Enabling distributed fault diagnosis in multicast-based IPTV delivery

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***Abstract*—We describe a monitoring approach which enables fast fault diagnosis in multicast based IPTV delivery.**

I. Introduction

The IPTV quality is jointly affected by network dependent and application specific factors. The network dependent part consists of, essentially, IP packet loss and jitter. A too large IP packet jitter translates into losses in the playback buffer [1]. The application specific factors include the video codec and coding bit rate, loss recovery technique, packetization scheme and content characteristics [1]. When the *Quality of Experience (QoE)* that an end user meets is insufficient there should be some relatively fast method to diagnose whether the reasons are in the network or in the application specific factors or, perhaps, in their joint incompatibility.

The three main IPTV delivery schemes are discussed, for example, in [2]. These are multicast based delivery, *Peer-to-Peer (P2P)* based delivery and *Download and Play (D&P)*. In this paper we only focus on monitoring of multicast based delivery in an operational network.

The paper is structured as follows. In Section II we provide a real life example of multicast based IPTV delivery, describe a problem related to that example and suggest a solution to the problem. Before discussing the solution more closely in Section IV we provide some background information in Section III. Finally, conclusions are made in Section V.

II. Motivation

Figure 1 below describes a real-world example of IPTV delivery. There are four participants. Digita is a Finnish governmental company that takes care of TV distribution. The *IPTV Service Provider* is a commercial company which sells IPTV to the end users but buys the IPTV transport, the multicast delivery, from *the Transport Operator*. The fourth participant is a different operator who owns the copper cables over which the ADSL connections to the end users are made.

The Transport Operator takes care of the IPTV multicast delivery. The IPTV Service Provider is a customer of the Transport Operator. An end-user is a customer of IPTV Service Provider.

We will adopt the point of view of the Transport Operator. The Transport Operator receives *Transport Streams (TS)* of all IPTV channels from the Headend, see Figure 1, and delivers each channel to all current subscribers of the channel. There are hundreds of channels available but not necessarily watched all of the time. Only those channels are delivered that are actually watched at the time. Between the Headend and DSLAMs the delivery is Ethernet multicast and between a DSLAM and the ADSL modem of a subscriber the delivery is over ADSL.

A. The problem

A problem identified is that it is not always easy to diagnose sufficiently fast whether the reason(s) for the bad QoE of customer(s) is (are)

1) Already before multicast transmission? This is not typical but seems to happen every now and then. It is always possible that the TS that the Transport Operator gets from the Headend is already damaged. It is also possible that the TS is formally correct but the encoded program that the TS contains is damaged. There is an indicating pattern that suggest whether the problem is already before the multicast transmission. Namely, many customers all over the city claim about bad QoE during a short period.
2) In the Ethernet part of the multicast tree? This seems to be quite seldom a problem since overdimensioning in this particular network should be sufficient even if all possible channels were delivered at the same time. Also, this is the part of the network that is solely under the control of the Transport Operator.
3) In the ADSL connections? This is very typical. The lengths of ADSL links vary and may be close to a practical maximum for the required bandwidth. Moreover, the interference with other customers may occur during the busy hours.
4) In the home network? This is also very typical. Home and, more generally, end customer network configurations vary a lot.

Especially, the question of interest in this study is whether the multicast delivery works correctly.

B. A suggested solution

Given the problem of Section II-A above we suggest the following solution:

