Statistical Analysis of Multicast versus Instant Channel Changing Unicast IPTV Provisioning

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***Abstract*— Bandwidth is a key constraint for video distribution and hence, there is a strong incentive for analysis and modelling of IPTV service. In this paper we provide statistical analysis of IPTV traces measured from real-life IPTV pre-operational network. The main target was to determine the trade off between the multicast distribution of IPTV and ICC (Instant Channel Changing) unicast distribution of this service to the end users. The results showed that multicast and unicast IPTV traffic have different self-similarity degrees, where the multicast is shown to be less self-similar, while ICC unicast traffic showed middle level burstiness. The obtained results provide important information for service and network providers in the area of network design for IPTV provisioning.**

***Keywords* — ICC, IPTV, multicast, traces, traffic, unicast.**

I. Introduction

Today IPTV is seen as one of the killer services, due to transition from analogue to digital television on one side, and having IP as common networking technology for all telecommunication services in near future, as well as having huge market for television services. Main challenges are transport of new real time sensitive traffic in their IP networks in order to keep the leading position as Internet services providers. Pre-request of using new services is creation of new statistical models of IPTV traffic. Currently, IPTV providers provide mainly two types of traffic: 1) multicast for delivering video channels and 2) unicast dedicated for channel changing, video on demand and other applications [1]. Here, we capture traffic traces from a live network and then examine the self-similarity of IPTV traffic with so-called Hurst parameter and autocorrelation function in different approach than traditional IP traffic models [2].

II. Channel Changing and Challenges

A. How it works?

Channel changing experience is a key factor in an IPTV subscriber's viewing satisfaction. A one-to-two-second delay is unacceptable to anyone who is switching channels (channel surfing). Channel changing delay can be described by three components: IGMP (Internet Group Management Protocol) delay, buffering delay, and decoding delay in STB (Set Top Box). Main percent of channel changing time is IGMP latency. In today's implementations of IPTV systems, it is common to utilize a GoP (Group of Pictures) structure to enable effective synchronization to the transmitted streams (i.e. channels). Using a predefined GoP structure is easy and effective solution to problems associated with stream switching and recovery from information loss. For example, in Fig. 1 we illustrate a subscriber performing a channel change (stream switch) in a typical GoP-based IPTV system. In this example the subscriber is synchronized to channel 1. At a particular time, the subscriber issues a switch command to channel 2, which triggers IGMP leave to the multicast stream group 1 and joins the multicast stream group 2. Then, the subscriber starts to receive multicast stream 2. Since "I" frames act as stream synchronization points for the subscriber decoder, the subscriber waits until an "I" frame is received. The received frames are discarded. The waiting time (channel changing gap) is determined by the number of frames being offered per second (Fig. 1). When the "I" frame is completely received and decoded, the subscriber is synchronized to the new stream, which is marked by STB.

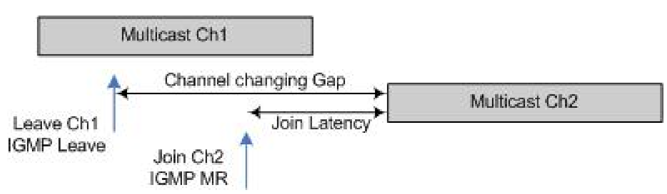

Fig. 1. Channel changing and IGMP delay.

Also, in this section, we will discuss other existing approaches towards reduction of channel changing time.

B. Broadcast Streams

The main approach is to distribute all TV channels same like cable providers. The basic idea is to pipe in channels to the customer premises. This approach is not recommended for IPTV providers that are using DSL technologies in their last mile.

C. Adjacent Multicast Join

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This approach is based on the same idea as the previous one. This utilizes the expectation that adjacent channels are going to be watched more frequently by viewers. The scheme is as follows, whenever a channel is requested, the adjacent channels in the multicast group along with the channel being requested are also subscribed for till the limit is reached. This is based on the localized channel surfing behaviour.

D. Rapid channel changing

Rapid channel-change technology [3] uses industry standard protocols Real-time Transport Control Protocol (RTCP) and Real-time Transport Protocol (RTP) to cost effectively deliver this capability and provide a better video experience. The approach reduces channel-change times from several seconds to less than one second by initiating video streams less than 100 milliseconds after a request is made. The result is, buffered stream from all channels will be queued on edge router and for demanded channel will be sent unicast RTP burst to the customer, who sees an uninterrupted channel-change followed by successive video motion. Main disadvantage is that memory of routers should be with big capacity, and they are very expensive.

