The Nucleus **49**, No. 2 (2012) 139-147

The Nucleus
A Quarterly Scientific Journal of Pakistan Atomic Energy Commission
NCLEAM, ISSN 0029-5698

PERFORMANCE ANALYSIS OF QoS CLASSES FOR ATM NETWORKS RUNNING DIVERSE APPLICATIONS

*M. A. KHAN

Department of Computer Science, Bahauddin Zakariya University, Multan, Pakistan.

(Received March 02, 2012 and accepted in revised form June 07, 2012)

This paper presents an in-depth analysis of the performance of various classes supported by ATM to attain Quality of Service (QoS). We incorporate a large network environment for analyzing the impact of the QoS classes CBR, VBR, ABR & UBR with regards to the FTP, E-mail & Database applications running on an ATM network. These applications are configured to execute in parallel with the Voice application. The simulations have been performed using the OPNET IT Guru Academic Edition v 9.1. Our experimentation results show that for the FTP application, CBR offers the minimum delay and is followed by VBR, UBR and ABR. For the Database application, all the classes of service perform almost similar, whereas for the E-mail application, the CBR service performs better and is followed by ABR, VBR and UBR in order.

Keywords: ABR, CBR, UBR, VBR, Computer Networks, Multimedia applications, QoS.

1. Introduction

High performance computer networks aim at minimizing the communication delays in order to benefit the end users running various applications. On the one hand, new communication protocols such as Asynchronous Transfer Mode (ATM) [1] are designed and on the other hand, existing protocols are improved by defining certain standards. In this regard, the Quality of Service (QoS) [2-5] is used to describe the requirements of a communication network in order to achieve better performance. The deployment of QoS in ATM networks makes it possible to efficiently transmit large volume of data. The QoS in ATM is provided by defining multiple classes of service including Constant Bit Rate (CBR), Variable Bit Rate (VBR), Available Bit Rate (ABR) and Unspecified Bit Rate (UBR) [6-10].

The computer networks using the ATM technology support transmission through multiple channels. The ATM technology provides efficient switching mechanism while incorporating time-division multiplexing (TDM) [1]. In contrast to the protocols using variable size data units (packets), ATM supports fixed size (53 bytes) data units called cells. Before transmission, a virtual circuit is formed by ATM connecting the source and the destination. The ATM protocol thereby results in efficient transmission of data over large distance and is therefore, used in public switched telephone networks (PSTN) and Integrated Services Digital Network (ISDN) [1, 11].

As the ATM cells are of fixed size, there is a need to ensure compatibility between the protocols that support varying sizes of the packets and ATM. It is implemented through ATM Adaptation Layer (AAL) [12,14]. The AAL standard defines the conversion to/from packets of other protocols and has been implemented through different mechanisms, each depending upon the class of service and the type of connection supported.

In this paper, we perform a comparative analysis of ATM classes of service including CBR, VBR, ABR and UBR, incorporated in the ATM networks running the FTP, Database and E-mail applications. Each application has different bandwidth requirement and execution pattern. To measure the performance, we have used the metrics: ATM cell delay, AAL delay, download response time, upload response time and database query response time. The simulation has been carried out using OPNET IT Guru Academic Edition v 9.1 [15].

* Corresponding author : mik@bzu.edu.pk

The rest of the paper is organized as follows. Section 2 describes the classes of service used by an ATM network. Section 3 describes the metrics used for performance evaluation. The related work is given in Section 4. The scenarios and the experimentation results are presented in Section 5 followed by conclusion and future work in Section 6.

2. ATM Classes of Service

The ATM protocol supports four main classes of service (CBR, VBR, ABR and UBR) to support or guarantee different QoS parameters such as the delay of a cell during transfer, the variation in delay and the number of cells lost during transfer of data. These classes are elaborated as follows.

2.1 CBR

The Constant Bit Rate (CBR) category [6,7] offers a fixed bandwidth to be available during the connection. It enables to maintain the Peak Cell Rate (PCR) during transmission. The Quality of Service is ensured by defining the values for the largest possible delay from source to destination, termed as Cell Transfer Delay (CTD) and the variation in delay termed as Cell Delay Variation (CDV) [1,2,3,7].

2.2. VBR

The Variable Bit Rate (VBR) [6,8] category supports real-time multimedia applications such as Voice over IP (VoIP) and Video Conferencing or applications that are sensitive to cell delay. It ensures to maintain the Sustained Cell Rate (SCR) and can also attain PCR. With the support of Maximum Burst Size (MBS), it transmits data in bursts that are not of fixed size.

