Visualization of a Hierarchical Aggregation in the IPTV Network Environment

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Summary
This paper deals with IPTV (Internet Protocol Television) system. It explains basic principles of multimedia transmission to wide range of user trough Internet. There is an overview of advantages and possibilities of IPTV in general given in the first part, hierarchical aggregation possible usage follows and then description of signalization management of IPTV system and its challenges are discussed. Main part of this paper is focussed on TTP protocol, gathering information and visualization of signalization tree structure.

Keywords
Multicast, Feedback, Hierarchical Tree, IPTV, TTP, Signalization Protocol

1. Introduction

IPTV is a system of classical TV signal broadcasting over computer networks using the IP protocol. Digital form of TV signal offers new possibilities and advantages for users and meets their requirements. This technology uses existing network structure and adds certain specific units (a stream server, a content manager, a set-top-box) to the network system.
One of the most desirable features of IPTV is user interaction. This approach is impossible in a classical TV broadcasting. Users can request a concrete TV channel or a movie, they have a program offer in EPG (Electronic Program Guide), they can pay for demanded programme if they want to watch it through the system, there is ordering and paying possibility for advertised items, betting etc. [7]. IPTV offers a lot and tends to be a universal system providing all services related to a television usage.

2. IPTV

ABC’s World News Now was the first television show broadcasted over Internet in 1994 [8]. A long time has passed and a lot of work has been done since this birth of television on Internet. A brief overview of what IPTV actually means is given in next paragraphs.
An analogue TV signal is firstly converted to a digital form before it can be sent to receivers over digital lines. Moreover compression codes are used for data load reduction. MPEG-2 and MPEG-4 are the most common algorithms in IPTV [9] however a new compression format H.264 [10] has been developed and is being gradually implemented instead of older versions.
Compressed data are sent in a video stream called PES (Packet Elementary Stream). Each PES is divided into 188B long blocks and inserted into a data part of RTP (Real Time Protocol) packet.
If the same IPTV content is transmitted over the network to a few receivers with a different location, the utilization of a unicast session is a bandwidth wasting. More effective way is to use a multicast delivery. Description of the multicast and its additional features can be found in [12][13].
The signalling part and the user feedback are ensured by RTCP control protocol as an accompaniment of RTP. RTCP adaptation for IPTV is discussed in [11].
In spite of the compression methods and the multicast transmission the transfer rate of a high quality video stream in MPEG4 is about 5Mbps [10]. This is relevant limitation of IPTV usage by a majority of possible users and an improvement of this issue is a current challenge in the IPTV research.

3. Hierarchical aggregation

RTCP protocol is used as a control protocol in multimedia stream and occupies up to 5% of bandwidth assigned to the media transmission. That means the more users in system the longer time interval between two signal messages of one specific user. This interval can reach unacceptable values of delay and jitter that leads to a long response of the stream server. Subsequently, users have to wait for reactions to their requests, the video quality of the stream can not be efficiently controlled which means the user machine can be overloaded or in case of data congestion in a network, the network regeneration takes longer time. For this reason the method of information summarization is needed.
The summarization, in general, is a presentation of only important parts of the data content. The process consists in two main steps, removing and separating.
This procedure is a universal explanation of the summarization problem resolving. We can say that the summarization is a process of the information

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compression and the separation of relevant parts to achieve less bandwidth utilization and network units load. Fig.1 shows transmission channels used in the IPTV system. Multimedia content is streamed from the IPTV server to end users in multicast channel whereas signalization information is sent back to the server in unicast channel in classical approach or it is summarized in the structure of feedback target (FT) nodes (the FT structure is drawn in Fig. 2) and then as a compressed package forwarded to the server. Using the hierarchical structure of FTs the information is summarized on the first FT by the determined hierarchical method. The FT sends the summarized information to another level of FT or to the IPTV stream server in case of the top positioned FT called Root Feedback Target (RFT).

