OPTIMIZING FEEDBACK PATH IN HIERARCHICAL AGGREGATION

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The main motivation for this work is to allow IPTV to be used by large scale groups of clients (up to millions) in one session. We have implemented 2 main methods to achieve this goal by reducing data, witch are transferred via feedback channel. These methods are summarization of client's data in nodes and creation of hierarchical feedback tree, thanks to which we can virtually extend the bandwidth used by end clients. The TTP protocol was developed based on these requirements. It includes the creation of a balanced hierarchical feedback tree, synchronization of created FT nodes and monitoring the created FT network. TTP can secure feedback channel stability by activating another FT instead of the corrupted one if necessary.

Keywords: feedback; aggregation; summarization

1. INTRODUCTION

Interest in multimedia services via Internet grows very rapidly nowadays. The technology of data processing has gone through numerous changes and thus technologies such as VoIP and IPTV (IP television) are very popular. There are more and more customers using these services, which run on protocols designed in the 1990's. This paper is focused on constructing a hierarchical tree in the feedback channel to increase the number of clients connected into the one IPTV session. IPTV uses the RTP/RTCP protocol 0 for data transition. RTP sends data via multicast and all clients are able to read them from it. The RTCP protocol assures the signaling of quality of service. 5% of the whole session bandwidth (BW_{RTCP}) are assigned to the RTCP channel. We can use only 75% of BW_{RTCP} for the feedback channel that means only 3.75% of the whole BW 0. All receivers (R) sending their feedback reports called RR packets in period between <5;∞) 0. If the information is of any use, it must be delivered as fast as possible. In that case, all (R) sending its RR packets in this interval and this interval limits the number of (Rs) which can be connected in the session. If the number of (Rs) calculates interval between <5; 15> seconds, everything works fine and all messages come with an acceptable delay. If there are more clients in the session than the limit is, the feedback channel cannot provide high-quality and reliable service. Another important factor is the dynamic change of the number of clients. Many clients can also use mobile connection and they change their position. The number of clients can change very rapidly, especially according to what kind of programme or show is broadcast. As we said, clients can connect from different places and it is very important correctly find their position from the source of a media server. A lot of methods and algorithms are used for finding correct positions such as Global Network Positioning (GNP) 0, Vivaldi 0, Netvigator 0 or Meridian 0. They use Round Trip Time (RTT) to calculate the distance from the ICMP delay information.

2. New Nodes Involved in Feedback Transmission

In the original specification of RTP/RTCP 0 exist only 2 members (except special mixer units) and these members communicate with each other. The main parts of the RTP/RTCP protocol are sender (S) and receiver (R). (R) is connected to the multicast group and receives the multimedia data which are broadcast by (S). Data are transmitted in RTP packets and the size of the packet in not influenced by the number of (Rs). The RTCP protocol cares of the quality of information delivery. This information is transferred in both ways, from (S) to (R) as SR (Sender Report) message and from (R) to (S) as RR (Receiver Report) message. Although only 1.25% of the whole BW are reserved for the SR channel. The SR channel is distributed via multicast so only one copy of information must be generated for all users. The RR channel represents a narrow point in the IPTV session. Everything works fine with a small number of receivers. They have enough bandwidth to send periodically their RR packet with a small delay. The time interval for feedback information grows very rapidly when many clients want to join in the same session. In this case, we need to integrate new feedback members in the multimedia session. These members are Feedback Target (FT), Root Feedback Target (RFT) and Feedback Target Manager (FTM), for more see Fig.1 and the next subsection.