E. Instant Channel Change

Instant Channel Change (ICC) using a buffering technique on channel changing servers. This method creates multiple unicast streams that are sent to the customer along with the broadcast multicast and it gets buffered for the amount of time that is the anticipated multicast establishment time. So when the user requests a channel swap it immediately switches to the buffered content as it proceeds with the new multicast request.

Channel changing servers maintain sliding bursts of live TV service streams for some period of time. The exact time depends on the bit rate of the stream, the structure of the key “I” frames in the GOP Group of Picture, the delay characteristics of the stream. Overhead is difference (in percentage) between multicast stream and unicast burst during the channel changing. IPTV provider should take in consideration tuning of overhead burst - parameter as very crucial function. Overhead has direct influence on two points in the network, limited bandwidth at customer premises and utilizing of backbone links. First point is during worst case scenario when the customer has two STBs and change channels in same time so overhead directly depends from maximum bandwidth at customer device. Second point is unicast traffic generated during channel changing should be transported through IP backbone links. The capacity of a Digital Subscriber Line ("DSL") channel is limited. Engineering a network to support channel change as described above requires several Mbps of reserved bandwidth. Such a configuration will either reduce the DSL serving area, reduce the number of video streams that can be delivered, and/or compromise other services during channel changing periods.

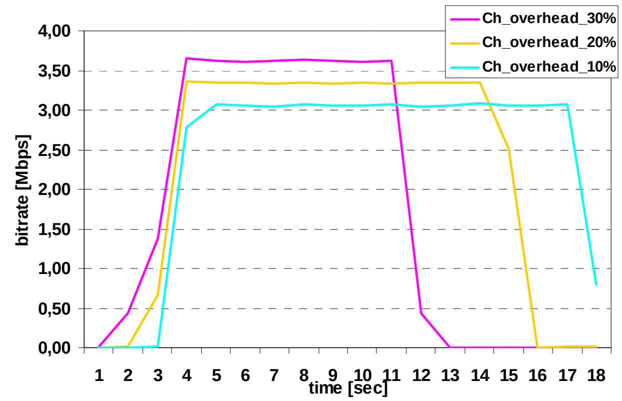

Fig 2. Measured unicast bursts for different value of overhead.

TABLE 1:ICC BURSTS BITRATE AND TIME

Ch. Overhead	30%	20%	10%
Bitrate [Mbps]	3,46	3,19	2,92
Unicast Bytes[MB]	3,84	4,78	5,11
Time [s]	10	12	14

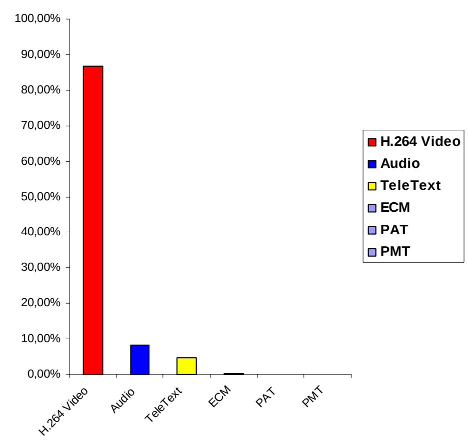

Fig 3. Histogram of IPTV captured traffic per program id.

If IPTV provider using DSL technology then it will set very low overhead, than time and distributed unicast traffic is very high so it will utilize backbone links. IPTV providers should made calculations and measurements on access network and first input for calculating overhead should be DSL bandwidth. Reasonable value for overhead is 20 %, with average bitrate of 3.2 Mbps, and burst time is around 10 seconds for standard definition stream, as we can see from captured IPTV traffic shown in Fig. 2.

Dimensioning of the demand of bandwidth is based on the following measurements in table I, for different percentage ICC overhead than bit rate of multicast stream. We have measured multicast stream with average bitrate 2.37 Mbps and maximum peak of 2.72 Mbps, where we can conclude that overhead is percentage of maximum peak of the stream.

Multicast stream was constituted mainly from 85 % of H.264 video stream, 8% audio stream MPEG1 and 4% from teletext stream, see Fig 3. This channel has all program IDs so we used as a model for measuring maximum burst bitrate – “worst case”.

Channel changing servers supply unicast television service to customers (this data is transmitted in RTP using UDP). If a server fails while it is attached to a subscriber, the subscriber switches to another channel change server carrying the same service, and if this server is again not reachable the subscriber will receive multicast stream directly with around 1 sec interruption.