Two types of VBR are implemented: real-time VBR (rt-VBR) [8] and non-realtime VBR (nrt-VBR) [16]. The rt-VBR is the most appropriate for real-time applications that are sensitive to delay. In contrast, the nrt-VBR class does not guarantee the similar QoS as in rt-VBR, but can attempt to conform to the latency/delay constraints.

2.3 ABR

The Available Bit Rate (ABR) [9] category supports the best-effort service with a bit rate that is not fixed. It offers the bandwidth that is adapted depending upon the availability of the resource during transmission. It also has a feedback based mechanism to implement the adaptation of the available bandwidth. It incorporates the parameter of Minimum Cell Rate (MCR) to ensure QoS and can also attain PCR.

2.4 UBR

The Unspecified Bit Rate (UBR) [10] category is useful for applications for which the transmission of data is not sensitive to the delays incurred. It has no guarantee of the Minimum Cell Rate (MCR) and is therefore, appropriate for data applications running over TCP/IP. In addition, it lacks the dynamic adaptation as performed by ABR.

3. Performance Metrics

The performance metrics used for evaluating the ATM QoS classes include the network specific metrics: ATM cell delay, AAL delay and the application specific metrics -- download/upload response times and the DB query response time. A succinct description of these parameters is given below.

3.1. ATM Cell Delay

The ATM cell delay parameter describes the delay (in seconds) incurred for a cell during transmission of data from the source to the destination. Since an ATM network transfers cells, the cell delay parameter represents the overall network performance as a global parameter.

3.2. AAL Delay

The AAL delay specifies the delay (in seconds) incurred at the AAL layer. It includes the conversion and the processing overhead required to make ATM cell format compatible with other protocol formats. Just like ATM cell delay, the AAL delay is also a manifestation of the network performance and represents a global parameter.

3.3. Download/Upload Response Time

For an FTP application, the Download Response Time parameter specifies the time (in seconds) taken by the application while the file was downloaded from the FTP server. Likewise, the Upload Response Time specifies the time taken for uploading the data to the FTP server.

For an E-mail application, the communication with the server takes place for a fixed size of the e-mail message. The download and upload response times therefore, refer to the communication times in the context of the e-mail message.

3.4. DB Query Response Time

For a database application, the DB query response time describes the time (in seconds) taken by the network to respond to the queries requested by the client. These queries are executed by the server and the results of each query are returned to the client.

4. Related Work

To the best of our knowledge, the performance comparison of the 4 classes of service with FTP, Database and E-mail applications being used in conjunction with Voice application has never been performed. An approach given in [17] performs a comparison of the performance of the applications for different QoS classes. Their model incorporates single QoS class for an application. In contrast, our approach compares the performance of the QoS classes of service in terms of various applications using 12 different scenarios.

The research work presented in [18] compares the QoS strategies such as FIFO, Priority Queue, WFQ etc., while incorporating intra-domain routing protocols including OSPF, RIP, IGRP and EIGRP. It differs from the comparison presented in this paper wherein we compare QoS classes of service including CBR, VBR, ABR and UBR that are used over an ATM network.

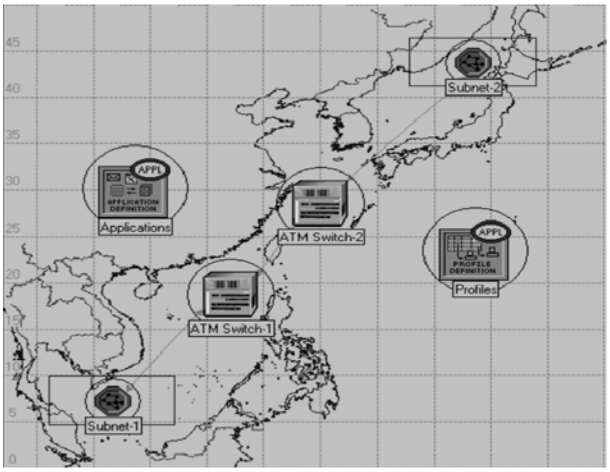

Figure 1. The simulated scenario with two subnets connected using ATM switches. The application object and profile object are used to configure the applications: Voice, FTP, E-mail and Database.

Similarly, the work presented in [19] compares the routing protocols for the performance of the applications. It incorporates a single queuing strategy First-In-First-Out (FIFO), to compare the performance of the routing protocols with regards to different applications, however, it does not target the QoS strategies as compared in this paper. In addition, we incorporate ATM protocol simulating a large network for performance evaluation.

5. Experimental Setup and Performance Results

Our scenarios simulate ATM network for the Asia region (supported in OPNET) using two subnets *Subnet*-1 and *Subnet*-2 as shown in Fig. 1. The subnets are connected using two core *atm8_crossconn_adv* switches named ATM *Swtich*-1 and ATM *Swtich*-2. The switches are connected to subnets using *OC3* links (maximum data rate of 155 Mbps).