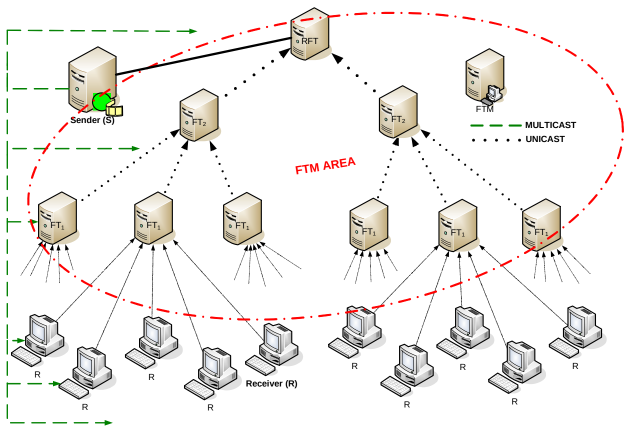

Fig. 1 - Hierarchical feedback tree

2.1. Feedback Target Manager (FTM)

FTM is responsible for initializing an optimized feedback tree, managing and monitoring the services. FTM receives messages from (FTs). The hierarchical tree is able to work independently for some time. FTM activates as many FT as need to be active to handle all connected members. We want to stabilize the structure of feedback channel for as long as possible. In practice, we suppose that there will be no big change in the tree during the program but only small changes. A rapid change of tree comes only at the end or at the beginning of the program. FTM represents a member which influences the time propagation of RR packets. Optimizing the hierarchical tree is described later in the paper.

2.2. Feedback Target (FT) and Root FT (RFT)

The biggest innovation and method responsible for the establishment of TTP protocol can be seen in (FT). (FT) is responsible for receiving packets from (R). It represents virtual (S) for (R) and (FTs) in the lower layer of the hierarchical tree. (FT) always knows how many members are connected in its group and how long receiving interval it provides. The collection and summarization of information in a defined time interval (generally 5s) is its main activity. It generates the so-called summarized packet (RSI packet) 0 in each defined period and sends it to the higher level of the hierarchical tree. (FTs) do summarization for data compression. They create histograms of main parameters and this method represents the reason why we are able to support more clients in a single session. (FT) sends the created RSI packet to a higher level, which does another summarization. This process continues until the packet is received by Root Feedback Target (RFT), which is on the top of the hierarchical tree. For more see again Fig.1.

As has been mentioned, summarization is nothing more than creating histograms of main parameters of the current session. (S) does not want to know all detailed information from all parts of the feedback channel, only the percentage expression of the quality of all clients is needed for it. At last, it must do this by itself in a normal RTP/RTCP session. Creating the histogram in the network is a tool for reducing the amount of information. (S) can then change the type of coding or transmitting data and provide a better multimedia service according to this information. Individual problems with receiving data are caused on the client side and must be solved there, not by changing session parameters.

3. TTP

If we need to extend the use of the RTP/RTCP protocol for feedback transmission in IPTV to a large number of clients, it is unavoidable to develop a new protocol, which will help us achieve this goal. The TTP protocol is an application protocol and can operate independently. It is designed for collecting specific data from a large number of end nodes. Speaking about IPTV, the TTP protocol provides opportunities to send more data in the feedback channel. Three types of messages (FTS, FTD and FTI) have been defined within the scope of TTP protocol version 0.5 and these messages form a complex set for construction of the feedback tree 0.

4. Mathematical Equations

The access layer of (FTs) enables access for (Rs) into the feedback channel. Each (FT) includes a defined set of (Rs) in its group. These (Rs) calculate their transmitting interval from this size of the group. The equation 1 represents a number of (FTs) in the H layer of feedback channel

$$FT_H = \frac{N \cdot \prod_1^H PL}{BW_{RTCP}^H \cdot \prod_1^H T} \quad [-] \qquad (1)$$

where

H	[-]	height of the feedback tree
FT_H	[-]	number of (FT) in a layer H
PL_H	[bit]	size of the RR/RSI packet
T_H [s]		interval of RR/RSI packet transmission
N	[-]	number of (R) in whole IPTV session
BW_{RTCP}	[bit/s]	of feedback channel (3.75% from bandwidth of IPTV session)

This equation can be extended to obtain a specific time interval on any level of the feedback tree. See equation (2), which defines the sending interval of RR packets according to the RTCP protocol or a fully optimized interval in equation (3).

$$T_{opt} = \sqrt[(H-1)]{\frac{N \cdot \prod_1^H PL}{BW_{RTCP}^H \cdot T_{RTCP}}} \quad [s] \qquad (2)$$

$$T_{opt} = \frac{\sqrt[H]{N \cdot \prod_1^H PL}}{BW_{RTCP}} \quad [s] \qquad (3)$$

5. Hierarchical Tree Initiation

5.1. Asynchronous feedback channel

You can see in Fig. 2 the total time of an RR delay in the hierarchical tree structure when we are using more and more levels. There is always the limit on the number of levels because after this limit time the delay of the propagation increases. So there is no reason to create a multilevel feedback tree. Managing the whole structure takes a lot of time because the size of the FTS packet will be bigger and the propagation in SR channel will takes longer. (FTM) would send a lot of FTD via unicast and this is also takes a lot of system requirements.

