The Nucleus **49**, No. 4 (2012) 299-308

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

APPLICATION SPECIFIC PERFORMANCE ANALYSIS OF FRAME RELAY NETWORK USING PVCS

*M. A. KHAN

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

(Received July 30, 2012 and accepted in revised form December 03, 2012)

Frame relay networks are incorporated in a Wide Area Network (WAN) to make communication possible across a large area. These networks use permanent virtual circuits (PVCs) to dedicate links for efficient communication by avoiding the repeated overhead of setup call. The PVCs use contract parameters such as Committed Information Rate (CIR), Committed Burst Size (BC) and Excess Burst Size (BE) to ensure specific standards of communication. With an application executing on a Frame Relay network, the PVCs affect the performance of the application depending upon the traffic passing through the network.In this paper, we analyze the performance of the Frame Relay network with respect to the applications executing on it. The PVCs are established in the network with high and low values of contract parameters (CIR, BC & BE). The throughput, network delay and delay variance are used as metrics for evaluating the performance of the network while executing FTP, Voice and Video applications. The experimentation results show that the increase in the values of the contract parameters reduces the delay for FTP application, whereas for the Voice application, the delay remains consistent. On the contrary, for the Video application, the network delay and delay variance increase with the increase in the values of the contract parameters. Furthermore, the throughput of the Frame Relay network increases for each application with the increase in the values of the contract parameters. With simultaneous execution of the three considered applications, the throughput, delay and delay variance increase with the increase in the values of contract parameters.

Keywords: Computer Networks, Frame Relay, PVC, Multimedia Application, FTP, Delay, Throughput, Committed Information Rate (CIR), Committed Burst Size (BC), Excess Burst Size (BE).

1. Introduction

Wide Area Networks (WANs) covering large areas for communication make use of several protocols such as ATM [1], X.25 [2] or Frame Relay [3]. These protocols have been optimized to facilitate transmission of data over large distances. The ATM protocol transmits voice and video by using small units of data called cells. These data units are of fixed size in contrast to the packets that may vary in sizes [1, 4] and are used by various protocols. Similarly, the X.25 protocol is also a protocol for WANs that initially supported packet switching for error-free communication. The Frame Relay network evolved after the X.25 protocol, however, in contrast to the X.25 protocol that operates on packets, the Frame Relay protocol works on frames. For communication in a WAN, all these protocols support virtual circuits or some equivalent mechanism for efficient transmission of data.

A Permanent Virtual Circuit (PVC) represents a dedicated link that continues to exist for a long time. In contrast, a Switched Virtual Circuit (SVC) builds connections on demand of a call and terminates the connection when the call is terminated [5]. A PVC therefore, incurs a small overhead by minimizing the call setup time. The Frame Relay networks are mostly used with PVCs for reliable and efficient transmission of data in a WAN. Each PVC may be configured with contract parameters that specify the Committed Information Rate (CIR), Committed Burst Size (BC) and Excess Burst Size (BE). The CIR value specifies the data transmission rate that is guaranteed by the network connection. Similarly, the BC value specifies the possible amount of data/burst that can be transmitted in a specific time interval. The BE value specifies the excess size of data that is not committed and may be delivered in a specific time interval. A PVC with high values of CIR, BC and BE is expected to ensure efficient transmission of data and vice versa. The design specific issues

* Corresponding author : mik@bzu.edu.pk

such as routing strategies or congestion control with virtual circuits and frame relay network have been analyzed in [6-9]. In contrast, this article presents a quantitative analysis of the performance of the frame relay network using permanent virtual circuits.

The performance of user applications depends heavily on the efficiency of the network. A client machine always requires timely transmission and reception of data for smooth running of its applications. An attempt to guarantee the efficient transmission of data requires the use of some parameters that are collectively termed as Quality of Service (QoS) [10-13]. Each application however has different bandwidth requirements. For example, each of the FTP, Voice and Video applications has different volume of traffic passing through the network at an instance. We, therefore, analyze the performance of these applications corresponding to contract parameters in order to tune them for efficient execution on the frame relay networks. The similar work reported in [14-17] also targets the performance analysis and optimization of the frame relay networks while taking into account different parameters. In [14], the authors use the Transmission Control Protocol (TCP) window size as a parameter to impact the performance of the network. A large value of window size specified at the TCP segment level improves the throughput of the network. The research work presented in [15] performs a performance analysis of the network file transfer using the parameters of IP address version, TCP window size and file size. It is shown that the network performance varies depending upon the IP address version corresponding to multiple window sizes and file sizes. In [16], the low priority traffic is shown to produce larger delays for Voice applications on frame relay networks. Similarly, the research work in [17] analyzes the performance of frame discarding mechanism in a Frame Relay network for leaky bucket and quantized moving window techniques. In contrast to these techniques, we evaluate the performance of the frame relay networks running the FTP, Voice and Video applications while simulating peer-to-peer (end-to-end) communication. We take into account high values of contract parameters termed as high configuration and low values of contract parameters termed as low configuration to represent various scenarios of the Frame Relay network. Each system can send and receive application data simultaneously. We measure the performance of the network using the metrics of throughput, delay & delay variance and also analyze the effect of high values of contract parameters on transmission of specific applications. The simulations are performed using the OPNET IT Guru Academic Edition v 9.1 [18] that supports network configurations with PVCs in a Frame Relay network.