Each subnet contains 6 clients: 4 application clients (*ApplicationClient*1-4) and two Voice clients (*VoiceClient*1-2) each of type *atm_uni_client_adv*, as shown in Fig. 2. The application clients are set to execute one of the FTP, E-mail or Database applications. The Voice clients use the IP telephony communication to simulate a peer-to-peer network. Therefore, no server is required for the peer clients of the Voice application. However, for all other applications, an application server is configured as the clients communicate with the server to send requests and receive response.

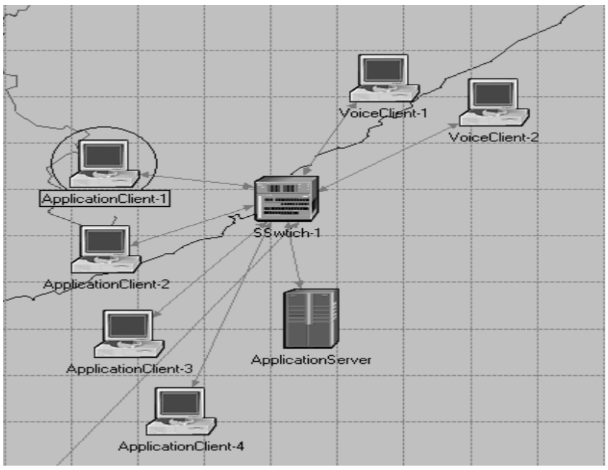

Figure 2. Each subnet contains 4 application clients and 2 Voice clients with one switch and an application server.

In each subnet, the clients are interconnected using Star topology with a switch (*SSwtich*-1 for *Subnet*-1 and *SSwitch*-2 for *Subnet*-2). The subnets use the ATM links of type *ATM_adv* that are configured to have data rate of *DS1* (maximum data rate of 1.544 Mbps). The central switch in each subnet is connected to the core switches so that the two subnets are also connected.

For all the scenarios presented in this paper, the simulations have been carried out for 300 seconds using the simulator OPNET IT Guru Academic Edition v 9.1. The performance metrics used for evaluating the ATM QoS classes include the ATM cell delay, AAL delay, download/upload response times and the DB query response time.

We simulate three different cases as given below:

Case-1: FTP application executing in parallel with the Voice application

Case-2: Database application executing in parallel with the Voice application

Case-3: E-mail application executing in parallel with the Voice application.

Each case contains 4 scenarios to cope with the CBR, VBR, ABR and UBR classes of service. Furthermore, for each case, the 2 Voice clients in *Subnet*-1 communicate with the 2 Voice clients in *Subnet*-2 through ATM network for each case. The 4 application clients in *Subnet*-1 communicate (send requests and receive response) with the application server in *Subnet*-2. Similarly, the 4 application clients in *Subnet*-2 communicate (send requests and receive response) with the application server in *Subnet*-1.

5.1 Case 1: FTP and Voice Application

An FTP client requests files from an FTP server. For this case, the application servers are configured to act as the FTP servers and the clients of one subnet request/receive files from the FTP server existing on other subnet. Each FTP client is set to request files of 500,000 bytes from the FTP server with an inter-request interval of 5 seconds.

For this case, the Voice application executes in parallel with the FTP application as indicated earlier. The Voice application is set to use the CBR class of service, whereas the FTP application is set to use the CBR, VBR, ABR and UBR classes of service, thereby producing 4 different scenarios.

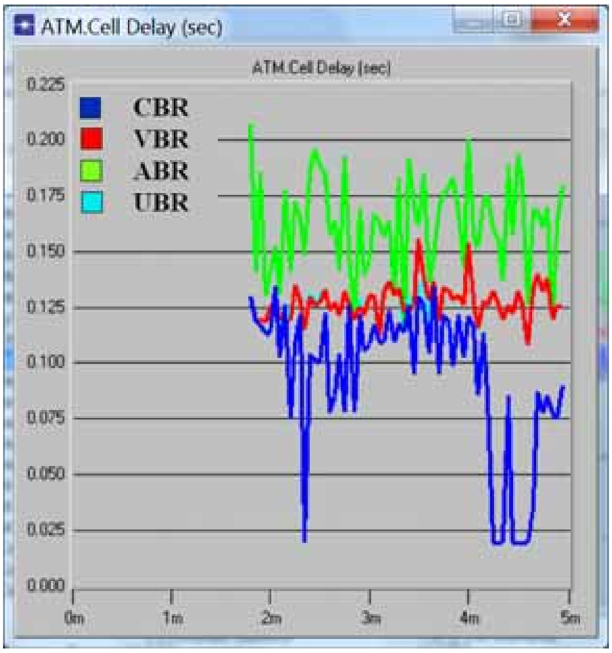

Figure 3. ATM Cell delay for Case-1 running FTP and Voice Applications.