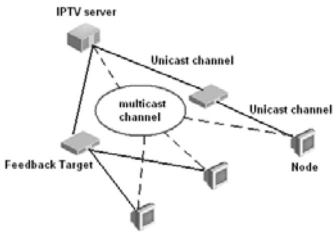

Fig. 1: IPTV transmission channels

4. Signalization in IPTV and TTP protocol

Sending signalization information is necessary for the system control and to ensure the user interactivity. There can be found a few certain solutions. Firstly, when a signalization information is transmitted from end users, DSLAM (Digital Subscriber Line Access Multiplexer) devices summarizes it and sends it to a main server to process in a defined time intervals. This whole process is very time inefficient because the information sent from end user to the main server takes in average tens of minutes.

Unicast is another possibility how to transmit all signalization to a defined address of the main server in real time. However, this solution is suitable only for small networks up to tens of nodes because the large amount of communicating nodes would overload the main server [4][5].

Much better and more effective option, that is still being developed, is to use unicast way with hierarchical aggregation and with dynamic change of all nodes addresses depending on the physical localization in a network. This signalization solution with hierarchical aggregation is deeply discussed in [5]. This paper is focussed on monitoring and visualization of relations of all units in the system and their signalization in the time of transmitting IPTV streams.

Signalization to the main server RFT and backward in the IPTV network is forwarded via FTs. These nodes summarize data by specific method and transmit them over dynamically constructed and modified tree structure to the main server to process. Feedback target system is divided into the levels. Level 0 contains only one RFT unit. Next levels are organized into a tree topology how can be seen in Fig. 2. IPTV tree manager, visualization, monitoring server and feedback targets are units using the TTP protocol to transmit the signalization data. This structure is referred as a coordinating system. To coordinate the tree structure, the IPTV tree manager needs to know certain basic information about each user node, its physical location in the network e.g. To detect real position, the system uses solution based on “Vivaldi” or “Global Network Positioning” algorithms. IPTV tree manager uses TTP protocol to dynamically coordinate relations between all FTs and RFT unit. Appropriate information is transmitted to the tree manager server from all nodes. The server will dynamically change the whole topology of FTs according to given information. The server has to be configured for the optimal management that depends on network type or provider needs.

Fig. 2 shows all units and important protocols of the signalization system using TTP and hierarchical aggregation.

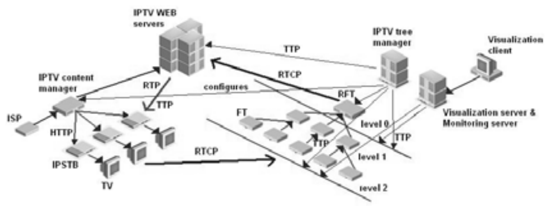

Fig. 2: Structure of TTP signalization system

Multimedia stream outputting the IPTV stream server is transmitted to end users’ IPSTB (IP set-up-box) in packets of the RTP protocol. A content of the multimedia transmission is controlled by ISP (Interenet Service Provider) through the IPTV content manager node. RTCP is used to realize the end user interactivity. Information in RTCP packets is summarized in FT structure before it is sent to IPTV stream server that subsequently reacts to the user action and transmission characteristic change.

There is also the requirement of topology visualization with additional information which is provided by monitoring and visualization server.

This TTP technology can be useful for many applications that use large amount of units that communicate with only one head-server [6].

5. Monitoring system

This part of the paper deals with the implementation of the monitoring server and the client application as a part of the TTP Monitor system for TTP structure monitoring and visualization. These programs were realized in the Java programming language for its robustness and universality.

Both described programs serve for obtaining the information from networks of various sizes. The server side is the first realized part of the application. It is a multithread program using two threads to improve efficiency of information collecting process. Nowadays, the most of programs use only one thread that brings problems when more processes need to be processed simultaneously. We can say that multithread applications have massive performance improvement by parallel run of threads in one program. Logically, multithreading means parallel run of different blocks.

The server side of application sends requests to a client whose address got from the MySQL database. The client side accepts the requests, processes them and regarding to information content generates random values on a separated thread in a specific time interval. These values are sent back to the first thread and they are transmitted (as an answer) to the source IP address of the server. The server accepts these answers and stores them into the MySQL database for their future use and visualization. Simultaneously a time stamp of received information (answer) is stored to monitor history of the whole system.

5.1. Definition and application

Next research of the applications will be concentrated to replace the thread for random values generator, in the client application, by the class for obtaining real values. For advanced functionality it is possible to construct a certain server-client class to receive the real values from various sources (nodes, routers, switches, sensors, etc.). The form of received values depends on a requested result and on an environment where the applications will be running. The program was construed as a universal communication system, where any changes are not problematic.