The remaining part of the paper is organized as follows. Section 2 describes the configuration together with the scenario used as a basis for performing simulation. The experimentation results are presented and analyzed in Section 3, followed by the conclusion in Section 4.

2. Experimental Setup and Configuration

Figure 1 depicts the main scenario with 2 workstations communicating in a Frame Relay network. The workstations (Workstation-1 and Workstation-2) are of type *fr_wkstn_adv* and communicate via a PVC configured for dedicated communication using contract parameters (CIR, BC & BE). The workstations are connected to switches (each of type *fr8_switch_adv*) which are further inter-connected using a Frame Relay cloud (of type *fr32_cloud*). All the connections use links of type *FR_T1_int* to make communication possible in the network. We use two configurations of contract parameters with the first one termed as low configuration supporting low values:

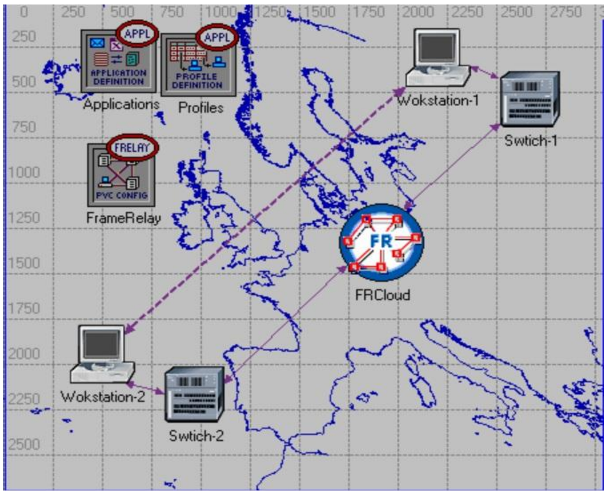

Figure 1. The main scenario describing and Frame Relay based network with 2 workstations communicating with each other through switches connected to a Frame Relay cloud. A PVC is maintained between the workstations for efficient transmission of data.

Table 1. Average Traffic Sent for each application and scenario in the Frame Relay Network.

No.	Application	PVC Configuration and scenario	Average Traffic Sent (Bytes/second)
1.	FTP	Low (FTP128)	46202.68
		High (FTP256)	61759.48
2.	Voice	Low (Voice128)	8289.68
		High (Voice256)	8128.72
3.	Video	Low (Video128)	752025.8
		High (Video256)	752025.8
4.	FTP, Voice & Video simultaneous	Low (FTPVoiceVideo128)	760818.9
		High (FTPVoiceVideo256)	762089.4

We perform experimentation for individual execution of each of the FTP, Voice and Video applications as well as for simultaneous execution of these applications. Consequently, there are eight scenarios used for experimentation with two configurations. Similarly, to record the impact of CIR on FTP, Voice and Video applications, we have nine additional scenarios (3 scenarios corresponding to each of the applications). Each scenario developed using IT Guru Academic Edition is set to execute for 400 seconds. The FTP application is set to transfer 10000 bytes with an inter-request time of 0.2 seconds. The Voice application is set to work in PCM Quality and Silence Suppressed mode, whereas the Video application is set to transfer high resolution video data. To evaluate the performance of the Frame Relay network, we use the throughput, delay and delay variance metrics corresponding to the traffic sent for each application.

3. Performance Results

The average traffic sent for each application corresponding to the considered PVC configurations is given in Table 1. The low configuration (for scenarios FTP128, Voice128, Video128, FTPVoiceVideo128) represents the configuration with CIR=128Kbps, BC=128Kbits & BE=32Kbits, whereas the high configuration (for scenarios FTP256, Voice256, Video256 & FTPVoiceVideo256) represents the configuration with CIR=256Kbps, BC=256Kbits & BE=64Kbits. It is evident that the Voice application transmits the smallest volume of data, and is followed by FTP and Video applications in order. For each application, the results of throughput, delay and delay variance are given in this section.

3.1. FTP Application

For the FTP application running on workstations, the results of throughput, delay and delay variance are given in Figures 2, 3 & 4 respectively. As shown in Figure 2, the scenario with high configuration produces a better throughput than the scenario with low configuration. The average throughput achieved by the network with low configuration is 70669.73 bits/second, whereas the average throughput achieved by the network with high configuration is 142781 bits/second. Consequently, the network with high configuration performs almost 2 times better than the network with low configuration.