Fig. 3 shows the results of the ATM delay. The CBR class produces the lowest average delay of 0.09417 seconds. The ABR class produces the largest average delay of 0.162434 seconds. The CBR class has improvement of 35.21%, 72.49% and 34.62% over VBR, ABR and UBR respectively.

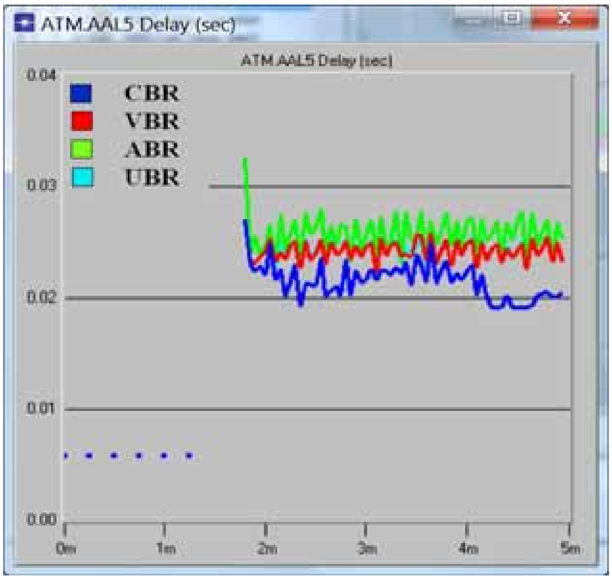

Figure 4. AAL delay for Case-1 running FTP and Voice Applications.

Similarly, the results of the AAL delay are shown in Fig. 4. The CBR class of service has the lowest average delay of 0.020 seconds, whereas the UBR class has the largest average delay of 0.023 seconds. The CBR class performs 12.23%, 19.36 and 12.40% better than VBR, ABR and UBR respectively.

The results of the FTP download response time are shown in Fig. 5. Although there is variation in the response time, the average response times for all the classes are very close. On average, the VBR class performs 3.52%, 0.89% and 0.39% better than CBR, ABR and UBR respectively. Similarly, for the upload response time, the results are shown in Fig. 6. The CBR class performs 4.22%, 51.04% and 9.9% better than VBR, ABR and UBR respectively. Overall, for the FTP application, the CBR class performs 21.63%, 56.42% and 24.46% better than VBR, ABR and UBR respectively.

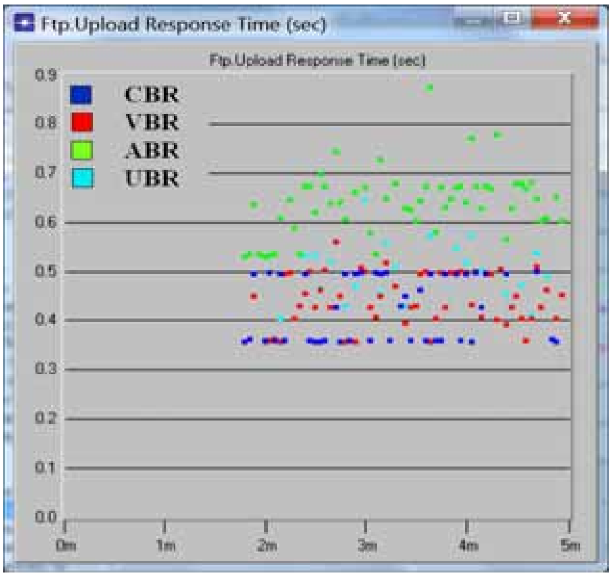

Figure 5. FTP Download response time for Case-1 running FTP and Voice Applications.

5.2. *Case 2: Database and Voice Application*

A database application with a transaction size of 32768 bytes is set to work with an inter-arrival time of 5 seconds.

The application clients send requests in the form of queries and receive response. The communication takes place with the database

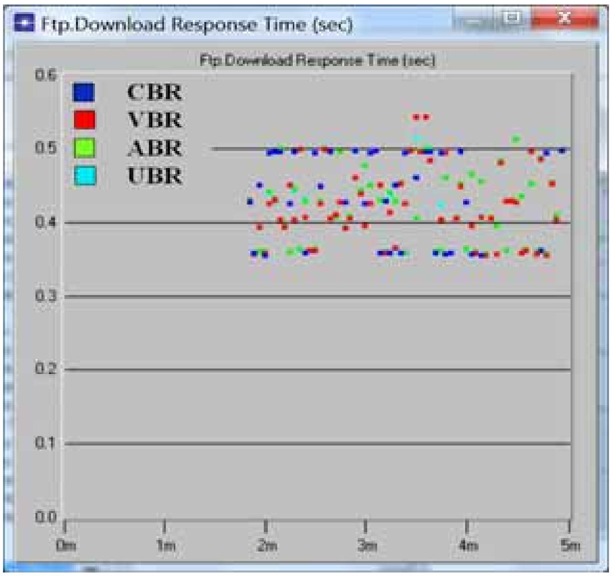

Figure 6. FTP Upload response time for Case-1 running FTP and Voice Applications.