The whole solution is made especially for the realization of the IPTV signalization but the system can be used for another application as well, sensor network e.g. If the network has millions of the sensors placed around many watersheds to get the information in the real-time, it will lead to overload of the data collecting server. The use of the hierarchical tree between clients and a server is the right solution.

The information exchange uses protocol TCP which is connection-oriented and lossless but from this reason the system loses performance. In the small networks (about 500 nodes) using of the TCP is not an issue but in the large-scale network (sensor network) the performance rapidly decreases. True is that all information from all nodes are not such important as their statistic representation in the large networks. It means that the system can lose some information but the results will be still excellent in the end. This fact opens a way to use the UDP protocol instead of the TCP for this type of application. The change of the program source code does not mean any big modification. The program has been constructed to make this modification easily realizable.

Communication on the application-layer transmits a data chain from the server in the request and from the client in the answer. This fact opens a space for possible attacks, especially if the system will be applied to an unsecured network (Internet). The form of the data on the application-layer can be modified to create false results or to freeze the application. The server is also not secured on the incoming port against DOS (Denial of Service) attacks. These issues can be resolved on the lower layers of the ISO/OSI model, anyway for the security, the system needs to be updated with certain encryption on the application layer.

The server and the client side of application represent on their outputs the error messages and other service information. In the distributed network this state is insufficient. Every thread of both programs can be modified to send the UDP packets with a service or error message to a specific logging server that stores these notifications. There will be also possible to monitor the activity of the whole system and to detect the specific attacks performed at this server.

5.2. Testing of the monitoring system

The TTP Monitor system was tested in various network environments. The point of this part of the work is to find the stability and errorless functionality.

Virtual 1 (Threads)

In the first part of construction programs were modified to transmit information from the first thread (server) to the second thread without the use of network environment just on local machine. The target IP address was replaced by loopback address.

Virtual 2 (Virtual machines)

In this part, the behaviour of the system was tested in the virtualized network with a small amount of nodes. The different operating systems (3x Microsoft Windows XP SP2 and 3x Linux Fedora Core 8) ran under this network to test the operation system independency of Java applications and the speed of communication. The client application was installed and lunched at these nodes. One node ran the server application that collects and stores received information to the local MySQL database. These values were compared with expected ones and later were processed by visualization server.

Real 1 (Planetlab)
This investigation was accomplished in the experimental large-scale network Planetlab [14]. This network has approximately 400 active nodes where each runs under the Linux Fedora Core 8. The client applications were installed and launched on these nodes. The advantage of this environment is a placement of these nodes around the entire world. It means that the common delay with the server is not constant. This brings a random and real server load.

Real 2 (Laboratory)
The installation to different environments of the experimental laboratory network was the last part of testing. The laboratory has approximately ten nodes including IPTV server that serves as a controller as well. Nodes ran different operating system (Linux based, Windows). The stability of this application in a long term was the main point of this test. The system performance was stable without any noticeable errors during the whole test.

All performed tests have demonstrated functional operation of both client and server side of TTP Monitor application and communication between them in the test environment.
The test results have shown multiplatform use of the application, stability thru different placements and operating systems.

6. Visualization

As previously described, signalization information sending towards the main server from each host in IPTV system would overload it. That is why the hierarchical aggregation and the TTP protocol are used to make communication faster and more effective. There is a tree structure of FT servers built in order to aggregate and partly process data information from end users. The intermediate FT servers form a multilevel tree topology with a RFT on the top of the structure.
There is a need of well-arranged visualization of the network structure. Moreover, specific information about location, reliability and source utilization of each node is important to obtain and to display it in a transparent form. This part of the paper deals with these requirements and discusses the visualization of the hierarchical tree structure of summarizing FTs and additional information.