As shown in Figure 3, the network with high configuration incurs a small delay in comparison with the low configuration. For FTP application, the volume of traffic is not very large thereby producing a small overhead of transmission and service of requests. Furthermore, the channel constructed by PVC with high configuration can cope with a large number of data units at an instance, therefore, it has a small value of delay as compared to that of low configuration. On average, the high configuration incurs a delay of 0.263 seconds, whereas the low configuration incurs a delay of 0.306 seconds. Consequently, the network with high configuration performs 1.17 times better than the network with low configuration.

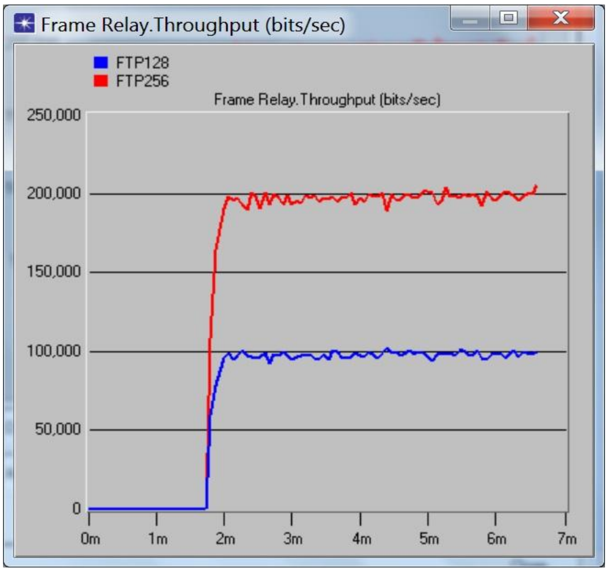

Figure 2. Throughput results for the FTP application executing on workstations

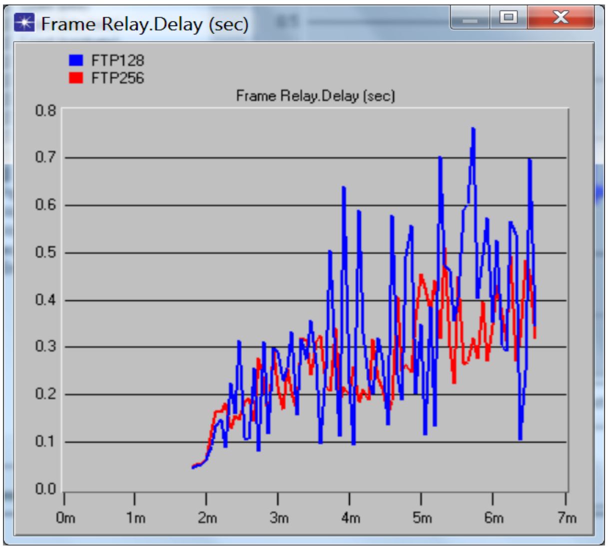

Figure 3. Delay incurred for the FTP application

The delay variance for the FTP application is shown in Figure 4. For both the configurations, there is a small gradual increase in the delay variance. It implies the fact that small bandwidth requirement for FTP applications makes them run smoothly. Overall, the FTP application with low configuration has an average variance of 0.055584, whereas, the high configuration has an average variance of 0.048211.

3.2. Voice Application

For the Voice application, the results of throughput, delay and delay variance are given in Figures 5, 6 & 7 respectively. As shown in Figure 5, the network scenario with high configuration produces a better throughput than the scenario with low configuration. This behaviour is similar to that of the FTP application. The average throughput achieved by the network with low configuration is 79001.95 bits/second, whereas the average throughput achieved by the network with high configuration is 106110.6 bits/second. Consequently, the network with high configuration performs almost 1.34 times better than the network with low configuration.

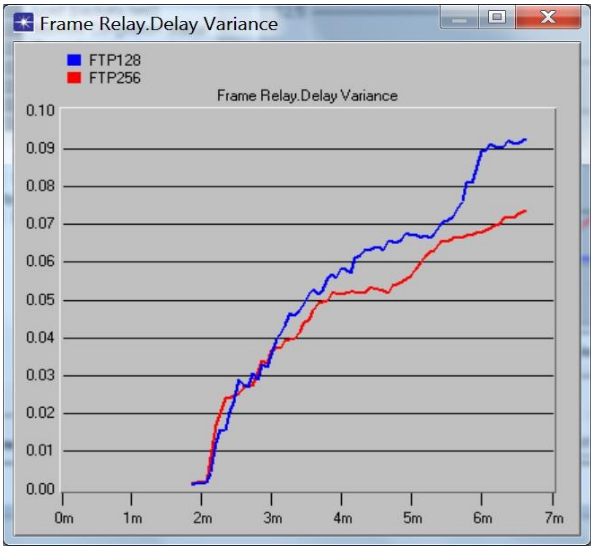

Figure 4. Delay variance for the FTP application.