F. Locating of channel changing servers

The number and location of Channel changing servers depend of number of expected subscribers and capacity of links. As the number of subscriber grows the number of stream will increase, and will consume more bandwidth in the core network. It prevents the user from getting a real time broadcast experience. In the first time Channel changing servers will be placed on Central location near IPTV servers further will be placed in remote location and also in other sites with IP network if there is a need. From IPTV providers view this mean hierarchical at first time channel changing servers will be placed near the Core routers or Core network after that on Edge routers as it was presented in Fig. 4, this will be rule for all providers because bandwidth of links has same hierarchical order, starting with greatest core links.

III. Mathematical Models

A. Model of single user

IPTV users in this paper will be defined in two states. First an active state *A(t)* with probability *P(A(t))*, and with two possible rates R_{UC} during channel changing and R_{MC} is defined as a multicast rate while he is watching channel. Second state is when users is non active *N(t)* - STB is turn off, with probability P(*N(t))=1-P(A(t))*. If the user have changed channel during a measurement period at least once, was in state *U(t)*, otherwise was in *M(t)* state. The probability distribution of the rate viewer demands at time *t* then is given by:

$$R_i(t) = \begin{cases} R_{MC} & \textit{with probability} \quad P(A(t))P(M(t)) \\ R_{UC} & \textit{with probability} \quad P(A(t))P(U(t)) \\ 0 & \textit{with probability} \quad P(N(t)) \end{cases} \qquad (1)$$

However, the main emphasis lies on the evaluation of the probability of changing channel *P(U(t))*. For measurements taken during the peak hour of the day, the probability of a user to be categorized as active was found to lay within 80 percent. If we make expectation on non active state, we can use outer ON/OFF model for modelling active state. Basically intended to show that traffic which is self-similar over a large time scale can be generated with a Markovian model. In this model R_{UC} is peak rate while ON, and R_{MC} rate over the entire process.

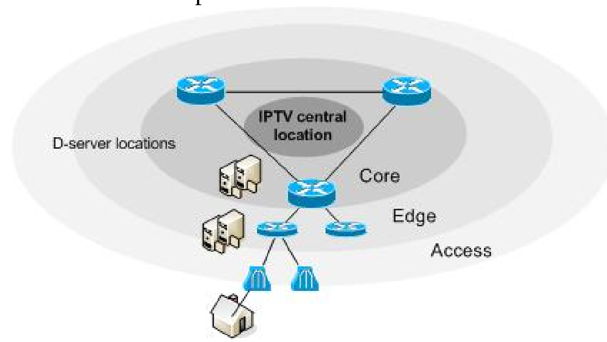

Fig 4. Channel changing servers locations.

B. Burstiness and self-similarity

Bursty traffic is more difficult to handle in a queuing system than traffic generated from non-bursty sources which produce a more continuous workload. Transmission burstiness is often measured by the following expression:

$$b = 1 - \frac{\overline{R}}{R_{MAX}} \quad \text{clearly } 0< b< 1; \qquad (2)$$

For *b* equal to zero, the source is not bursty, for *b* approaching 1 we have a bulk arrival process.

Our statistical analysis of IPTV traffic traces will be presented with autocorrelation function. We obtain correlation coefficients from the traffic trace in the following manner: for a given measurement with *N* samples, with samples y_1, y_2,,…,y_N , at time moments x_1, x_2,….x_N, the lag *k* correlation coefficient is defined as:

$$r_k = \frac{\sum_{i=1}^{N-k}\left(Y_i - \overline{Y}\right)\left(Y_{i+k} - \overline{Y}\right)}{\sum_{i=1}^{N}\left(Y_i - \overline{Y}\right)^2} \qquad (3)$$

The degree of self-similarity can be defined using the so-called Hurst parameter *H*, which expresses the speed of decay of the autocorrelation function. For a self-similar process, 0.5<*H*<1, if *H* = 0.5 the time series is short range dependent, for H→1 the process becomes more and more self-similar. Since slow decaying variance and long range dependence (i.e. slow decaying autocorrelation functions) are both related to self-similarity, it is possible to determine the degree of self-similarity using either of those properties.

IV. Statistical and Analitcals Models

Single user model depends upon customer behaviour for channel changing and watching. Hence, single user behaviour can be modelled using the Markov model with three states with probabilities obtained from IPTV traffic measurements, as shown in Fig. 5. Three states in the model are defined as: probability of changing channel is *P(U(t))*, probability of channel watching is *P(M(t))*, and probability when STB is off or in “stand by” mode *P(N(t))*.

This model may be used in future planning of new channel changing servers and utilizing network links. Also, it may point out where the network operator needs dedicated server for a particular group of subscribers.

