Transactions. Georgian Technical University. AUTOMATED CONTROL SYSTEMS - No 1, 2006

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IP Multicast Routing Protocols and Algorithms for TVoIP

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Abstract

There has been a great interest in developing and delivering the live TV broadcast over an all-IP infrastructure in the same way as the TV is broadcasted today through satellite, cable or terrestrial network. This paper basically discusses the main aspects of IP multicasting that can be used for broadcasting live TV. Multicasting technology is an important feature that can be used by IP-networks and allows an efficient distribution of content from single source to multiple destinations and it is a practical solution in implementing the services like TVoIP/VoIP, VoD/MoD, and Internet access over an existing infrastructure using broadband technology like DSL (Digital Subscriber Line). The paper mainly concentrates upon the multicast protocols and algorithms used by these protocols in order to provide a platform to support one-to-many and many-to-many applications as, presently most of the IP infrastructure is based on unicast networks whereas IP –multicast networks are much more efficient.

1. Introduction

There is an enormous growth in Internet during the recent years. Internet applications are now involving voice, video and data applications in an all-IP network and the terms like video conferencing, streaming video, video/ music on demand (VoD/MoD), VoIP/TVoIP are becoming part of our day-to-day life. All these services not only require high-speed Internet connection like Broadband DSL but also required an efficient communication technology. VoIP is an important and complex service that is being introduced on an Internet during the last few years. On the other hand there is an increased interest in utilizing IP networks to not only providing services like VoIP and VoD but also to use IP to deliver broadcast or live TV.

Voice, video and data when transmitted over an all-IP network are called Triple Play scenario. Voice and data i.e. Internet access is already available to the users over an IP network but in order to provide TV broadcast access to the users in the same manner as the TV is broadcasted today by means of satellite, cable or terrestrial networks there is a need of more efficient communication mechanism. In order to provide live TV broadcast over an IP the first and most important issue is that how will the user get access to all the services that are available? Another important issue is that with satellite, cable or terrestrial networks it is quite simple that the user has to select the particular frequency and the TV channels that are available on that frequency can be easily accessible, where as, with TVoIP user cannot access all the channels simultaneously because it occupies lots of bandwidth. Hence, the traditional system is not effective; rather, user has to access the particular IP address.

Here the question arises that whether there will be a separate IP address for every channel? If it is so then the bandwidth requirement grows incredibly and also the solution is not cost effective. In order to access multiple channels IP networks must be adequately support many-to-many communication. Although the current IP networks are not adequately adapted to support these services as most of IP networks are currently based on IP unicast, whereas, IP multicast provides an efficient mechanism to support many-to-many communication. The rest of the paper is organized as follows, section 2 gives a brief introduction about what TVoIP is? Section 3 discusses the multicast packet forwarding while section 4 discusses the multicast protocols. Finally, the conclusion is given in section 5.

2. TVoIP

The rise of cable TV, satellite services and the use of HDTV (High Definition TV) has all left their landmark over the last decade on TV broadcasting. With the advancement of technology the TV of future will become more interactive and will involve electronic delivery over packet-switched networks as the Internet. With this concept it is true that the technologies of TV and computers are converging under the concept of TVoIP. TVoIP means a system which is capable of receiving and displaying video contents that are encoded as a series of IP packets. Today most television services are carried over satellite, cable and terrestrial network, however, in order to provide services like TVoIP and VoD there is a need of high speed Internet connection as these services are real-time which are intolerant to delay, jitter and latency. Broadband technology [Ollmar et.al 02] not only provides high-speed connection but also supports voice, video and data and the connection is always on. Broadband access is currently available through xDSL, cable and Broadband Wireless Access (BWA).

TVoIP describes a system where a digital television service is delivered to subscribing consumers using the Internet Protocol over a broadband connection. This service is often provided in conjunction with Video on Demand and may also include Internet services such as Web access and VoIP where it may be called Triple Play.

TVoIP covers both live TV (multicasting) as well as stored VoD. The playback requires either a personal computer or a set-top-box connected to a TV. Video content can be delivered through MPEG2TS (MPEG over IP Transfer System) via multicast, a method in which information can be sent to multiple computers at the same time. The underlying protocols used for TVoIP are IGMP (Internet Group Management Protocol) (RFC 988) for channel change signaling i.e. for live TV and RTSP (Real Time Streaming Protocol) for video on demand (RFC 2326). Simultaneous delivery of channels is an important concern in order to compete TVoIP with the traditional system of cable TV, which will require a very efficient IP multicast mechanism. In section 3 it will be discussed how packets are forwarded in a multicast environment .