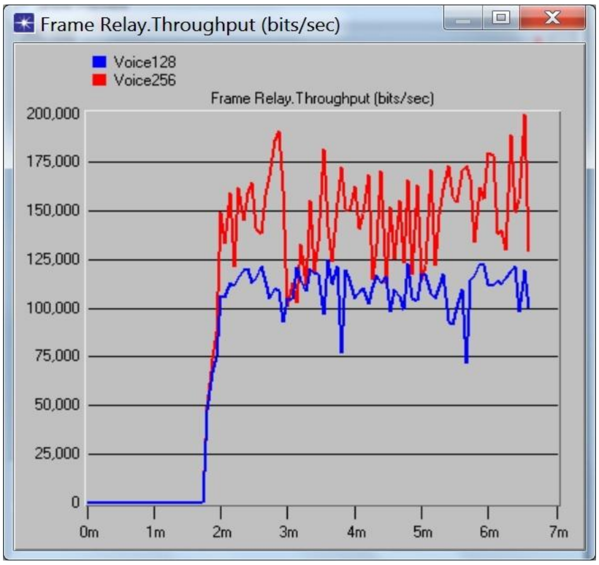

Figure 5. Throughput results for the Voice application executing on workstations.

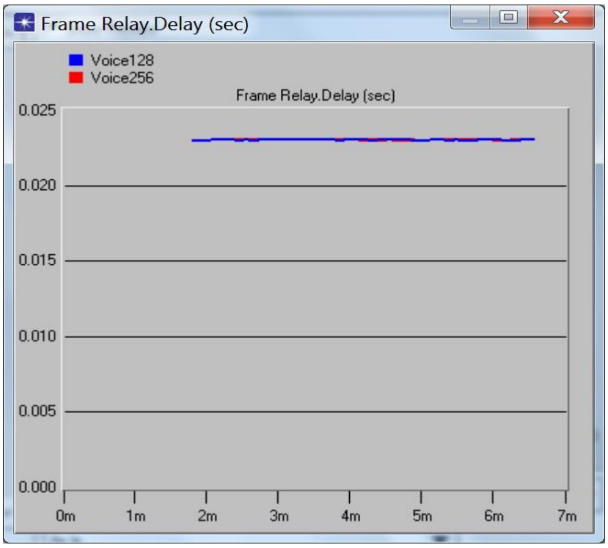

Figure 6. Delay incurred for the Voice application.

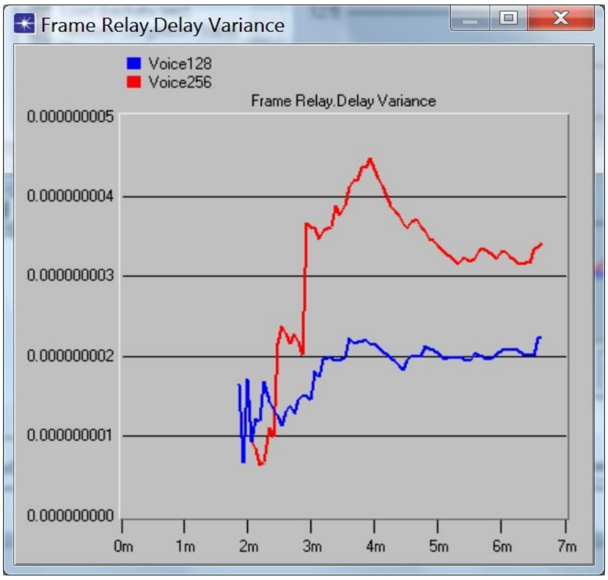

Figure 7. Delay variance for the Voice application.

It is evident from Figure 6 that both the configurations of the Frame Relay network have small delays. The Voice application has the smallest volume of traffic being sent across the network in comparison with the other considered applications, as mentioned in Table 1. Consequently, the delay incurred is also very small for both the cases. The network with high configuration has an average delay of 0.023025 seconds, whereas the network with low configuration has an average delay of 0.023022 seconds. It implies that the packets for both the configurations are being processed at the very similar speed in terms of transmission and service of requests.

The delay variance for the Voice application is shown in Figure 7. The Voice application has a low variance in comparison with the FTP application due to small bandwidth requirement. However, for both the configurations, there is a large increase in the delay variance. Since it impacts the packet arrival time, the performance of the Voice application executing in a real-time environment degrades gradually. Overall, the Voice application with high configuration produces 1.688 times more (average) delay variance than that with the low configuration.

