KNOWLEDGE ENGINEERING: PRINCIPLES AND TECHNIQUES
Proceedings of the International Conference on Knowledge Engineering,
Principles and Techniques, KEPT2009
Cluj-Napoca (Romania), July 2–4, 2009, pp. 25–30

DISTORTION-BASED MEDIA-FRIENDLY CONGESTION CONTROL

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Abstract. This paper describes a media-friendly congestion control algorithm suited for multimedia streaming in best-effort networks. The transmission rate computed by this algorithm follows the shape of the transmission rate of a TCP-friendly congestion control, but it considers also the distortion it would create in the stream perceived by the receiver. Based on this predicted distortion, the media-friendly congestion control algorithm alters the TCP-friendly transmission rate so that it minimizes this distortion.

1. Introduction

The multimedia traffic in the Internet has increased in the latest years. This increase was boosted by the rise of bittorent and peer-to-peer file sharing applications. Multimedia streaming applications, as opposed to file transfer applications, have great bandwidth demands and strict real-time requirements, demands which do not coexist well with the best-effort nature of the Internet that does not offer any QoS guarantees. Due to these expectations of multimedia streaming, it is of paramount importance for the stability of the network that this type of applications perform congestion control. However, traditional congestion control performed by TCP's AIMD (Additive Increase Multiplicative Decrease) [6] is not suitable for multimedia streaming because of transmission rate fluctuations incurred and because of delays incurred by retransmissions. TFRC (TCP-Friendly Rate Control) [1, 2] alleviates to some extent the problems of TCP's AIMD by smoothing out the transmission rate, so that in the long term it has a throughput approximately equal to the throughput of a TCP flow in the same network conditions. The TCP-Friendly Rate Control is a rate-based congestion control that has two main components: the throughput function and the WALI (Weighted Average Loss Intervals) mechanism for computing the loss rate. The throughput function

2000 *Mathematics Subject Classification.* 90B18, 68M20.
Key words and phrases. media-friendly congestion control, TCP-friendly congestion control, multimedia streaming.

is the throughput equation of a TCP-Reno source [3]:

$$X(p) = \frac{s}{R\sqrt{\frac{2p}{3}} + t_{RTO}(3\sqrt{\frac{3p}{8}})p(1 + 32p^2)}, \tag{1}$$

where X is the sending rate in bytes/sec, s is the packet size, R is the round-trip time (RTT), p is the steady-state loss event rate and $t_{RTO} = 4 * R$ is the TCP retransmit timeout value. This throughput function is behind TCP-friendliness of TFRC. WALI, the mechanism for computing the loss rate as a weighted average of the last 8 loss intervals, is responsible for the smoothness of throughput. However, although smooth congestion controls improve the delivery of multimedia streams, they are not the optimal solution, because they don't take into consideration media characteristics of the stream (i.e. they are not media-friendly) [4].

If we refer to the average available bandwidth in the network throughout the streaming session by AAB and to the average bitrate of the stream by *ABS*, generally, we have the following scenarios:

- if AAB is much higher than *ABS* and the available bandwidth in the network does not fluctuate consistently, typically *no congestion control is required* during streaming;
- if AAB is at least twice as *ABS*, typically TCP's AIMD congestion control *is acceptable* for obtaining good quality at the receiver [7];
- if AAB is only a little higher than *ABS*, TFRC *is good* for multimedia streaming [1];
- when AAB is around (more or less) *ABS*, UTFRC (Utility-driven TCP-Friendly Rate Control)*is optimal* for multimedia streaming[4];

The structure of this paper is as follows. Section II discusses about Utility-driven TCP-Friendly Rate Control, a general class of congestion control functions for non-uniform QoS demanding applications. Then section III presents our distortion-based media-friendly congestion control which is based on Utility-driven TCP-Friendly Rate Control. Section IV is devoted to simulations and the paper ends with conclusions.