3. Multicast Packet Forwarding

Multicasting is implemented by special multicast routers. Multicast is an extremely powerful feature that allows the distribution of information from one-to-many and is the mechanism that can be used by applications like VoIP/TVoIP, VoD/MoD, conferencing services like Netmeeting etc. Multicasting is based upon the concept of distribution trees, in that case each source is called as the root of the tree while the receivers are treated as the leaves of the tree. Routers replicate the packets at each branch of the tree and that point is called as the bifurcation point. It means that only one copy of the packet would travel over any particular link in the network and this makes multicasting extremely efficient in order to distribute the same information to multiple receivers.

This is the greatest advantage of multicasting as it not only reduces the bandwidth usage but also reduces the source-processing load, which is not possible with unicast mechanism. Multicast can be [Sun 05] either Best-effort or Reliable. By Best-effort it means that the packet is delivered without any QoS guarantee that the packet is delivered to all the group members. As it might happen that some of the members do not receive the packets. While, Reliable means that the sender must implement an efficient mechanism to ensure that all the group members of the multicast transmission have received all the packets sent and this requires a reliable multicast protocol.

Since, class D IP addresses [Tanenbaum 03] are reserved for multicasting and unlike class A, B, and C IP addresses, class D IP addresses are not associated with any physical network number or host number, rather, class D addresses are associated with a multicast group that works in the manner as a radio channel, i.e. a member of the group receives multicast packets sent to this address and as a result multicast router, also called as mrouter, use that address to route the packet to users that are registered for a multicast group. IGMP (Internet Multicast Group Management Protocol) [Deering 89] is the protocol that can be used for this purpose as it provides the mechanism by which a terminal registers for a group, it is described in the next section.

4. Multicast Protocol

Multicasting [Deering 89] is accomplished by IP multicast protocol over the MBONE (Multicast Backbone) in the Internet. MBONE is defined as, when the scope of multicast is [Ballardie 97] extended beyond local sub network then the subnet must be attached to a multicast capable router which in turn is virtually connected to another multicast capable router and so on. Hence, forming an Internet's MBONE or simply it can be said that MBONE [Erikson 94] is a virtual network overlaid on the Internet.

There are a number of protocols which play an important role in IP multicast and multimedia content distribution as shown in figure 1. Figure 1 shows [Cha et.al.97] the IGMP which is used for user registration to a multicast group. Similarly, RSVP (Resource Reservation Protocol) is used for resource reservation, whereas [Schulzrinne et.al.96] RTP (Real Time Protocol) and RTCP (Real Time Control Protocol) are used for audio and video streaming i.e. to manage multimedia session.

SIP (Session Initiation Protocol) [Handley et al. 99] is used for signaling and session management takes place with the help of SDP (Session Description Protocol) and SAP (Session Announcement Protocol). RTSP [Schulzrinne et.al 98] (Real Time Streaming Protocol) is used for VoD services.

This section particularly describes the working of IGMP as it is particularly required for establishing IP multicast group. IGMP is particularly helpful for providing the services of TVoIP as with the help of IGMP the channel changing capability can be achieved for live TV broadcasting.