server. The server in each subnet works as a database server to respond to the clients' queries for this case. Similar to the previous case, the clients from one subnet communicate (request/response) with the database server in other subnet, for this case as well. The communication for the Voice application uses the CBR class of service, whereas the database clients are set to use the CBR, VBR, ABR and UBR classes of service for 4 different scenarios.

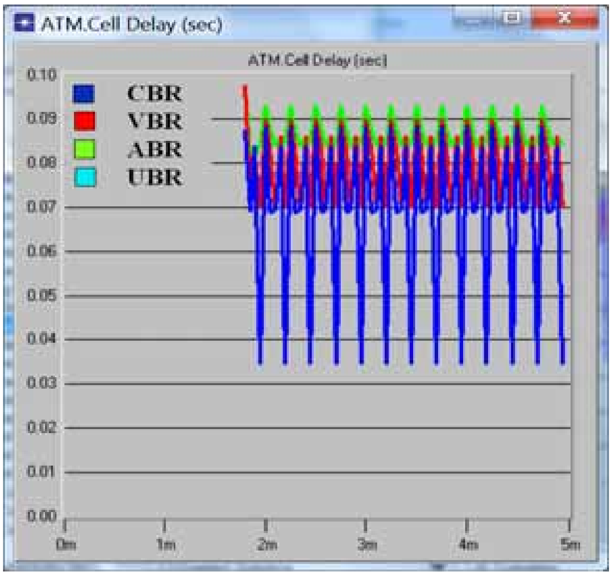

Figure 7. ATM Cell delay for Case-2 running Database and Voice Applications.

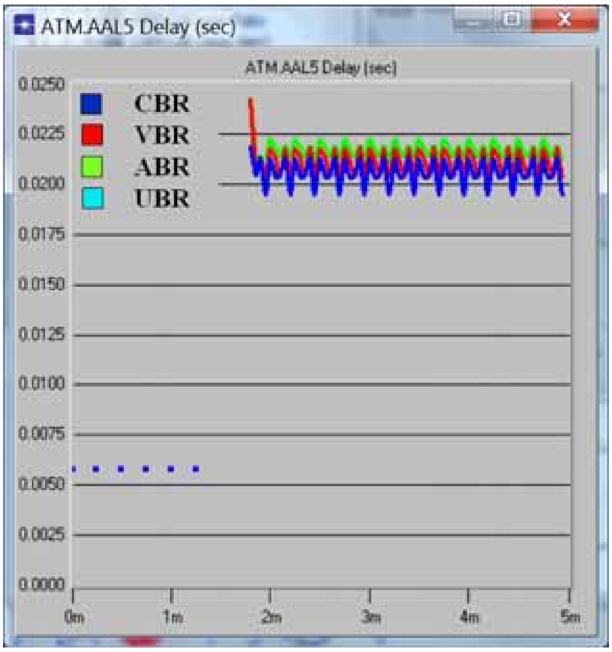

Figure 8. AAL delay for Case-2 running Database and Voice Applications.

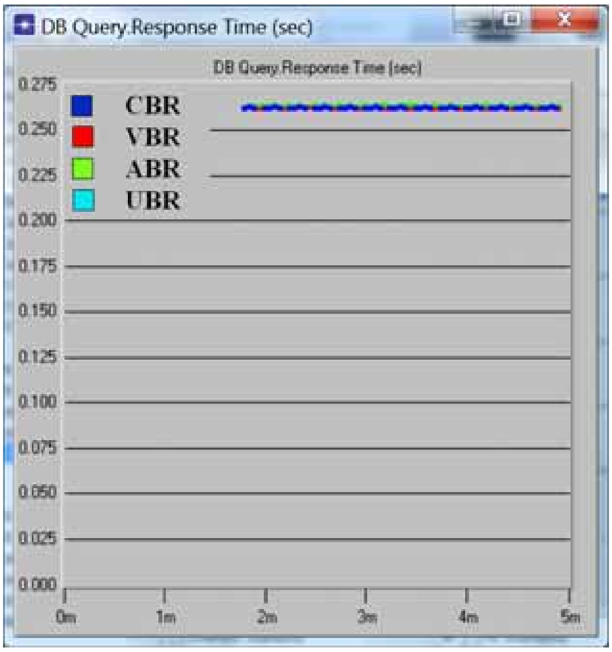

Figure 9. Database Query response time for Case-2 running Database and Voice Applications.