3.3. Video Application

The results of throughput, delay and delay variance for the Video application are given in Figures 8, 9 & 10 respectively. As shown in Figure 8, the scenario with high configuration produces a better throughput than the scenario with low configuration. The average throughput achieved by the network with low configuration is 72186.42 bits/second, whereas the average throughput achieved by the network with high configuration is 146646.3 bits/second. Consequently, the network with high configuration performs almost 2.03 times better than the network with low configuration.

As shown in Figure 9, the network with high configuration incurs a high value of delay in comparison with the low configuration. For Video application, the volume of traffic is very large thereby producing a huge overhead of transmission and service of requests. Furthermore, the channel constructed by PVC with high configuration produces a high throughput implying that large number of data units are passing through it at an instance. It significantly affects the service time, and consequently, the performance of the network in terms of the delay deteriorates despite the high values of contract parameters. On average, the high configuration incurs a delay of 25.915 seconds, whereas the low configuration incurs a delay of 13.418 seconds. Consequently, the network with high configuration performs 1.93 times worse than the network with low configuration.

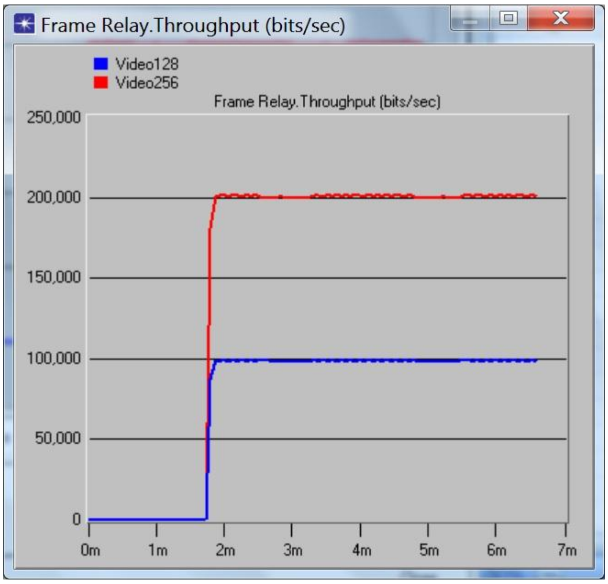

Figure 8. Throughput results for the Video application executing on workstations.

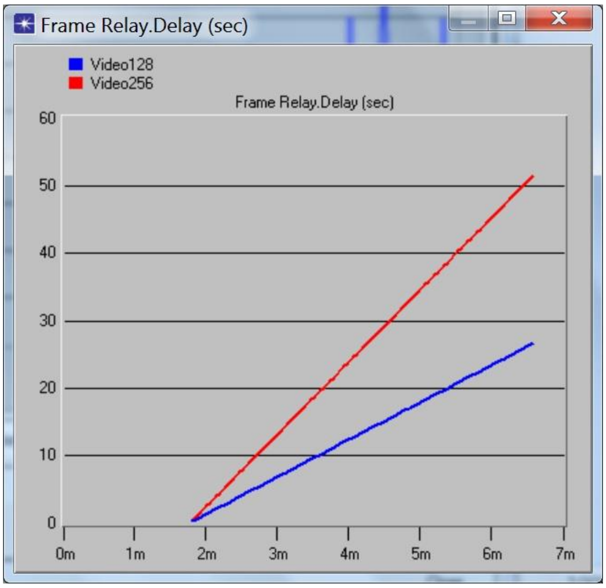

Figure 9. Delay incurred for the Video application.

Figure 10 shows the delay variance for the Video application. The Video application has a large variance in comparison with other applications due to large bandwidth requirement. For both the configurations, there is a large increase in the delay variance. Consequently, a real-time video application will not execute smoothly. Overall, the Video application with high configuration has an average delay variance of 80.106, whereas with low configuration it has anaverage delayvariance of 20.15. Consequently,

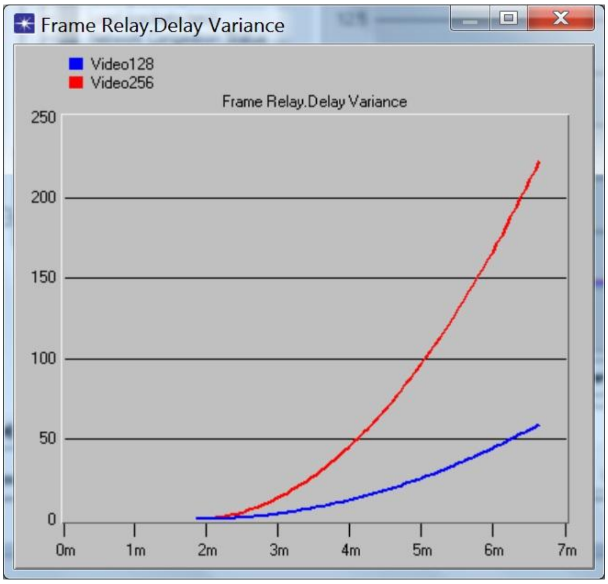

Figure 10. Delay variance for the Video application.