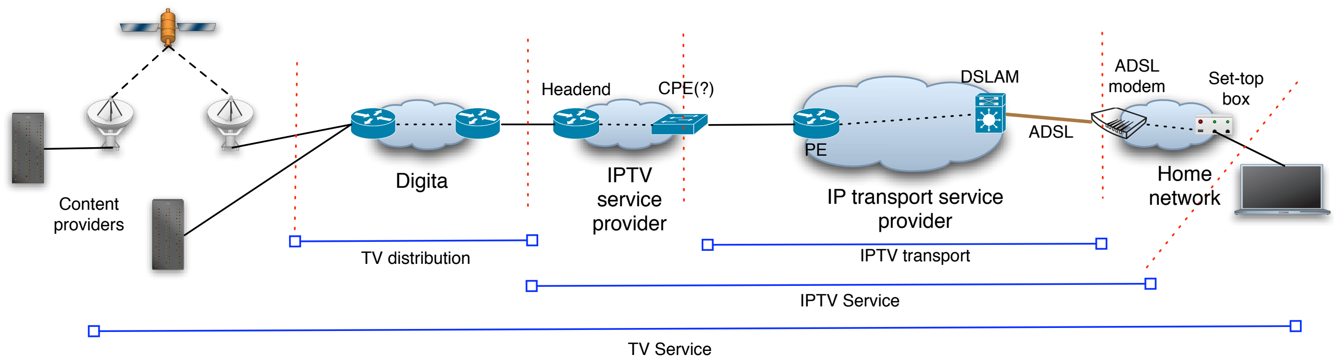

Fig. 1. A real-world example of multicast based IPTV delivery.

1) Measure *the availability of the TS* which carries a channel. (We will describe what we mean by the phrase 'availability of the TS' in Section III-D below.)
2) For a given channel, make the availability measurement continously at the root and then, periodically, multicast the measured availability value to all leafs (and nodes) of the multicast tree of the given channel's delivery.
3) At any node or leaf of the multicast tree that is of interest, make the same availability measurement of the TS, receive the corresponding availability measurement from the root and *compare* these two values.

III. Background

Before describing the details of the suggested solution of Section II-B above we provide some background information.

A. Fault diagnosis

A survey of fault localization techniques is given in [3]. The process of fault diagnosis is divided in [3] into three steps:

1) *Fault detection* is a process of capturing on-line indications of network disorder provided by malfunctioning devices in the form of alarms.
2) *Fault localization* means that a set of observed fault indications is analyzed to find an explanation of the alarms. *Event correlation* and *root cause analysis* are synonyms for fault localization.
3) *Testing* is a process that, given a number of possible hypotheses, determines the actual faults.

We will adopt the language of [3] as the framework in this paper. The main aim is to describe a system that is able to produce such alarms which enable fault localization in the multicast delivery of IPTV.

According to [3] very little theoretical work has been done in the area of distributed fault localization. However, a distributed approach is quite natural in the context of multicast. At least [4] contains some theoretical discussions about the subject.

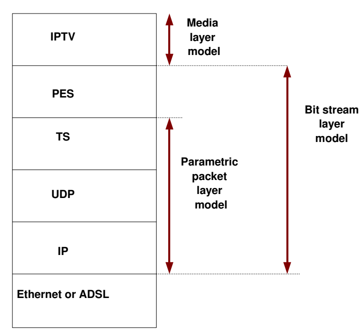

Fig. 2. Media- and Bitstream Layer Models.

B. Transport Stream

MPEG-2 Transport Stream (TS) is introduced in [5]. TS is a coding syntax which is necessary and sufficient to synchronize the decoding and presentation of the video and audio information. The aim is also to ensure that data buffers in the decoders neither overflow nor underflow. In the case of a TV channel, voice, audio, subtitles and other ingredients each form a separate *packetized elementary stream (PES)* and these PESs are then multiplexed into a single TS. Figure 2 shows the positions of TS and PES in the protocol stack.

C. Media- and Bitstream Layer Models

The paper [6] discusses QoE assessment of IPTV. Three types of model are considered in [6]: *media-layer models*, *parametric packet layer models* and *bit stream layer models*, see Figure 2. Media-layer models are essentially *Mean Opinion Score (MOS)* type of models where the knowledge of the human visual system is utilized in order to predict the subjective quality of video. Media-layer models can further be classified according to whether they use *full-reference (FR)*, *reduced reference (RR)* or *non-reference (NR)* methods. FR and RR methods utilize the original source video and its processed counterpart. NR methods operate solely on the information from the processed signal and, therefore, are most useful in an operational network [6].

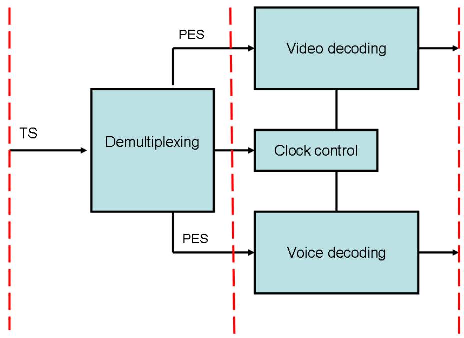

Fig. 3. Decoding process of TS.