Fig. 7 shows the results of the ATM delay in seconds for the Database application being executed with the Voice application on the ATM network. Using the CBR, VBR, ABR and UBR classes of service, the average ATM cell delay is 0.069, 0.0797, 0.0869 and 0.0869 seconds respectively. Consequently, the CBR class of service performs better than VBR, ABR and UBR by 15.87%, 26.32% and 26.29% respectively.

Similarly, the results of the AAL delay are shown in Fig. 8. All the classes perform very similarly and do not differ by a large margin. The CBR class performs 2.64%, 5.58% and 5.55% better than VBR, ABR and UBR respectively.

The results for the Database query response time for all the classes of service are shown in Fig. 9. All the classes of service perform very similar and produce the average delays of 0.2617, 0.263 and 0.262 seconds respectively. The CBR class of service although performs better than all other services, the margin of improvement over other classes is less than 1%.

Overall, for the Database application, the CBR class of service performs 13.88%, 28.33% and 27.74% better than VBR, ABR and UBR respectively.

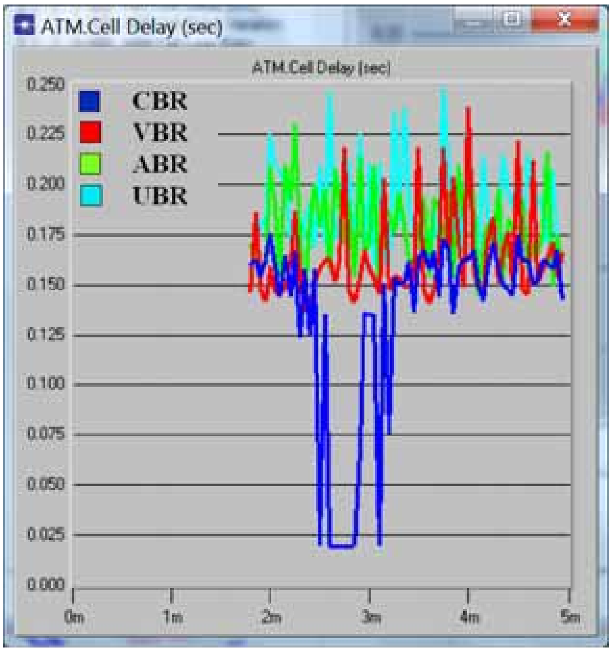

Figure 10. ATM Cell delay for Case-3 running E-mail and Voice Applications.

5.3 Case 3: E-mail and Voice Application

An E-mail client sends/receives message to/from an E-mail server. The application server in each subnet is configured to act as an e-mail server. The clients of one subnet communicate with the e-mail server on the other subnet.

The size of each message is set to be 20,000 bytes. The communication takes place multiple times and the messages are sent with an inter-arrival time of 5 seconds. Similar to the previous cases, the Voice application executes in parallel. The Voice application is set to use the CBR class of service, whereas the E-mail application is set to use the CBR, VBR, ABR and UBR classes of service, thereby producing 4 different scenarios.

The results for the ATM cell delay for case-3 executing E-mail and Voice applications are shown in Fig. 10. The CBR, VBR, ABR and UBR classes of service produce respectively the delays of 0.135, 0.163, 0.179 and 0.189 seconds respectively. Consequently, the CBR service performs 20.98%, 32.72% and 3.88% better than VBR, ABR and UBR respectively.

Similarly, the results of the AAL delay are shown in Fig. 11. The CBR class performance is very close to that of VBR and ABR, however, it performs better than UBR by a big margin. On average, it performs 0.36%, 10% and 35.89% better than VBR, ABR and UBR respectively.

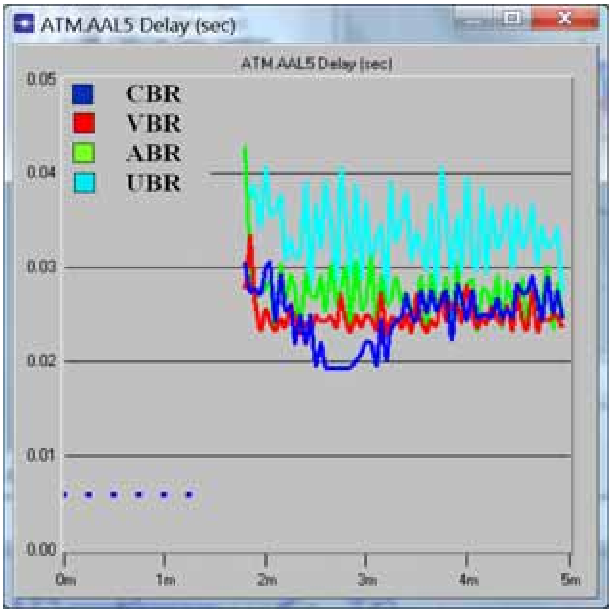

Figure 11. AAL delay for Case-3 running E-mail and Voice Applications.

