Cost Efficient Proxy-Based Real-Time Streaming System

Akbar Badhusha Mohideen, M. I. Buhari, and Haja M. Saleem

***Abstract*—Appropriate QoS adjustments are required to provide efficient real-time multimedia streaming over the Internet. Usage of real-time streaming tools like IP-TV, Internet TV is on the raise with due support from NGNs like 4G, IMS, VoIP, etc. Enhancing real-time streaming is discussed in recent literatures with regards to various types of networks and with various traffic shaping techniques. This paper proposes traffic management based on client's geographical location awareness. Location proximity on the Internet provided by Autonomous System(AS) is used with proxy based multicast support to reduce the inter-ISP and redundant traffic which has direct impact on the cost. Decisions made of the overlay are brought forth to the Network layer to adjust the routing information. Suitable architecture for traffic enhancement is discussed along with analytical study.**

***Index Terms*—Real Time, Streaming, Distributed, Multicast, Proxy.**

I. Introduction

Utilization of the Internet has been on the raise due to availability of cheaper, easier and user-friendly modes of communication. Earlier, Internet traffic was mostly made of textual information with occasional multimedia content. However, as the world is moving towards Next Generation Networks (NGN) the scale of the media contents transmitted over the Internet, have increased tremendously. These are due to the fact that Internet Protocol (IP) is being utilized for television broadcast (IPTV), online games, e-learning, IP-telephony, etc [1]. Audio and video streaming consume lot of bandwidth both in the wireless and wired network infrastructure. Thus causing concerns on energy efficiency and Quality of Service (QoS). Some of the IPTV streaming and online games are peer-to-peer in nature and the traffic generated by them is very huge [2]-[4].

Multicasting is the preferred mode of multimedia content distribution if the streaming is received by more than one user [5]-[9]. In this paper, we address the problem of real-time content distribution through multicast during a specific scenario when many people around the globe wish to watch a live event like football match. Depending on the parties involved in the specific game, concurrent viewers of the event might be densely concentrated in specific regions and therefore are clustered in nature [10].During these times, the server is overloaded with too many requests from multiple users in a clustered manner that results in unusual demand on bandwidth. These huge bandwidth requirements could be handled amicably if the routing of the traffic is managed efficiently by capitalizing the clustered nature of the clients. Various contributions to solve this problem from different perspectives could be in the literature. Energy efficiency is of concern for the real-time multicast of video in 4G network [7], whereas fault tolerance and QoS are other concerns [11] in these aspects. Our approach to this problem is to minimize the above mentioned issues by means of proxy based multicasting with the knowledge of underlying topology of the network. We particularly take into consideration the ISPs involved in these scenarios, so as to reduce the inter-ISP traffic and increase the QoS. Our scope in this paper is to illustrate and analyze the benefits obtained by proxy based multicast.

II. Related Work

Placement of proxy for retransmission of lost packets has been discussed in [12], whereas our approach in this paper is to employ a proxy even for the main streaming of real-time packets. Authors in [5] have proposed application-oriented middleware for multicast and authors in [10] have proposed overlay multicast for multi service based content distribution. Their scope does not cover the underlying topological consideration. Energy efficiency has been discussed in [6] for the 4G network which is also a main concern that is addressed by our approach. QoS enhancements while streaming of e-learning content has been discussed in [13]. Here the QoS has been enhanced by improved video coding, screen share algorithm, etc. Our work further leverages the benefit obtained in [13] by introducing the proxy based approach with topological consideration. Fast recovery of multicast tree in case of any node failure is discussed in [7]. Our approach again complements this by making the recovery process easier to implement as the branches of the multicast tree are minimized. Authors in [8] have employed RTP/RTCP adaptive control strategy to improve the QoS of the media content.

III. Proxy Based Approach

Our approach is to reduce the inter-ISP traffic in the backbone network so as to reduce the cost and efficiency of live streaming over the Internet. Figures 1 and 2 shows the network architecture used and the impact of proxy based approach on them.

ISP-A is the ISP area where most of the users (clients) are requesting (or subscribed) to watch the live streaming of a football game. The target server which webcasts the required

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Akbar Badhusha Mohideen is with King AbdulAziz University, Jeddah 21589, Kingdom of Saudi Arabia (e-mail: akbar@kau.edu.sa).

M. I. Buhari is with University of Brunei Darussalam, Jalan Tungku Link, Gadong BE1410, Brunei Darussalam (e-mail: ismail.buhari@ubd.edu.bn).

Haja M. Saleem is with Universiti Tunku Abdul Rahman,Jalan Universiti, Kampar, 31900, Malaysia (e-mail: hmsaleem78@yahoo.com).