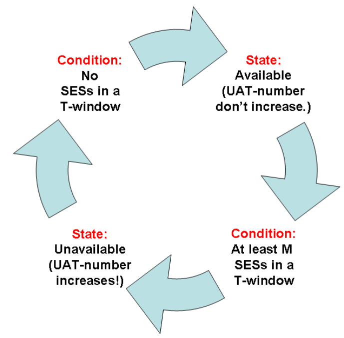

Fig. 4. Availability process.

The packet layer models are based on the packet header information only. They have the drawback that they do not look at the payload information. Thus, it is impossible for them to take into account the dependence of quality on audio and video content [6]. Furthermore, one can ask why to measure and process the IP-layer data, IP packet loss and jitter, since the inference from this information to the QoE is either trivial or extremely difficult.

From the Transport Operator point of view the most important thing is that the multicast delivery is successful. In order to be able to say whether the multicast delivery was successful one must be able to decode, that is, to process the TS at any leaf (node) of the multicast tree. This kind of reasoning suggests that the essential thing to be measured must be something that is able to take into account the requirement of continuous demultiplexing and decodability of the TS. This leads to bit stream layer model considerations.

D. Availability of TS

Measurement and analysis of the MPEG-2 TS is defined in [7]. The recommendation [7] also describes a number called *Unavailability Time (UAT)* which attempts to measure whether the TS is available or not. The definition of [7] is not applicable as such since it is not defined for IPTV but, however, the main idea of the UAT number is worth of considering. We will discuss about what properties an optimal UAT number should have. These properties are motivated from what properties the UAT number of [7] has. Apparently, only minor changes or clarifications seem to be required.

Consider the decoding of TS as depicted in Figure 3. The availability control must, of course, be able to check that demultiplexing works correctly. This is based only on the information on the TS packet headers. In addition to this, the concept of TS availability should provide some level of guarantee that the decodings of the PES streams will work.

Two-state state machines can be defined which measure the working/not working status of each of the processes (demultiplexing, video decoding, voice decoding, clock control) and transitions (TS, PES) in Figure 3. These include buffer under/overflow situations. The transitions between the working/not working states must be defined exactly, then they can be used to classify time periods into good and bad periods. Individual lower level state machines that measure the working/not working status of the demultiplexing and decoding processes of Figure 3 work in microsecond scale. It means that these state machines can be used to classify milliseconds into good or bad milliseconds according to the condition that the state machine does not spend too many microseconds in a not working state. Then, with the help of these lower level state machines, a top level state machine can be defined which classifies seconds into good or bad seconds depending on whether or not all the lower level state machines are working sufficiently well or not in a millisecond scale.

For example, [7] speaks about Severly Errored Seconds (SES) and then the state transition from available state to unavailable state can be defined if there are more than M SESs in a window of size T seconds. The transition from unavailable state to available state occurs only if there are no SESs in a T-window. The M and T are parameters which can be tuned according to user experience. Once there is a clear method to classify each second as good or bad then the unavailability time could be defined in the same way as in [7], see Figure 4. Every second that is spent in the unavailable state increases the UAT number, in the available state the UAT number does not change.

The main point of view is that an optimal UAT number is a single number that is directly comparable and understandable without any further processing.

IV. Details of the Suggested Solution

We will now provide more details to the suggested solution of Section II-B.

The main idea is that the comparison of the availability of TS, when measured at the root and at a leaf (or at any other node) of the multicast tree with exactly the same decoding parameters will automatically suggest whether the multicast delivery from the root to the leaf (node) is working correctly. For example, if the observed availabilities are sufficiently close to each other it implies that IP packet loss and jitter have not been too serious. The availability of TS cannot improve

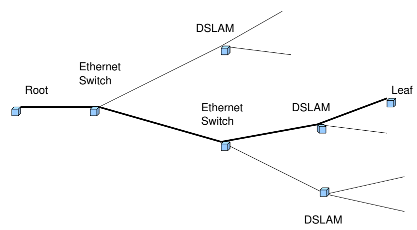

Fig. 5. Multicast tree.

during the delivery, but the comparison measures how much the availability was degraded.