The results for the download response time are shown in Fig. 12. The CBR, VBR, ABR and UBR classes of services produce the response times of 0.522, 0.78, 0.433 and 0.675 seconds respectively. It implies that the ABR class of service outperforms CBR, VBR and UBR by 20.39%, 80.10% and 55.67% respectively.

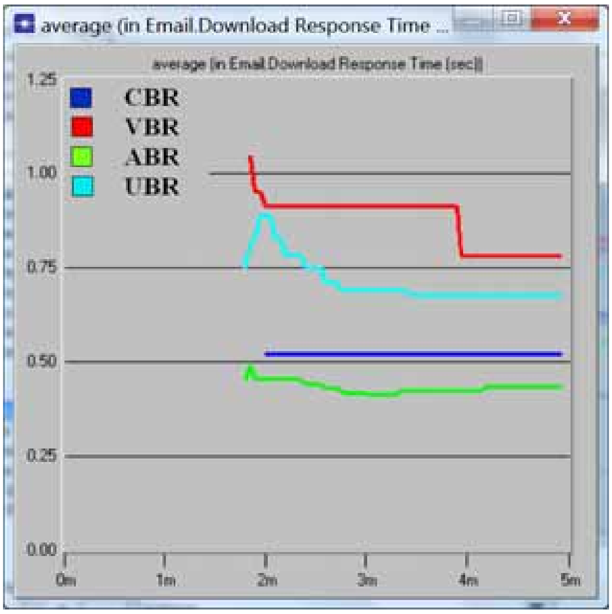

Figure 12. Download response time for Case-3 running E-mail and Voice Applications.

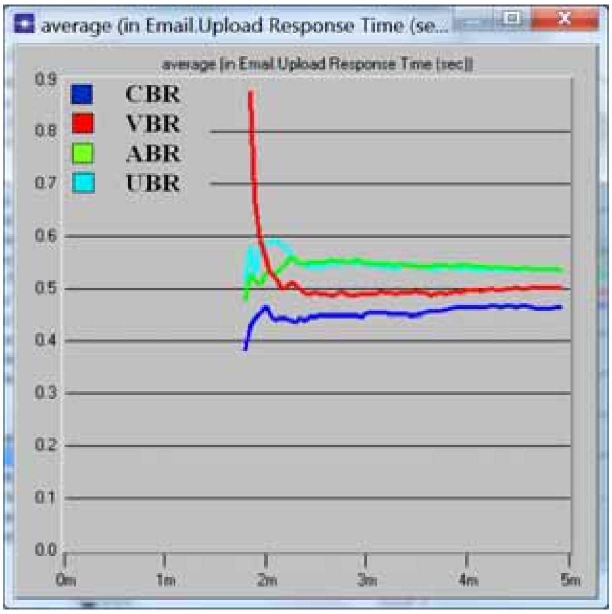

Figure 13. Upload response time for Cse-3 running E-mail and Voice Applications.

Similarly, the results for the Upload response time for case-3 are shown in Fig. 13. The CBR, VBR, ABR and UBR classes produce the average response times of 0.463, 0.502, 0.535 and 0.533 seconds respectively. The CBR service therefore performs better and has an improvement of 8.45%, 15.61% and 15.22% over VBR, ABR and UBR respectively.

Overall, for the E-mail application, the CBR class performs better than VBR, ABR and UBR by 28.96%, 14.94% and 69.17% respectively.

6. Conclusion

This paper presents a comparative analysis of the performance of the ATM classes of service. The analysis mainly aims at facilitating the researchers and users in improving the performance of the Voice, FTP, Database and E-mail applications (with diverse bandwidth requirements) being run on ATM networks. We consider CBR, VBR, ABR and UBR classes in this study. The performance metrics of ATM cell delay, AAL delay, download response time, upload response time and query response time have been used for evaluation. The simulation has been carried out using the OPNET IT Guru that is set to execute the Voice application in parallel with the FTP, Database and E-mail applications, thereby producing 3 cases (12 scenarios).

The networking scenarios simulate a large network running ATM protocol. Two subnets communicating with each other through core and edge ATM switches are deployed in the simulated network. The clients at a subnet connect to the server at other subnet for sending requests and receiving response. For each scenario, the Voice application executes in parallel and its 2 clients in one subnet communicate with 2 clients in other subnet by using the CBR class of service. For other applications, all the classes of service CBR, VBR, ABR and UBR are configured to execute.