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streaming is present in ISP-B. The traffic between ISPs is very expensive and our approach tackles this problem by way of choosing a proxy to multicast in the target ISP on behalf of the server side edge router (Node E).

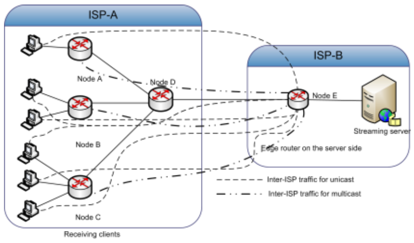

Fig. 1. Unicast and multicast.

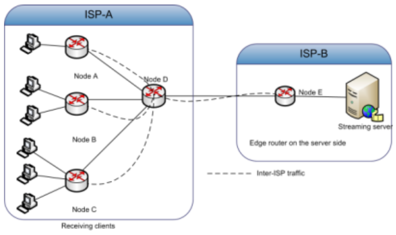

Fig. 2. Multicast with proxy.

IV. Analysis

Streaming something from a server to a receiver requires two-way communication; requests from clients and reply from server. Initially, the clients need to contact the server to register themselves as clients which would receive the streaming data. In response, server streams the content to the individual clients. This communication response when done using unicast, consumes lot of bandwidth compared to using multicast. Furthermore, the communication cost could be reduced by using proxy multicast. Communication cost is based on connection setup cost, communication between client-side edge router and client, communication between client-side and server-side edge routers, communication between server-side edge router and source.

As shown in Fig. 1, for unicast communication, there will be individual streaming of packets from the source to each client and thus there will be six concurrent streaming. Also shown in Fig. 1, for multicast, individual streaming from source is provided to edge routers (Nodes A, B and C) and thus there will be three concurrent streaming. Edge routers then distribute the streams to the clients connected to them. Proxy multicast is shown in Fig. 2, where there will be one stream from the source to the proxy (Node D). Proxy then forwards one individual stream towards Nodes A, B and C respectively.

Communication between edge router and client includes uplink and downlink bandwidths, indicated as $UB_{ER,C}$ and $DB_{ER,C}$ respectively. Communication between edge router and source includes uplink and downlink bandwidths, noted as $UB_{ER,S}$ and $DB_{ER,S}$ respectively.

Total communication cost or bandwidth consumed (B) for video streaming is:

$$B = B_{ConSetup} + UB_{ER,C} + DB_{ER,C} + UB_{ER,S} + DB_{ER,S} \quad (1)$$

Bandwidth consumed due to connection setup ($B_{ConSetup}$), uplink and downlink between client-side edge router and client remains the same for unicast and multicast based streaming. The traffic between the client-side and server-side edge routers contributes towards inter-ISP bandwidth consumption. Connection setup is performed between the client and source, which includes a three-way handshake.

Bandwidth between Client-side Edge Router and Client ($B_{ER,C}$): Clients contact the edge routers with their requests and replies with protocols like RTMP (Real Time Messaging Protocol) or RTMFP (Real Time Media Flow Protocol). This request flow from client to edge router (uplink) is represented as $UB_{ER,C}$. The edge router that is directly connected to the clients has to stream the data via unicast. If the number of users viewing the stream simultaneously is Nc, then downlink $DB_{ER,C}$ is the product of number of users and stream bit rate. The quality of the video determines the rate at which streaming is performed.

$$DB_{ER,C} = N_c \cdot B_0 \quad (2)$$

Bandwidth between Client-side Edge Router and Source: The communication between the source and the edge router can be effectively improved by using multicast communication. Using multicast communication, only a single stream is transferred from the source to the edge router, where the stream is copied according to the number of users. These requests are sent from the router near server (Server-side edge router, Node E) to client-side edge routers (Node A, B and C in Figures above). Bandwidth consumed for multicast communication $DB_{ER,S(m)}$, is related to the average multicast tree size Lm.

$$DB_{ER,S}(m) = B_0 \cdot L_m \quad (3)$$

Using proxy multicast, the B_0 will remain the same but the L_m value will be reduced by a factor α, which is between 0 and 1. Bandwidth consumed for multicast communication $DB_{ER,S(pm)}$, is given as:

$$DB_{ER,S}(pm) = B_0 \cdot \alpha \cdot L_m \quad (4)$$

If streaming is done for multiple videos (g), then bandwidth consumed due to multicast transmission is:

$$DB_{ER,S}(m) = B_0 . \sum_{i=1}^{g} L_m \quad (5a)$$

$$DB_{ER,S}(pm) = B_0 . \propto . \sum_{i=1}^{g} L_m \quad (5b)$$

It is not straightforward to calculate the average multicast tree size given the number of users and the topology of the network. The relationship between unicast and multicast could be obtained using the *power scaling law* described in Chuang and Sirbu [10]. Power scaling law relates as:

$$\frac{ML}{UL} = N^{k} \tag{6}$$

Where *ML* is calculated as the total number of edges that make up the tree, *UL* is calculated as the average distance for a unicast packet from source to the destination, *N* is the number of receivers (routers) in the multicast group and *k* represents the scalability factor for multicast and unicast. The value of *k* is between 0 and 1.