6.1. Visualization requirements

There can be found several methods and solutions for a tree topology displaying. Previously described features of the IPTV system and the summarising TTP topology bring following requirements on the visualization application design.
Accessibility – IPTV is a technology providing worldwide multimedia services for interconnected users. That is why the application should be accessible everywhere via Internet. Portability and no specific software installation would also increase accessibility and ease of usage.
Up to date reflectivity – The number of members and tree topology is changed over the time. The application should reflect these changes and react to them by scheme modification. This function will ensure that the scheme is up to date. It does not mean real time monitoring of topology however it is necessary to set up an appropriate refreshing time interval in which the topology will be controlled.
Scalability – The IPTV service is still being developed and improved to satisfy users and ISP demands. It has to follow new trends and demands of the network technologies such as the IP addressing scheme change from the IPv4 to the IPv6. This leads to the developing of scalable application that is ready for easy modification.
Robustness – The assumption of hundreds of thousand users in the whole system and thousands of end users for one summarizing server makes relevant demands that have to be considered during application development.
Additional information providing – The only topology displaying is useful but more information about nodes in the FT tree can be obtained from RTCP packets. This information should also be accessible for users who are interested in. Besides the tree structure scheme displaying the following information is given.

- IPv4 and IPv6 address
- Application port of connection
- Tree membership (there can be more than one tree in the system)
- Tree sharing
- Size of the group the node belongs to
- Data volume of packets transmitted between two FT servers
- Time period of RTCP packets
- Node activation/log on time
- Receivers’ data loss
- Delay (only for end users)
- Jitter (only for end users)

6.2. Data storage

Data storing of node and topology information is necessary for future information processing (displaying the past situation in the network, statistics compilation, etc.). However this function has also one big disadvantage - rapid data amount increasing and data storage capacity requirements. With the assumption of data gathering for example from 10.000 nodes every 60s (the time interval is a compromise between up-to-dateness and stored information volume). It represents 5.256.000.000 information messages in one year. If each message has 11 items and each item has 3 bytes in average it is 173GBytes of data without overhead information in year. Also further data processing (speed of reading and writing information) has to be considered during design.

There was a database data storage selected after options examination (XML, CVS, database). This choice is the most suitable from a few aspects. Data are stored in tables transparently with automated processing and optimizing by a database engine; it is fast and all transparent. MySQL database was chosen as a database system since its easy installation, maintenance and web pages implementation.

MySQL offers a few table types. The MyISAM is the most used type of data storages. It is optimized for fast reading from database on SELECT query [1] and that is why this table type was chosen for the database. There is an assumption that information requesting will occure more often than information storing in the database.

There can be found two types of information stored in the database. Firstly static data that are related to static information of end nodes connected to IPTV hierarchy. Static data are assumed to be changed rarely and are stored in the specific table HOSTINFO (Fig. 3). IP address of a node or its DNS name is included in the static data types for example. Next data type is referred as dynamic type in sense of faster record change. Tree structure, node position or jitter is representative of dynamic data type. Each record in the table for dynamic data (TREEMEMBER) has its timestamp stored separately in the third and last table referred as LOG.

Due to this database structure, we are able to design and draw the whole tree topology scheme with related information and meet all laid requirements.

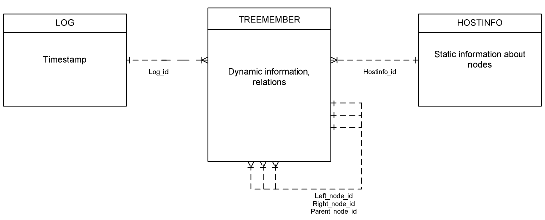

Fig. 3: Database relationship diagram

6.3. Visualization tools

The application requirement for worldwide accessibility without special software can be fulfilled by displaying the tree topology scheme in a web browser as a web page. There is a lot of tools and programming languages for web generation; each with its special offer, pros and cons. JSP (Java Server Pages) with SVG (Scalable Vector Graphic) was selected as the most suitable tool TTP structure visualization. JSP is a Java technology that allows software developers to dynamically generate HTML, XML or other types of documents. JSP is a suitable tool when web page is mostly static with only dynamic part unlike similar technology of servlets. It supports user defined tags based on XML format that are used in library function recalling. Most of the functions are included in JSTL (JavaServer Page Tag Library) [2].

SVG is a language for describing two-dimensional graphics and graphical applications in XML. It describes a vector based graphic. SVG images and their behaviours are defined in XML text files. It has new opportunities in graphics processing and operation with graphic itself. More information is available in [3]. User interaction is one of the useful functions (besides lot of others) supported by SVG that is used in our application. This feature allows displaying detailed additional information after the certain user action.