For case-1 representing FTP application being executed with Voice application, the CBR class of service outperforms all other classes of service by a big margin. The performance of the CBR class is followed by VBR, UBR and ABR in order respectively.

Similarly, for case-2 representing Database application being executed with Voice application, all the classes of service perform very similarly. However, the overall CBR performance is 13.88%, 28.33% and 27.74% better than VBR, ABR and UBR respectively.

For case-3 representing E-mail application executing with Voice application, the overall CBR class performance is followed by the performance of ABR, VBR and UBR in order. The CBR class outperforms VBR, ABR and UBR by 28.96%, 14.94% and 69.17% respectively.

As future work, we intend to consider the interaction of the ATM protocol with the classes of service. It would facilitate in analyzing the impact of scalability on the performance together with other factors that may increase the communication delays.

References

[1] ITU-T, “B-ISDN asynchronous transfer mode functional characteristics”, ITU-T Recommen-dation I.150 (1999).

[2] ITU-T, “Terms and definitions related to quality of service and network performance including dependability”, ITU-T Recom-mendation E.800 (1994).

[3] ITU-T, “Internet protocol aspects - Quality of service and network performance”, ITU-T Recommendation Y.1540, (2007).

[4] IETF, “Framework for IP Performance Metrics---RFC 2330”, Internet Engineering Task Force (IETF) RFC-2330, 1998. Available: htp://www.ietf.org/rfc/rfc2330.txt.

[5] IETF, “Specification of Guaranteed Quality of Service -- RFC 2212 (Standards Track)”, Internet Engineering Task Force (IETF) RFC-2212, 1997. Available: http://www.ietf.org/rfc/rfc2212.txt.

[6] P. Ferguson and G. Huston, "Quality of Service: Delivering QoS on the Internet and in Corporate Networks", John Wiley & Sons, USA (1998).

[7] Cisco Inc., “Understanding the CBR Service Category for ATM VCs”, Cisco Documentation, USA, 2005. Available: http://www.cisco.com/en/US/tech/tk39/tk51/technologies_tech_note09186a0080094e6a.shtml

[8] Cisco Inc., “Understanding the Variable Bit Rate (VBR-rt) Service Category for ATM VCs.”, Cisco Documentation, USA, 2005. Available: http://www.cisco.com/en/US/tech//tk39/tk51/technologies_tech_note09186a0080094cd0.shtml

[9] Cisco Inc., “Understanding the Available Bit Rate (ABR) Service Category for ATM VCs.”, Cisco Documentation, USA, 2005. Available: http://www.cisco.com/en/US/tech/tk39/tk51/technologies_tech_note09186a00800fbc76.shtml

[10] Cisco Inc., “Understanding the UBR Service Category for ATM VCs.”, Cisco Documentation, USA, 2005. Available: http://www.cisco.com/en/US/tech/tk39/tk51/technologies_tech_note09186a00800a4837.shtml

[11] E. Ayanoglu, N. Akar, “BISDN (Broadband Integrated Services Digital Network)”, Encyclopedia of Telecommunications, April. 2003, John Wiley & Sons Pub., USA.

[12] ITU-T, “B-ISDN ATM Adaptation Layer Specification: Type 5 AAL”, ITU-T Recommendation I.363.5, 1996.

[13] Cisco Inc., “Guide to ATM Technology”, Cisco Documentation, USA, 2000. Available: http://www.cisco.com/univercd/cc/td/doc/product/atm/c8540/12_1/pereg_1/atm_tech/techgd.pdf

[14] IETF, “Multiprotocol Encapsulation over ATM Adaptation Layer 5---RFC 1483”, Internet Engineering Task Force (IETF) RFC-1483, 1993. Available: http://www.ietf. org/rfc/rfc1483.txt

[15] OPNET Tech., “OPNET IT Guru Academic Edition”, OPNET Technologies, USA, 2011. Available: http://www.opnet.com/university_program/itguru_academic_edition/

[16] Cisco Inc., “Understanding the VBR-nrt Service Category and Traffic Shaping for ATM VCs.”, Cisco Documentation, USA, 2005. Available: http://www.cisco.com/en/US/tech/tk39/tk51/technologies_tech_note09186a008010242.shtml

[17] S. Jain, S. Vijay and S. C. Gupta, Global Journal of Computer Science and Technology **2** (1987) 131.

[18] M. A. Khan, Journal of Peer-to-Peer Networking and Applications, (Submitted for publication, May 2012).

[19] A. Karim and M. A. Khan, Australian Journal of Basic and Applied Sciences **6** (2011) 1605.