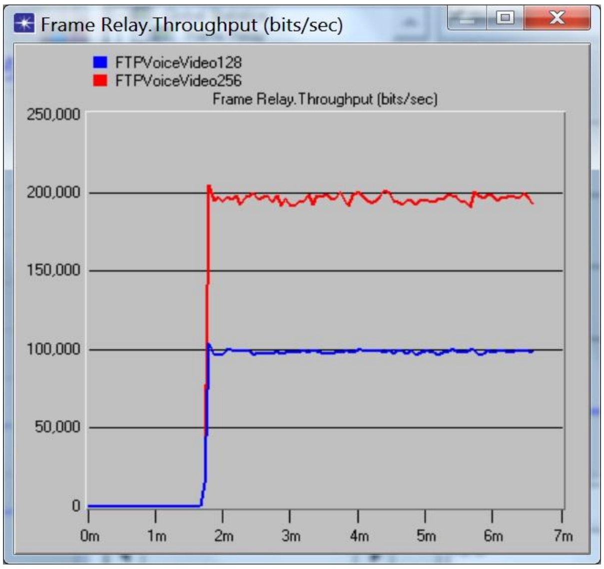

Figure 11. Throughput results for the FTP, Voice & Video applications executing simultaneously on workstations.

the application with low configuration performs 3.97 times better than high configuration.

3.4. Combined FTP, Voice and Video Applications

For the FTP, Voice and Video applications executing simultaneously on workstations, the results of throughput, delay and delay variance are given in Figures 11, 12 & 13 respectively. As shown in Figure 11, the scenario with high configuration produces a better throughput than the scenario with low configuration. The average throughput achieved by the network with low configuration is 72039.81 bits/second, whereas the average throughput achieved by the network with high configuration is 143508.2 bits/second. Consequently, the network with high configuration performs almost 2 times better than the network with low configuration.

As shown in Figure 12, the network with high configuration incurs a large delay in comparison with the low configuration. With simultaneously executing applications, the volume of traffic is very large thereby producing a huge overhead of transmission and service of requests. On average, the high configuration incurs a delay of 16.3 seconds, whereas the low configuration incurs a delay of 9.417 seconds. Consequently, the network with low configuration performs 1.73 times better than the network with high configuration.

The delay variance for the scenarios with simultaneously executing applications is shown in Figure 13. For both the configurations, there is a large increase in the delay variance. Overall, the scenario with low configuration has an average variance of 18.59, whereas the high configuration has an average variance of 75.812, thereby making the applications with low configuration execute smoothly in comparison with the applications executing with high configuration.

A performance comparison of the individual and simultaneous execution of applications is given in Table 2. It is evident that with both configurations (high and low), the combined execution of the applications has a very similar type of throughput as obtained for individual execution of the Video application. The Video application in both the cases transmits a large amount of data in comparison with other applications. It implies the fact that the network traffic in both the cases almost attains its threshold and a small difference occurs due to the packet processing time of the applications. Similarly, the average delay and the delay variance obtained with the simultaneous execution and individual execution of the Video application are very close. As the amount of traffic passing through the network at an instance decreases for the simultaneous execution of the applications, the delay also reduces in comparison with the individual execution of the Video application. It is therefore concluded that instead of creating individual virtual circuits/links for each application, a single virtual circuit may be used to execute FTP, Voice & Video applications simultaneously in order to obtain a very similar network performance at the same cost.

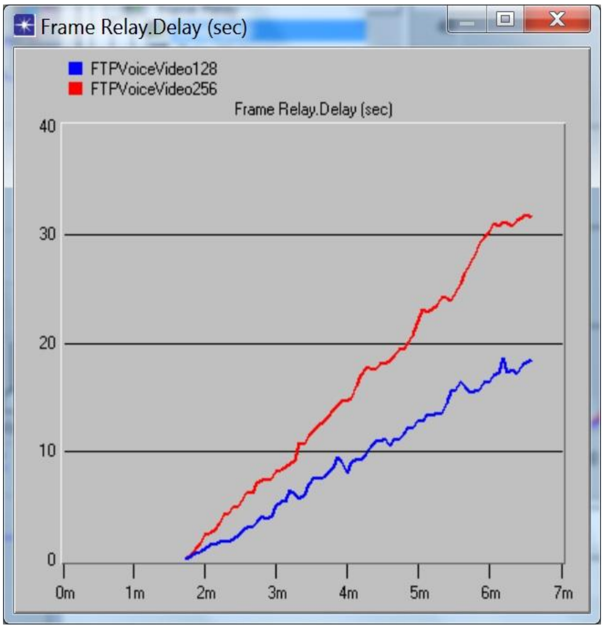

Figure 12. Delay incurred for simultaneous execution of FTP, Voice and Video application.