The availability of the TS must be *measured* at the root. One must not assume that it is automatically 100% (or that UAT is 0%) at the root. In order to get this measured value at any node of the multicast tree it must be delivered alongside of the tree. This can be a separate multicast tree that spans only those nodes that are willing to receive this information or it could be sent automatically to every member of the multicast group and those nodes which do not use it simply ignores it. The amount of information that is required to be sent is very small: we suggest periodic sending of one multicast packet per minute where the payload of the packet contains 2-5 numbers. These numbers would be UAT values of the last 1, 5 and, perhaps, last 60 minutes and some synchronization information.

The receiving node must somehow synchronize itself with the root so that the availability of the TS is measured during the same period. This synchronization could be based on the information in the stream itself, and transmitted together with the UAT values, or it could be based, for example, on NTP.

As a conclusion we argue that if the monitoring scheme described in this paper is implemented then we can answer the problem stated above in Section II-A. Namely, whether the reason for the bad QoE is

1) Already before multicast transmission? If the TS is formally correct but the content is damaged this could be partially solved by making a NR based MOS measurement at the root. (If the operator finds it worthwhile to try to react before the indicating pattern exists). If the TS itself is damaged then the TS availability measurement should notice it.
2) In the Ethernet part of the multicast tree? This is solved by comparing the TS availability measurement values between the root and the DSLAM.
3) In the ADSL connections? This is solved by comparing first measurement values between the root and the DSLAM and between the root and the ADSL modem. Then, comparing these comparisons allows to conclude about ADSL quality.
4) In the home network? The availability (and possible MOS) measurement at the root suggests whether the problem is already before the multicast transmission. Then, comparison of availability of the TS between the root and the ADSL modem allows to conclude about whether the problem is in the multicast delivery. The remaining possibility is that the problem is in the home network.

A. *Pros and cons of the suggested solution*

Pros include

- The suggested scenario enables relatively fast fault diagnosis and fault localization. First results can be obtained in few minutes from the beginning of the measurement.
- The measurement process can be maintained for very long periods.
- Actually, the suggested solution could be applied into any type of streaming data transfer, not necessarily multicast nor IPTV.

Cons include

- It may not be applicable to more than only to a few simultaneous multicast trees at the time.
- It may not be applicable to pay charged channels that have an additional encryption.

V. Conclusions and Further Work

We have described a monitoring approach which enables fast fault diagnosis in multicast based IPTV delivery.

We are seeking for collaborators and companies to help us in prototyping the monitoring scheme.

Acknowledgment

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References

[1] S. Tao, J. Apostolopoulos, and R. Guérin, “Real-Time Monitoring of Video Quality in IP Networks,” *IEEE/ACM Transactions on Networking,*, vol. 16, no. 5, pp. 1052–1065, October 2008.

[2] Y. Won, J.-K. Hong, M.-J. Choi, C.-K. Hwang, and J.-H. Yoo, “Measurement of Download and Play and Streaming IPTV Traffic,” *IEEE Communications Magazine*, pp. 154–161, October 2008.

[3] M. Steinder and A. Sethi, “A survey of fault localization techniques in computer networks,” *Science of Computer Programming*, no. 53, pp. 165–194, 2004.

[4] I. Katzela, A. T. Bouloutas, and S. B. Calo, “Centralized vs. distributed fault localization,” in *Proceedings of the fourth international symposium on Integrated network management IV*. London, UK, UK: Chapman & Hall, Ltd., 1995, pp. 250–261.

[5] *Information technology–Generic coding of moving pictures and associated audio information: Systems*, ISO.

[6] A. Takahashi, D. Hands, and V. Barriac, “Standardization Activities in the ITU for a QoE assessment of IPTV,” *IEEE Communications Magazine*, February 2008.

[7] *Digital Video Broadcasting (DVB); Measurement guidelines for DVB systems*, ETSI.