used in the simulations i.e. (FTP, HTTP, Email and Remote login) and download response time for email, HTTP,FTP Remote login and

TCP delay. The short coming of this experiment was that the different applications were simulated differently and hence the researchers couldn't determine the response time and download response time when all the applications are run on the ATM network. In a similar vein, (Ibrahim Ali & Diyeb, 2017) have done a comparative study between the ATM and the Frame Relay protocol using OPNET as a simulation tool to analyze the performance of real time application such voice. The performance metrics used by the authors include (traffic sent, traffic received, delay, Jitter and the end-to-end delay). The results show a high value in traffic sent and received in ATM than Frame Relay protocol. The authors conclude that the ATM has a better transmission performance than the Frame relay. Also, the authors just dwell on only one application which is voice and the big questions as to what will the effect be on the system performance when all the multimedia applications are routed through an ATM system remains unanswered.

(Ikbal Ali et al., 2018), performed a simulation-based experiment using riverbed simulator to compare the performance of Synchronous Optical Network (SONET), ATM and Fiber Optic Link in WAN connection. In terms of the delay, the Fiber Optic link recorded the lowest delay, but cannot used to send message over a long distance. To the authors, SONET has a best result for delay but has time synchronization problem. The ATM network offers less delay than the SONET but has some packet loss than the SONET.

METHODOLOGY

The focus of this paper is to examine the impact of all the AAL and all the service classes on the system performance. An evaluation of the performance of the distributed network was conducted through a simulation using the riverbed academic edition 14.5 simulator. In each of the experiment, there were two (2) scenarios, in which the various applications deployed was configured to have the AAL2 and AAL5 on each category of the service classes. The experiment was conducted on Intel® Core ™ i5-8400 CPU @ 2.80 GHz with installed memory (RAM) of 4.0 GB on a 64-bit Operating system, x64 based processor running windows 10 Pro. The simulation was done across an enterprise network consisting of 20 workstations at each enterprise unit with different multimedia applications such as voice, audio, video and data being transmitted across the distributed environment. There were four subnets namely Ho subnet, Accra subnet, Takoradi subnet and Kumasi subnet with each subnet having five different clients assessing the different multimedia application across a server hosting the multimedia apps. The scenarios include CBR scenarios which was created by configuring the CBR service class and AAL2, AAL5 being the only service class and adaptation layer. The remaining scenarios were also created by altering the services classes that corresponds to the scenarios being created. In each of the experiments, the following multimedia applications (Database, SMTP, FTP, Voice and Video) were deployed in a distributed system in which 20 workstations were assessing all the application across a server with the respective service classes and adaptation layers.

To measure and do comparative analysis of the performance of the various AAL and the service classes category on system performance, we adopted the following known performance indicators - Throughput, upload and download response time, queuing delay, jitter, packet drop, link utilization and cell lost ratio. The simulation was then run for 3 hours and results collected and analyzed.

RESULTS AND DISCUSSION

This paper looks at the impact of all the service classes and adaptation layers on the network performance of a distributed system. This section discusses the results of the experimentation. The first research question was to find an answer to the impact of ATM Adaptation Layers and service Classes on network performance. The network performance metrics used to quantity the good performance of a network include; Link Utilization (%), Packet Delay Variation (Jitter) measured in seconds, Bandwidth and Data throughput is the same as in (Aju & Olajide, 2020). Table 1 shows the percentage of the available bandwidth consumed by each service class in the simulation exercise. From the table 1, it can be seen that, CBR service class consumes averagely 74.33% of the link capacity as compared to 71.67% for ABR service class. UBR service class records 51.67%, 65.33% for rt VBR class and 66.67% for the nrt VBR class. The packet delay variation (Jitter) as seen from table 1, records an average value of 0.402 seconds for CBR class, 1.34sec for UBR, 1.006sec for ABR, 0.482 sec for rt VBR and 0.196 sec for nrt VBR. Bandwidth shows how much data can be transmitted in the system. Bandwidth was measured by traffic received indicator (bits/sec) as shown in table 1. Averagely, 88.85bits/sec was recorded as email received in the CBR service class, 38.09bits/sec for UBR service class, 37.63bits/sec for ABR service class, rt VBR service class recorded 82.29bits/sec and 90.80bits/sec for nrt VBR service class. Data throughput which was the amount of data transmitted was measured in bits/sec as shown in table 1, with an average value of 84.23bits/sec for CBR service class, 50.51bits/sec for UBR service class, 58.46bits/sec for ABR service class, 88.99bits/sec for rt VBR service class and 62.76bits/sec for nrt VBR service class.

In answering RQ1, we analyzed the following performance metrics shown in table 1.