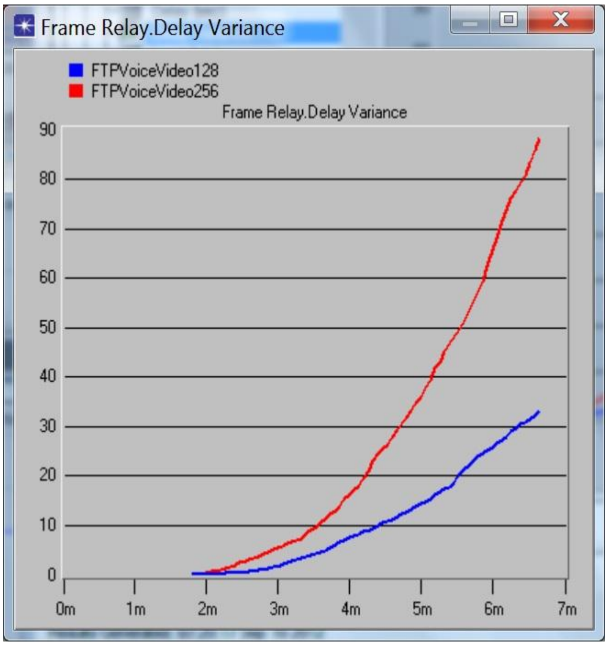

Figure 13. Delay variance for simultaneous execution of FTP, Voice and Video application.

Table 2. Performance comparison of individual and simultaneous execution of applications using high and low configurations.

No.	Metric	Configuration	Applications			
			FTP	Voice	Video	Combined
1.	Avg. Throughput (bps)	High	142781	106110.6	146646.30	143508.2
		Low	70669.73	79001.95	72186.42	72039.81
2.	Avg. Delay (sec)	High	0.26267	0.023025	25.91498	16.30085
		Low	0.306438	0.023022	13.41792	9.417175
3.	Avg. Delay Variance	High	0.048211	3.13e-9	80.10652	75.81164
		Low	0.055584	1.856e-9	20.14984	18.58985

Table 3. Delay corresponding to different values of the CIR parameter (64K, 128K, 256K, 512K) and BC=128K, BE=32K.

No.	Application	Committed Information Rate (CIR)			
		64Kbps	128Kbps	256Kbps	512Kbps
1.	FTP	0.209265	0.306438	2.312698	0.071407
2.	Voice	0.02302	0.023022	0.023025	0.023025
3.	Video	6.80885	13.41792	26.62623	53.02993

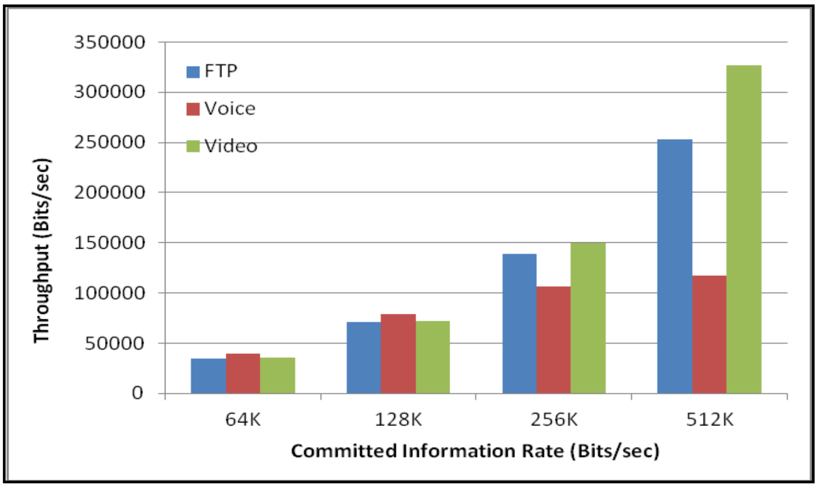

Figure 14. Throughput corresponding to different values of CIR parameter (64K, 128K, 256K, 512K) and BC=128K, BE=32K.

3.5. Impact of CIR Parameter

Table 3 shows the impact of CIR parameter on the performance of the applications in terms of the delay incurred. The Voice application has the smallest delay with a very consistent performance that is almost independent of the CIR parameter. This is due to the fact that the Voice application has a very small bandwidth requirement in comparison with other applications. For the FTP and Video applications, the delay increases with an increase in the CIR value for most of the cases. As the CIR increases, a large number of packets are transmitted over the network and the delay incurred also increases for these applications.

The throughput obtained for the applications with different CIR values is given in Figure 14. It is evident that an increase in the CIR value increases the throughput of the network. The Voice application has a small variation, however, the FTP and the Video application both have a large increase in the throughput corresponding to an increase in the value of the CIR parameter.