2. Media-friendly and TCP-friendly Congestion Control

The work presented in this paper builds upon our previous work in media-friendly and TCP-friendly congestion controls for multimedia streaming [4, 5]. More specifically, we are considering the UTFRC (*Utility-driven TCP-Friendly Rate Control*) media-friendly congestion control. By the name UTFRC (*Utility-driven TCP-Friendly Rate Control*) we refer to a general class of congestion control algorithms which compute the transmission rate in the following way:

$$X_{UTFRC}(t) = U(q(t)) * X_{TFRC}(t) \tag{2}$$

where t is time, $X_{TFRC}(t)$ is the transmission rate computed by TFRC at time t using Eq. 1, $U(q(t))$ is a utility function (i.e. a media-friendly function) which is increasing with respect to $q(t)$ and $q(t)$ is an n-dimensional function giving the values of various media characteristics over time:

$$q(t) = (m_1, m_2, .., m_n)(t)$$

where t is time and each of $m_1(t), m_2(t), .., m_n(t)$ is a function that measures one media characteristic like bitrate, PSNR value, client buffer fill level etc. The function $U(q)$ embodies the usefulness of increasing TFRC's throughput above the rate computed with Eq. 1 to the streaming application.

3. Distortion-based Media-friendly Congestion Control

The main contribution of this paper is to define a media-friendly function, $U(q(t))$, which includes the signal power of each frame from the video stream. By the signal power of a frame we understand the variability (i.e. difference) of that frame with respect to the previous one, that is the non-redundant, original, information this frame adds to the video stream. In order to quantify the signal energy (i.e. power) contained in each video frame, we compute for each frame the distortion induced in the perceived stream by not delivering that specific frame. For measuring this distortion we use a simple MSE (Mean Squared Error) metric. Note that also Peak Signal to Noise Ratio could have been used for measuring the distortion caused by a missing frame. After we have computed the signal energy contained in each video frame (i.e. the distortion induced by not delivering that frame), we compute using these values an average signal energy across the whole video stream. All these computations are typically done off-line, but can be done on-line also at a computation cost. Then, during streaming, whenever UTFRC updates its transmission rate (i.e. once per RTT or when a loss event is detected, whichever comes first), it uses for the media-friendly function a value greater than 1 if the signal energy of the current streaming second is above average (i.e. the distortion is above average) or a value smaller than 1 if the signal energy of the current streaming second is below average (i.e. the distortion is below average). This way, the transmission rate of UTFRC will also track the signal energy distribution of the video stream (i.e. UTFRC is thus, media-friendly).

More specifically, the Distortion-based Media-friendly Congestion Control uses UTFRC's transmission rate described in Eq. 2 with the following media-friendly function (utility function):

$$U_{DMFCC}(q(t)) = \frac{SP(t)}{SP_{avg}} \tag{3}$$

where the time, t, has a 1 second granularity, $SP(t)$ is the average signal power (i.e. distortion computed using MSE) for the t-th second of the video stream and SP_{avg} is the average of $SP(t)$ computed across all the seconds of the video stream. Using this media-friendly function should be beneficial for the video streaming process because when temporal adaptation (i.e. dropping frames at the server) or other forms of adaptation are needed, it should improve the video quality perceived by the client.

4. Simulations

In this section we present the results of simulations run using the NS-2 simulator [8]. We have implemented the Distortion-based Media-friendly Congestion Control (DFMCC) described in the previous section in ns-2. In our simulation environment we have a single 22.4Mbps link shared by 17 TCP-Reno flows and one multimedia flow. In the first experiment we have used TFRC for the multimedia flow, while in the second experiment we have used the DMFCC for the multimedia flow. We have used in our simulations a 2 minutes and 40 seconds long sequence from the movie Cars encoded with MPEG4, 23 frames per second and a resolution of 576x238. The signal power (energy) of the video is depicted in Fig. 1 as squared root MSE for each second.