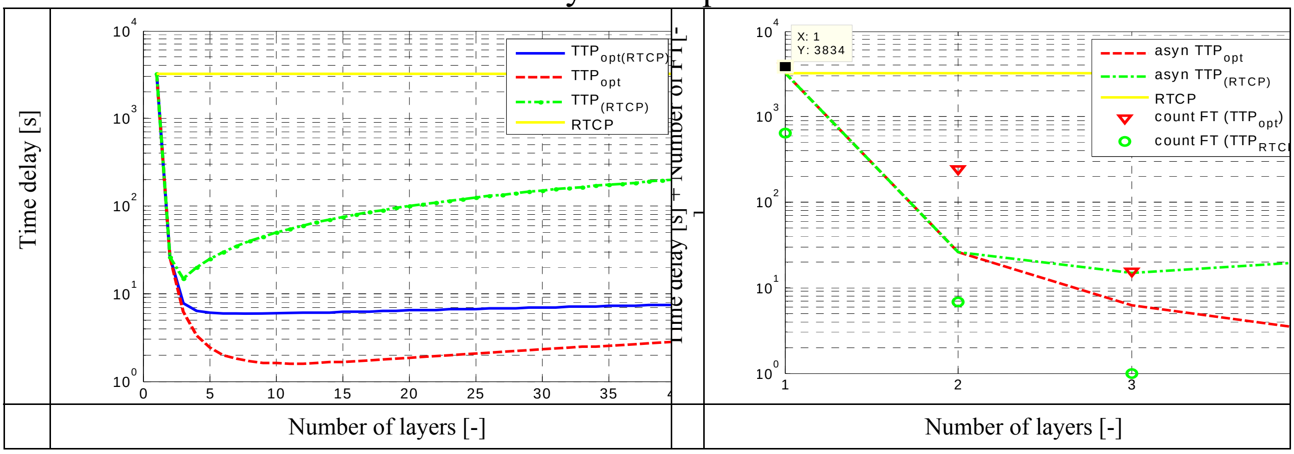

Fig. 2 – Total delay in the feedback channel using hierarchical tree + Detail

The number of layers was reduced to H = 4 in Fig. 2 (Detail)**Error! Reference source not found.**. The maximum height of the feedback tree defined in the TTP protocol in FTD packet is 8 (3bits). As we described and as you can see in Fig. 2, there is no need for more levels. Fig. 2 also gives the number of (FTs) in each layer of the 4-layer optimized tree (red) and the number of (FTs) in each layer of 3-layer non-optimized tree (green).

5.2. Synchronous feedback channel

Another optimization represents the synchronization of FTs interval transmission in the feedback tree. The synchronization of FTs intervals provides a shorter delay of the propagation of RR packets in the whole feedback tree. If we have a lot of FTs in one session and only some of them are active, we can use others for optimization. Another way is that we can use a faster channel in the hierarchical tree except the access layer. These two methods start from equation (3):

$$T_{opt} = \sqrt[(H-1)]{\frac{N \cdot \prod_1^H PL}{BW_{RTCP} \cdot \prod_2^H BW \cdot T_{RTCP}}} \quad [s] \qquad (4)$$

where

BW_{RTCP}	[bit/s]	bandwidth of feedback channel (3.75% of bandwidth of IPTV session)
$\prod_2^H$	[bit/s]	bandwidth from 2 to H layer of hierarchical tree