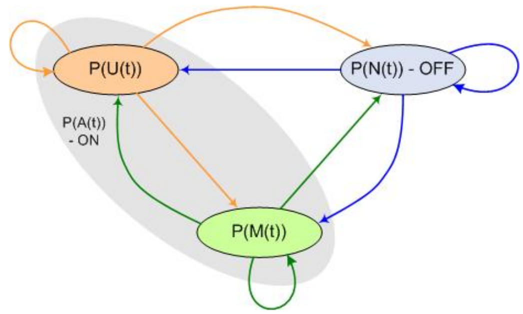

Fig 5. Markov model for average customer behaviour.

If we look into the popularity of channels reports[3], top 10-20% of channels account for nearly 80% of the viewer share, indicating that channel popularity follows the Pareto Principal (or 80-20 rule). We also observe that the distribution during all day for top popular channels is constantly (static). This demand of bandwidth is covered by multicast distribution. Measured unicast traffic for changing of popular channels is around 80% of all ICC unicast traffic.

We made 100 seconds traces, scanning live IPTV traffic on edge router network interface towards clients' side. Measurements and analyses are made per traffic type, multicast from all popular channels and unicast from all instant popular channels changing as well as the aggregate traffic (Fig.6).

Autocorrelation functions of all mentioned traffic types are shown on Fig. 7. The autocorrelation of unicast and aggregate traffic decays hyperbolically rather than exponentially fast. This shows that are self-similar processes while Multicast traffic is not. Using the calculated Hurst parameters for IPTV traces, given in Table 1, one can conclude that Hurst parameter for unicast and aggregate traffic are higher than the one for the multicast. The Hurst value for unicast IPTV is 0.75, which shows that this traffic has middle-level of self-similarity. Additionally, we can conclude that IPTV traffic model can be approximated with unicast traffic model, which heavily depends upon users' behaviour.

Aggregate IPTV traffic depends with a high percentage from unicast channel changing traffic, hence we are proposing the following for practical IPTV system implementations:

1. IP multicast distribution in the backbone should use static trees, where popular channels are delivered to all end users. Only the tree branch for all others channels, from IPTV Platform to customers dynamically to change.

2. Information about which are popular channels should be delivered to STB. During the channel surfing of popular channels STB should not use unicast bursts from channel changing servers, but Adjacent Multicast Join approach.

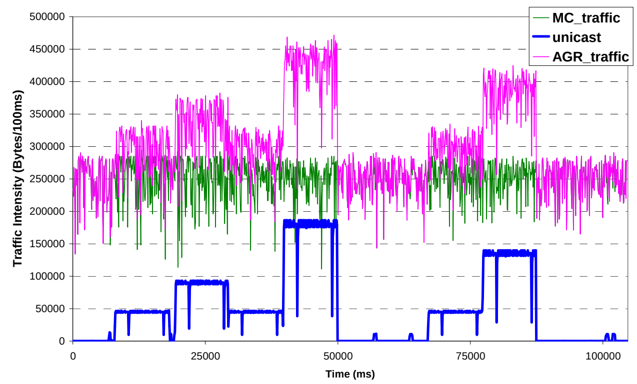

Fig. 6. Traffic trace.

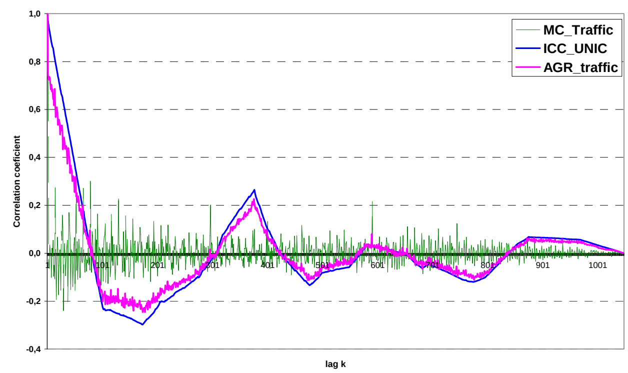

Fig. 7. Autocorrelation Function for Multicast, Unicast and

V. Conclusion

We performed statistical analysis of the captured IPTV traffic from a real testbed network, which should be commercially launched in near future. We analyzed the traffic per type, i.e. multicast, unicast, as well as aggregate traffic.

First main conclusion in this paper is that the unicast IPTV traffic has middle-level self-similarity, i.e. Hurst parameter is around 0.75, while the classical multicast distribution has lower level of self-similarity, with Hurst below 0.6. Second is that models of aggregate IPTV traffic can be approximated with models for ICC unicast traffic (e.g. Pareto). Such models can be used for simulation or analytical analyses of IPTV services, which is of paramount importance for analysis and design of channel changing servers as well as dimensioning and engineering of IP backbone links.

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