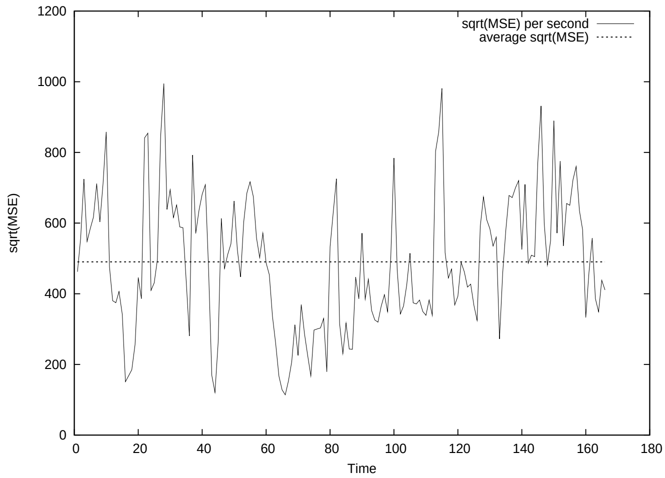

Figure 1. The signal power of the video stream

If at the beginig of a new streaming second, the throughput in the previous second was X and X is less than the average bitrate of the stream, then we apply adaptation to the stream, so that only $X * 100/average_bitrate_of_stream$ percent of the next second is streamed to the client and the rest is discarded. The transmission rates of TFRC and DMFCC are depicted in Fig. 2. The average throughput of TFRC was 138909 bytes/sec and the average throughput of DMFCC was 147244 bytes/sec, thus these are very close with a slight increase for DMFCC.

When we have used DMFCC we estimated that on average, only 122.099 MSE of the signal energy was lost during streaming, while in case of TFRC this value was 135.523 which is higher. If less signal energy is lost (MSE), the PSNR is higher, thus we obtain a better quality at the receiver.

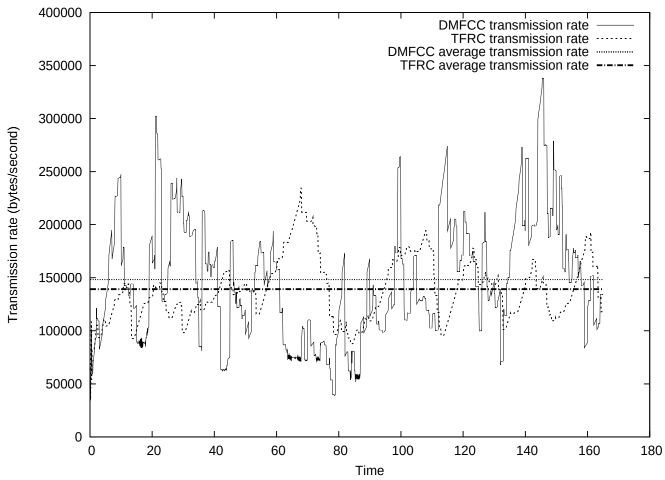

FIGURE 2. The transmission rates for TFRC and DMFCC

5. CONCLUSION

This paper introduced a particularization of Utility-driven TCP-Friendly Rate Control, namely Distortion-based Media-friendly Congestion Control (DMFCC). DMFCC is TCP-friendly and media-friendly and preliminary simulations showed that it conserves more signal energy than TFRC in case some form of adaptation must be applied to the video stream. A real implementation of DMFCC should further prove its benefit on video streaming.

REFERENCES

[1] S. Floyd, M. Handley, J. Padhye, J. Widmer, *Equation-Based Congestion Control for Unicast Applications*, ACM SIGCOMM 2000.

[2] S. Floyd, M. Handley, J. Padhye, J. Widmer, *TCP Friendly Rate Control*, RFC 3448, January 2003.

[3] J. Padhye, V. Firoiu, D. Towsley, and J. Kurose, *Modeling TCP Throughput: A Simple Model and its Empirical Validation*, SIGCOMM Symposium on Communications Architectures and Protocols, Aug. 1998.

[4] A. Sterca, *Congestion Control in Streaming Protocols*, PhD thesis, Babes-Bolyai University, Cluj-Napoca, 2008.

[5] A. Sterca, *UTFRC - Utility-driven TCP-Friendly Rate Control for Multimedia Streams*, in Proc. of the 17th Euromicro International Conference on Parallel, Distributed and Network-Based Processing, IEEE Computer Society, pp. 167-172, Germany, February 2009.
[6] M. Hassan, R. Jain, *High Performance TCP/IP Networking*, Prentice Hall, 2003, ISBN 978-0130646347.
[7] B. Wang, J. Kurose, P. Shenoy, D. Towsley, *Multimedia Streaming via TCP: An Analytic Performance Study*, in Proc. of ACM Multimedia, October, 2004.
[8] The Network Simulator - ns-2, http://www.isi.edu/nsnam/ns/.

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