All (Rs) generate RR packets in a random interval between 2.5-7.5 seconds. (R) sends its RR packet randomly in this interval to produce a balanced traffic in the feedback channel. It takes 5 seconds on average in the normal case. (FT) in the access layer receives all packets in a defined cyclic interval of 5 seconds, but it has also a second interval for sending the RSI message. This interval is shorter than the interval in the access layer (let us say 1 second) and FT_1 sends the RSI packet in the interval 0-1 second. (FT) then waits for the rest of the 5 second interval for generating a new "sent time". (FT) in the next layer receives all RSI messages on its input interface. It knows that it is in the second layer and therefore it must wait for time T_1 and generates a sending interval between 1-2 seconds from the 5 second period. The reason is that the interval between 0 and 1 second is the synchronization time for FTs in the access layer; the interval from 1 to 2 seconds is the synchronization interval for FTs in the next layer and so on. Generally said, T_H is the interval for sending RSI messages and each (FT) knows in which layer it operates, so it multiplies T_H by H in order to find the correct interval of sending RSI packet in given layer. There is base a condition for the synchronization process of (FT) in the feedback tree, because without it the blue line in Fig. 2 would be almost the same as the green one. If we use equation (4), we can operate with a wider feedback channel between (FTs). As you can see in Fig. 3, this structure helps us to reduce the number of layers (number of (FTs)), because we can build 2-layer feedback tree for 10^7 clients in session, where is only the access layer of (FTs) calculated from equation (1) and one (RFT). The bandwidth between (FT) and (RFT) is 10Mb/s and all other parameters are the same as in the previous simulations.

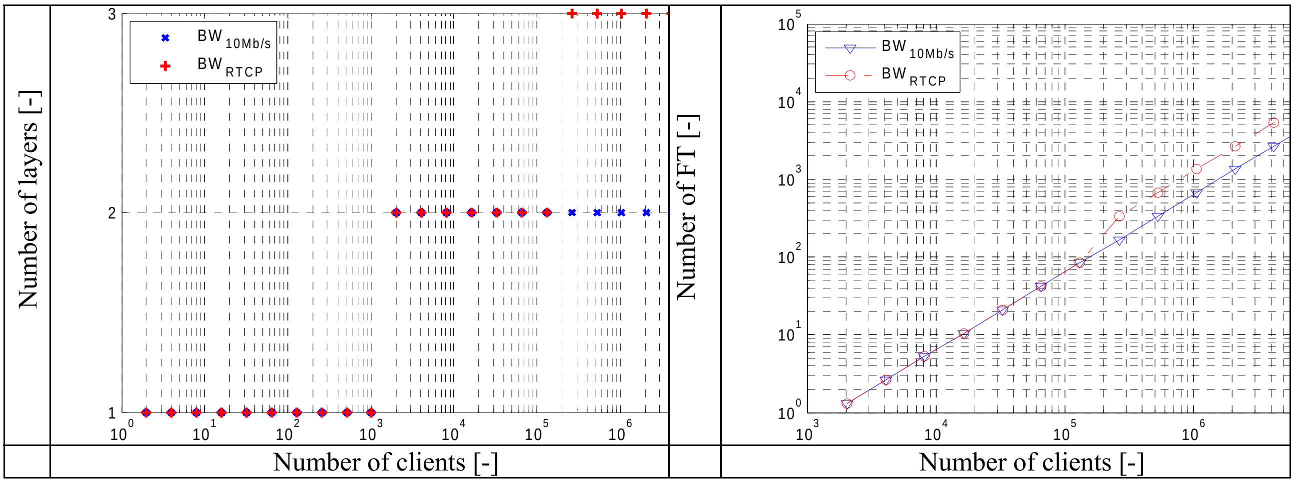

Fig. 3 – Synchronous tree with 10Mb/s feedback channel

6. Conclusions and Guidelines for Future Work

There are many ways how to allow collection of data from end users. The sender is limited in the IPTV session by the narrow feedback channel and then the TTP protocol comes with a method of constructing an optimized hierarchical tree in a narrow feedback channel. The tree is composed from so-called Feedback Target nodes. They represent points in the network where information from (R) is summarized and a new type of the packet (so-called RSI packet) is generated. The TTP protocol is an application protocol and can be used in many applications. Therefore it comes with the asynchronized and the synchronized tree. The asynchronized tree is a self-operating structure and does not need any synchronization information for its work. It is easier for construction but it needs more network resources and does not take the best advantage of them. On the other hand, the synchronized tree needs some information to synchronize itself. It is harder to manage and construct but it is able to use all resources to the maximum and is able to offer a better quality of service.

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