Browser support is required for SVG graphic displaying. This can be resolved by additional plug-in (Internet Explorer version 7 with Adobe AVG viewer) or by native implementation of SVG viewer into browser (Firefox from version 2.0.0.16 and Opera from version 9). SVG support is not identical in each particular browser which can lead to a different image interpretation, but it is not an issue in this application.

Topology scheme is inserted into webpage as an object with appropriate tag. Since a topology tree is generated dynamically in a predefined time interval, it is useful to create a JSP page that will generate SVG object instead of SVG file storing locally and its subsequent displaying, as shown in Fig. 4.

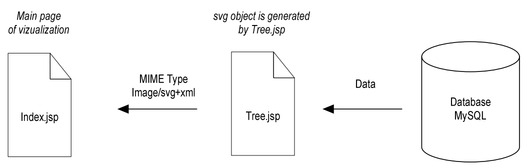

Fig. 4: SVG object insertion

Actual network situation presentation is one of the laid requirements. This can not be met by any XHTML or JSP function, unfortunately, so it has to be done alternatively. One possibility is through F5 key or "refresh" button, but it is significantly uncomfortable. Java script utilization is much better and more sophistic methods however Java scripts do not have to be allowed on each system (network policy e.g.). Fortunately, there is one more quite elegant possibility in using of a meta tag for page redirecting. This solution is not ideal because of the whole page refreshing instead of only graphic refreshing but it is acceptable for our requirements.

6.4. Visualization test

There were two types of test performed - empirical test with predefined values and the test with real values obtained from experimental PlanetLab network [14].
Firstly, the sample data file based on predefined model was stored in the database. The created model took into account various situations that can occur and the designed scheme created by application was compared with the model situation.
Speed test was performed on PC with 1,5Ghz Turion X2 TL52 processor and 2048MB RAM. 45000 records were stored in database for these purposes. The only records listening took 1,38s but the scheme design itself took much longer depending on tree hierarchy - from 2s to 10s. Time results are much better in case of cache usage.
Real network data were also used besides the sample model for application test. Data from information packets from experimental laboratory network were stored in the database and the scheme was subsequently created.

6.5. Visualization output

An output of the visualisation application is a result of the monitoring system (see Fig. 5). The output of the algorithm construed to get the information from an end node (the server and the client) is included in the next figure (Fig. 6).

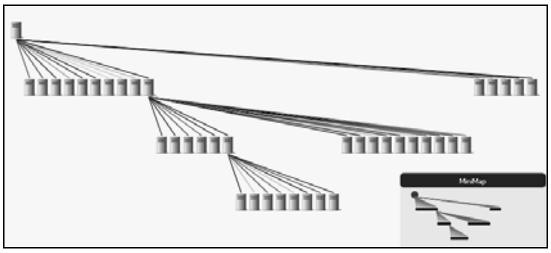

Fig. 5: Example of visualization output

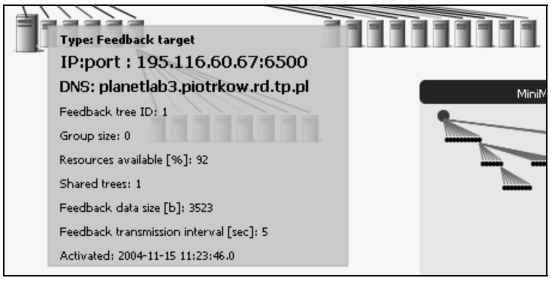

Fig. 6: Detail of the specific node output.

7. Conclusion

The multimedia transmission over Internet is a wide field of the current research. This paper contributes to this topic by the discussion of the user feedback improvement. User interaction is a new feature that IPTV brings unlike classical TV broadcasting. It provides a lot of attractive additional services for users that makes development really interesting.
User feedback messages are transmitted as a signalization part in the RTCP packets. Issues arisen from the overloading of the video server are solved by the TTP protocol and hierarchical aggregation. TTP creates trees of the FT servers that have to be monitored and maintained. This brings a requirement of transparent visualization of the TTP topology. Monitoring and visualization applications are developed in our approach by JAVA based tools with data storing in the database for its robustness and scalability. SVG Vector graphic was used as a modern and powerful tool with useful features.

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