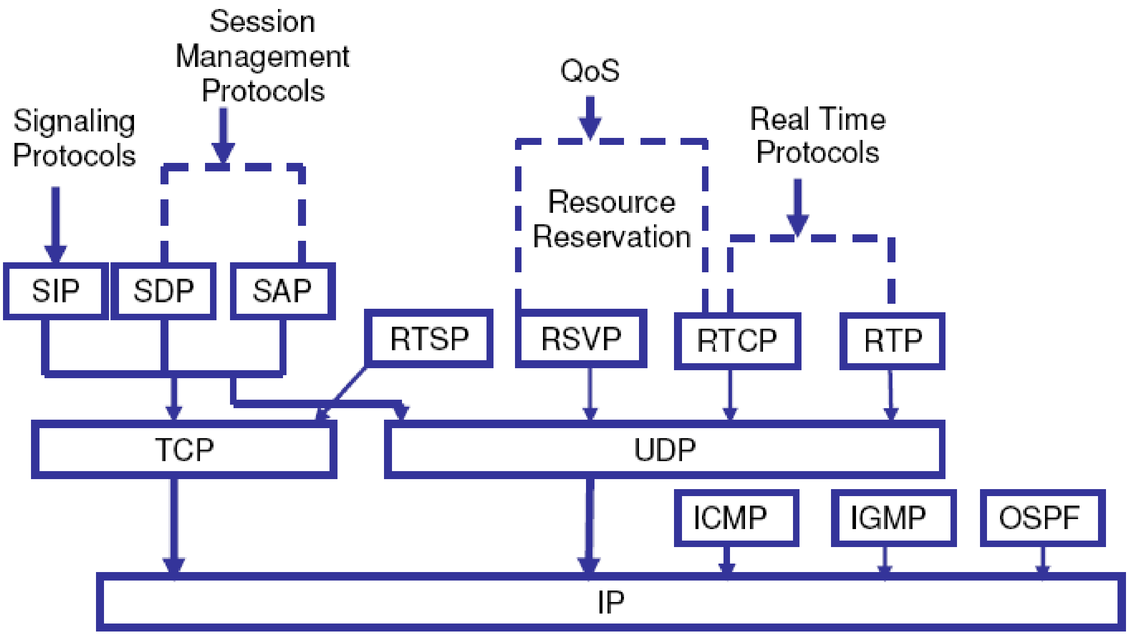

Figure 1. Multimedia Protocol Suite

IGMP [Sun 05] is the transport-layer multicast protocol based on class D addressing scheme. It is used to establish membership in multicast groups. In order to make efficient use of network resources, the network sends multicast packets to only those networks and sub networks that have users that belong to the multicast group. IGMP allows terminals or hosts to show interest in receiving a multicast transmission. The working of IGMP is quite simple. There are three types of messages generated by IGMP. The Join, Query, and Leave.

Join: A host uses a report message to join new group.

Query: It is used to discover which hosts are members of the given group.

Leave: This message is sent when the host wishes to leave a given group.

When a terminal wants to receive a multicast transmission it issues an IGMP join report message which in turn is received by the nearest router and this join message contains the class D IP address. While IGMP query messages are periodically issued by the routers to the IP multicast address of the group in order to confirm the state of the terminals that are receiving multicast. When a terminal receives such query, it sets up separate timer for each of its group memberships. When the timer expires, the terminal issues an IGMP join report message to confirm that it still want to receive multicast transmission. In order to prevent duplicate join messages from the same class D group address, IGMP has a good mechanism that if a terminal has heard for a join message from another terminal of the same group, it stops its timer and does not send the join message again. This mechanism helps avoid flooding the sub networks with IGMP join messages. In the end a terminal issues a leave message when it wants to stop receiving the multicast transmission. IGMP v2 supports [Deering 89] the leave message request whereas, in IGMP v1 the terminal simply change its state to non-member and does not issue any leave request to the router and as a result if all the members of the group have stop receiving the multicast transmission and hence the router will not send any multicast packet to that subnet.

A router builds routing tables in order to send packets from source to destination. In a unicast transmission the routing table contains information about specific path that leads towards a particular IP destination address. i.e. the router takes into account the destination

IP address to route the packet. In case of multicast transmission this type of routing table is not useful because the multicast packets do not contain information about the destination of a packet. Therefore, multicast routers utilize different routing protocols to form multicast tree in order to find delivery paths that enable forwarding of multicast packets across the Internet. Multicast routing protocols basically address the issue to identify the most appropriate route for data to be transmitted over the network from the source to all its destinations thereby minimizing the network resources required for this. A number of protocols has been proposed by IETF (Internet Engineering Task Force) to achieve this task. Multicast routing protocols are:

� Distance Vector Multicast Routing protocol (DVMRP)

� Multicast Open Shortest Path first (MOSPF)

� Protocol Independent Multicast (PIM)

� Core Based Tree (CBT) IGMP simply forwards multicast traffic from the local router to all the group members that are attached to those subnetworks. IGMP provides the final step in multicast packet delivery and is not responsible how packets are forwarded across the entire network. Internetwork delivery of multicast packets is accomplished by using an appropriate multicast routing protocol. Multicast routing protocols are not only responsible for creating multicast distribution trees but are also responsible for packet forwarding. Multicast routing protocols require an efficient multicast packet forwarding algorithm in order to accomplish this task. The difference between the performance of the multicast routing protocols mentioned above lies mainly in the way each of them build a multicast distribution tree based upon the routing algorithm that protocol use. Routing algorithms are discussed in the next section.