Table 1: Performance Metric Indicators

Scenarios	Link Utilization (%)	Jitter (seconds)	Bandwidth(bits/sec)	Throughput (bits/sec)
CBR	74.33	0.402	88.85	84.23
ABR	71.67	1.006	37.63	58.46
UBR	51.67	1.342	38.09	50.51
rt VBR	65.33	0.482	82.29	88.99
nrt VBR	66.67	0.196	90.80	62.76

From the table 1, it can be seen that CBR service class show great achievement in the performance indicators followed closely by nrt VBR service class and then rt VBR. From these values, it can be deduced that, the service classes; CBR, nrt VBR and rt VBR have a significant influence on the performance of the network as compared to the service classes ABR and UBR.

The research questions 2, seeks to access the QoS requirement of a network infrastructure in providing good system performance. QoS can be quantitatively measured using the following parameters; bandwidth, jitter, packet loss, packet end to end delay, link cell loss ratio and latency. Without QoS guaranteed in a network system, the network becomes disorganized, degrades systems performance and shuts down the entire network infrastructure. From table 1, the bandwidth usage is very high in services classes CBR, rt VBR and nrt VBR recording data bandwidth of 88.85bits/sec, 82.29 bits/sec and 90.80 bits/sec respectively. With this high usage of bandwidth, it will give an assurance to the multimedia applications traversing the network a guarantee QoS. Too much jitter in a network system degrades the network performance in terms of quality voice and video communication. From table 1, a CBR class records 0.402sec, 0.482sec for rt VBR and 0.196sec nrt VBR for jitter which shows a good indicator of QoS. Similarly, table 2, records the packet end to end delay for all service classes simulated. It shows an average record of 0.614sec for CBR, 0.921sec for rt VBR and 0.401sec for nrt VBR which again is a good indicator of QoS. Table 2, shows a record for link cell loss ratio with an average loss ratio of 0.577 for CBR, 0.785 for rt VBR and 0.488 for nrt VBR. From the analysis of the QoS indicators, they all record a smaller value for CBR, rt VBR and nrt VBR as compared to a slightly higher value for ABR and UBR service classes. From the above analysis, we can conclude that, QoS is achieved with the CBR, rt and nrt VBR service classes.

Table 2: Performance Metrics Indicator 2

Scenarios	Traffic Received(bit/sec)	Link Cell Loss Ratio	Packet End to End Delay (sec)
CBR	88.842	0.577	0.614
UBR	38.094	1.539	1.519
ABR	37.636	1.105	1.231
rt VBR	82.291	0.785	0.921
nrt VBR	90.801	0.488	0.401

The research question three is on how much bandwidth is needed to ensure QoS in an ATM network. From table 1, the link utilization shows the percentage of bandwidth consumed by each of the service classes. It can be seen that, nrt VBR have recorded 65.33 % link utilization achieving a higher throughput of 88.99bits/sec as shown in table 1. This goes to answer our RQ3, suggesting that, for QoS needed in an ATM network, there should be 65% link usage in the bandwidth of the available channel. All the results of our experiment goes to confirm the findings of (Aju & Olajide, 2020), which states that, FTP and email applications have QoS when configured on UBR and ABR service classes whiles voice application have better results when configured on CBR service class

CONCLUSION

The research work was conducted to find the impact of the different ATM adaptation layers and services classes on the performance of the distributed systems. Five different scenarios were simulated representing the various service classes (UBR, CBR, ABR, rt VRB, nrt VBR) and imposed on the various scenarios were the AAL2 and AAL5. Different multimedia applications were made to traversed the entire distributed system comprising of four different subnets each linking with an ATM network as the backbone. The simulation was done for three (3) hours and the results picked ten times, after which an average value for each of the various performance metrics were computed and analyses.

The study has found out that, some applications do have a high performance when configured on certain classes and AALs. Multimedia applications such as voice, audio and video which requires a tight constraint on delay should be configured on either CBR, nrt VBR and rt VBR for high QoS and higher performance. Text-based applications like email, ftp and http have a high performance when configured on UBR and ABR service classes. For database application, we found that, they have an optimized system performance and achieving QoS when configured on ABR service class.

RECOMMENDATION

For optimized network performance and QoS for multimedia applications on the network, we recommend that, application with tight constraints on delay should be configured on CBR, nrt VBR and rt VBR service classes. Text based applications should be configured on UBR and ABR service classes. Database applications should be on ABR service class for optimized system performance and high QoS.

Future Work

In this paper, we were limited by the Riverbed Modeler Academic edition 14.5, in that, we could not simulate all the AALs as the software is only limited to two AALs, that is AAL2 and AAL5. In the future work, we intend to simulate all the AALs to find their impact on network performance.

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