Conclusion

This paper presents an analysis of the performance of Frame Relay networks with respect to the FTP, Voice and Video applications. The Frame Relay workstations are configured to communicate as peers using a Permanent Virtual Circuit (PVC) with low and high values of contract parameters (CIR, BC and BE).

For the FTP application, the network scenario with high configuration performs 2, 1.17 & 1.153 times better than the network with low configuration in terms of throughput, delay and delay variance respectively. For the Voice and Video applications, the network with high configuration performs 1.34 & 2.03 times better than the low configuration in terms of throughput. For the Voice application, both the configurations produce a similar delay. However, for the Video application, the delay and the delay variance for the network with high configuration is respectively 1.93 & 3.97 times worse than the delay for the network with low configuration mainly due to a large amount of data transfer.

With simultaneous execution of the FTP, Voice and Video applications, the throughput increases almost 2 times with the usage of high configuration. However, the delay and the delay variance with the high configuration are respectively 1.73 times and 4.08 times worse than those with the low configuration. Moreover, an increase in the value of a single parameter CIR results in an increase in the throughput of the network. It is also found that the performance of simultaneous execution of applications is very close to the performance of individual Video application. Therefore, instead of establishing multiple virtual circuits for the FTP, Voice and Video applications, a single virtual circuit with high contract parameters would be a cost effective solution for executing these applications on the network.

References

[1] E. Ayanoglu and N. Akar, BISDN (Broadband Integrated Services Digital Network), John Wiley & Sons, Inc., USA (2003).

[2] ITU-T, Recommendation X.25 (10/96), International Telecommunication Union, USA, URL: http://www.itu.int/rec/T-REC-X.25-199610-I/en/ (1996).

[3] T. Bradley, C. Brown and A. Malis, Multiprotocol Interconnect over Frame Relay, Internet Engineering Task Force (IETF), URL: http://tools.ietf.org/html/rfc1490 (1993).

[4] ITU-T, Recommendation I.150, Series I: Integrated Services Digital Network: General Structure -General Description of Asynchronous Transfer Mode - B-ISDN Asynchronous Transfer Mode Functional Characteristics, International Telecommunication Union, StruRecommendation X.25 (10/96),International Telecommunication Union, USA, URL: http://www.itu.int/rec/T-REC-I.150/ (1999).

[5] Cisco-Inc., Permanent Virtual Circuits (PVC) and Switched Virtual Circuits (SVC), Cisco Systems, URL: http://www.cisco.com/en/ US/ tech/ tk39 / tk48/ tsd _ technology _ support - protocol_home.html (2011).

[6] D. Tipper and M.K. Sundareshan, An Optimal Control Approach to Decentralized Dynamic Virtual Circuit Routing in Computer Networks, In Proceedings of the IEEE INFOCOMM '90, USA (1990) pp. 926-933.

[7] R. Gawlic, C. Kalmanek and K.G. Ramakrishan, Online Routing for Permanent Virtual Circuits, In Proceedings of the IEEE INFOCOMM '95, USA (1995) pp. 278-288.

[8] K.K.Y. Ho, Comparative Analysis of Virtual-Circuit Routing Control for ISDN Frame-Relay Networks", In Proceedings of the IEEE Global Telecommunication Conference GLOBE- COM '90, USA (1990) pp. 1421-1425.

[9] K.J. Chen and K.M. Rege, A Comparative Performance Study of Various Congestion Controls for ISDN Frame-Relay Networks, In Proceedings of the IEEE INFOCOMM '89, USA (1989) pp. 674-675.

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

[11] R. Fielding, J. Gettys, J. Mogul, H. Frystk, L. Masinter, P. Leach and T.B. Lee, Hypertext Transfer Protocol - HTTP/1.1, IETF, 1999 URL: http://tools.ietf.org/html/ rfc2616 , Retrieved (July 17, 2012).

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

[13] ITU-T, Internet Protocol Aspects - Quality of Service and Network Performance ITU-T Recommendation Y.1540, International Telecommunication Union, USA (2007).

[14] G. Singh and J. Singh, International Journal on Computer Science and Engineering **3**, No. 10 (2011) 3431.

[15] M.K. Sailan and R. Hassan, Network file transfer performance: Effect of IP address, TCP window size and file size, In Proceedings of 2nd International Conference on Network Applications, Protocols and Services (NETAPPS), Malaysia (2010).

[16] T. Khan and M.A. Rashid, Res. Lett. Inf. Math. Sci. **6**(2004) 41.

[17] J.B. Evans, L. Neir, J. Singh and V.S. Frost, Access traffic control implementations for frame relay, IEEE International Conferences on Communications (ICC93), Switzerland (1993).

[18] OPNET-Tech, OPNET IT Guru Academic Edition, OPNET Technologies, USA, URL: http: // www. opnet.Com/university_prog-ram/ itguru_ academic_edition/ (2011).