4.1 Multicast Routing Algorithms

Different routing algorithms are utilized by multicast routing protocols. They are:

� Flooding

� Spanning Tree

� Reverse Path Broadcasting (RPB)

� Truncated Reverse Path Broadcasting (TRPB)

� Reverse Path Multicast (RPM)

4.1.1 Flooding

Flooding algorithm is the simplest technique to deliver multicast datagram to all the routers in an Internetwork. When the router receives a packet that is addressed to a multicast group it starts the flooding procedure. In the flooding algorithm [Plunkett 94] every incoming packet is sent to every outgoing line except the one from which it is arrived. The multicast router then employees a protocol mechanism to see whether this is the first time this packet has been seen or it was seen before. If the router has seen the packet for the first time then it is forwarded to all the interfaces with the guarantee that the multicast packet will be sent to all the routers in an Internetwork.

Otherwise the packet is discarded. Flooding algorithm is easy to implement but it is not scalable for Internet-wide applications as it generates large number of duplicate packets and utilizes all available paths across an Internetwork instead of just a limited number. As a result it not only makes an inefficient use of the available bandwidth but also makes an inefficient use of router memory resources because each router has to maintain a distinct table entry for every packet that has been seen recently.

4.1.2 Spanning Tree

An effective solution is to use spanning tree algorithm. In this algorithm a tree structure is formed where one active path connect any two router on the Internet as shown in figure 2. After the formation of spanning tree a multicast router simply forwards each multicast packet to all the interfaces that are part of the tree except the one from which the packet is arrived. Hence, it makes an efficient utilization of bandwidth and the network resources.

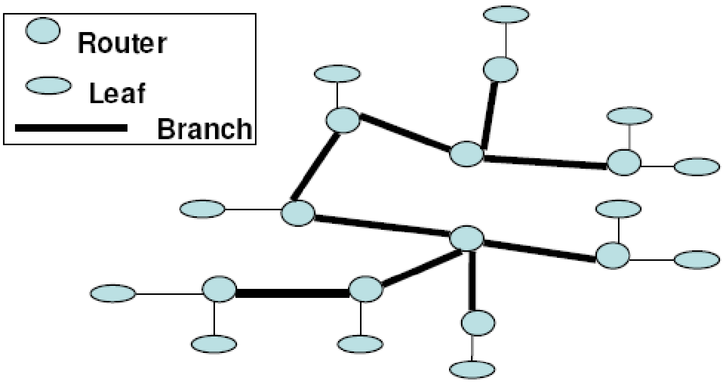

Figure 2. Spanning Tree

4.1.3 Reverse Path Broadcast (RPB)

In the spanning tree algorithm a single spanning tree is build for the entire network which rather creates burden on network traffic. Hence, instead of building a single spanning tree for the entire network, group-specific spanning trees can be build for each subnetwork. Such spanning trees would result in source-rooted delivery trees originating from the subnetwork directly connected to the source station.

Hence, a different spanning tree is constructed for each active (S,G) pair, (where S indicates the IP address of the source and G indicates the group address) because there are many potential sources for a group. Since, the source tree implies that the route between the multicast source and receiver is the shortest available path therefore for each (S,G) pair, if a packet arrive on a link that is considered as a shortest path back to the source of the packet by the local router then the router will forward the packet to all its interfaces except the one from which it is arriving or otherwise the packet would be discarded.

The interface at which the router expects to receive a multicast packet from a particular source is called the parent link whereas the links over which the router forwards the incoming packets are called the child links. RPB is efficient as compared to spanning tree and flooding algorithms as the router does not require having the knowledge about the entire spanning tree and also the router does not require a special mechanism to stop the forwarding process as is required in flooding. On the other hand RPB provides efficient delivery of multicast packets as multicast packet always follow the shortest path available from source to destination.