Thus *ML* is calculated as *UL* * *Nk*. *ML*, the total number of edges of the tree is approximately equivalent to L_m, which is the average multicast tree size.Thus, bandwidth consumed for unicast communication is,

$$DB_{ER,S}(u) = N_c \,.\, B_0 \,.UL \tag{7}$$

In addition to bandwidth consumed due to streaming, some control messages are required for proxy multicast and multicast. The control traffic is performed periodically every τ seconds. This traffic is send either to all the nodes of the multicast tree or only to those nodes that are not pruned from multicast traffic, depending upon whether sparse or dense mode of multicasting is used.

In sparse multicast, a multicast tree of ML edges is to be constructed for multicast based data transfer. Periodically, control messages are to be send from clients in this tree to the source to indicate their willingness to be part of the multicast group.In dense multicast, initially multicast tree contains all the nodes in the network. Then, any node which does not want to receive the stream generates prune message to the source. So, prune messages are generated periodically by those nodes that does not belong to the multicast group, which is all nodes of the network minus the nodes in the multicast tree.

For sparse multicast,

$$\text{Bandwidth for Control traffic } BCT = ML / \tau \tag{8}$$

For dense multicast,

$$BCT = (\text{All nodes} - ML) / \tau \tag{9}$$

Bandwidth requirements caused due to combination of control and streaming traffic of multicast or proxy multicast should be smaller than the unicast traffic. This could be proved using the following equations:

Total Bandwidth for Multicast traffic, without proxy = $DB_{ER,S}(m) + BCT$

Total Bandwidth for Multicast traffic, with proxy = $DB_{ER,S}(pm) + BCT$

From (3), assuming L_m is equivalent to ML, $DB_{ER,S}(m) = B_0 \,.\, ML = B_0 \,.N^k \,.\, UL$

$$\text{Thus, total bandwidth} = B_0 \,.N^k \,.\, UL + BCT \tag{10}$$

Comparing (7) and (10), it is obvious that N_c should be greater than N_k to the extent that the impact of *BCT* is minimal.

V. Conclusion

In this paper we have discussed a model for reducing the inter-ISP traffic for multicasting of real time streaming traffic. We also have analyzed its model mathematically and proved the enhancement obtained in terms of performance analytically. However, the dynamic identification of the proxy node according to varying traffic pattern needs to be studied. In future, we are planning to study the possibility of employing message level intelligence for optimal placement of proxy and study its performance through simulations.

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Akbar Badhusha Mohideen is currently working as a faculty member in the Faculty of Computing and Information Technology at King AbdulAziz University, Jeddah, Saudi Arabia. He received his B.E. degree in Computer Engineering from Madurai Kamaraj University, India, in 1996, and Master of Engineering degree in Computer Science and Engineering (1998) from Bharathiar University, Coimbatore, Tamil Nadu, India.

He was with School of Computing and Communications at the University of Technology Sydney, Australia from 2004 to 2010. He was with Information and Computer Science Department at King Fahd University of Petroleum and Minerals, Saudi Arabia from 1999 to 2004. His current research interest includes routing in wireless sensor networks, body area networks and energy efficient routing.

M. I. Buhari is a Senior Lecturer in the Faculty of Science, Universiti Brunei Darussalam, Brunei Darussalam. He received his B.E. degree in Computer Engineering from Madurai Kamaraj University, India, in 1996, and M.E. degree in Computer Science and Engineering from Bharathiar University, India, in 1998. He has obtained his Ph.D in Information Technology from Multimedia University, Malaysia. From 2000 to 2006, he was with Information and Computer Science Department, King Fahd University of Petroleum and Minerals, Saudi Arabia.

Dr. Buhari's current research interests are in the areas of grid computing, IPv6 performance testing and high performance computing.

Haja M. Saleem is a lecturer in the Department of Computer and Communication Technology at University Tunku Abdul Rahman, Malaysia. He received his B.E. degree in Electrical and Electronics Engineering from Madurai Kamaraj University, India, in 1996, and M.E. degree in Computer Science and Engineering from University of Mardas, India, in 1998. He has obtained his Ph.D in Information Technology from Universiti Teknology Petronas, Malaysia in 2012.

Dr. Saleem's research interests are Application Oriented Networking, P2P overlays, Distributed Query Routing in the IP-Layer.