The mechanism results in an efficient bandwidth utilization since a different tree is formed for each (S,G) pair. The major disadvantage of RPB is that it does not take into account multicast group management when building the spanning tree for (S,G) pair and because of this datagrams are forwarded unnecessarily over the subnetworks that have no members in the destination group.

4.1.4 Truncated Reverse Path Broadcast (TRPB)

To overcome the drawback of RPB, TRPB is developed. It has the same mechanism as that of the RPB accept that in TRPB routers determine the group membership with the help of IGMP on each leaf subnetwork and hence avoid unnecessary forwarding of datagram onto a leaf network if it does not have any member of the destination group. Hence, the router truncates the spanning tree delivery if the leaf subnetwork does not have group members. TRPB solves the limitation of RPB to certain extent by eliminating unnecessary traffic on leaf subnetworks but it does not consider group memberships when branches of the distribution tree are build.

4.1.5 Reverse Path Multicast (RPM)

Reverse Path Multicast is an extension to RPB and TRPB and it creates a spanning tree that spans only to the subnetworks that have group members and routers and subnetworks along the shortest path to subnetworks with group members. RPM forwards multicast packets based on the information of IGMP. RPM allows that the source-rooted spanning tree should be pruned so that datagrams are only forwarded along the branches that lead to members of the destination group. Prune [Plunkett 94] is a control packet and a leaf router can transmit a prune message to its parent link in order to inform the upstream router that it should not forward packets for a particular (S,G) pair on the child interface. Prune messages are only sent one hop back towards the source. If all the leaves connected to that router are pruned that router will also be pruned and hence no more multicast packets will be forwarded to that. Hence, the succession of prune messages creates a multicast forwarding tree which consists of only live branches that means branches that lead to active group members only.

In RPM there is a dynamic change in the group membership as well as network topology therefore it is important that the pruned state of the multicast forwarding tree must be refreshed periodically. Before the forwarding of the next multicast packet takes place for the (S,G) pair to all leaf routers, previous information of pruned messages is removed from all the routers and a new set of pruned messages will result which allows the multicast forwarding tree to adapt the changes in multicast delivery requirements of the Internetworks.

Hence, RPM is more scalable than RPB and TRPB as it not only utilizes the bandwidth and network resources efficiently but [Deering 89] also makes use of IGMP information for both the parent and the child interfaces and does not forward multicast data packets for a multicast group that does not have members. Multicast protocols as listed in section 4 are used to establish a connection between the routers based upon any one of the algorithms discussed above. The next section will discuss the working of multicast protocols.

4.2 Multicast Routing Protocols

DVMRP (Distance Vector Multicast Routing Protocol) [Diot 00], MOSPF (Multicast Open Shortest Path First), and PIM-DM (Protocol Independent Multicast-Dense Mode) build multicast spanning trees depending upon the shortest path from each source i.e. they are based upon source tree approach while PIM-SM (Protocol Independent Multicast-Sparse Mode) and CBT (Core Based Tree) [Ballardie 97] build spanning trees depending upon the shortest path from a known central core which is called as the rendezvous point (RP).

A RP is a common point where a receiver joins to learn about the active sources. RP is used in shared tree approach where multicast sources must have to transmit their traffic towards RP or it can be said that RP is nothing but the root of the tree. DVMRP is based upon the mechanism of DVRP (Distance Vector Routing Protocol) and used to forward multicast datagrams across the Internetwork. DVMRP is a flood-and-prune protocol based upon the TRPB algorithm. DVMRP is [Waitzman 88] an interior gateway protocol which is best suited within an autonomous system but not suitable between different autonomous systems. DVMRP uses the TRPB algorithm in which [Diot 00] the source of the multicast group forwards multicast datagrams across the entire network after computing the shortest path tree from the source to all possible destinations of the datagram.

The datagrams that are received by the router on the reverse path interface back to the source are simply ignored and a prune message is sent to the neighboring router. The router which does not have any group member interested in receiving the multicast packet also send a prune message back to the spanning tree. MOSPF is [Diot 00] an extension to OSPF (Open Shortest Path First). MOSPF make use of the unicast routing protocol so that every router has information about all the available links and each router will calculate its route from the source to all possible group members. MOSPF is [May 94] heavily based on OSPF and works only within those networks which have a small number of multicast groups and those which uses OSPF.

In case of many multicast groups, MOSPF takes a lot of CPU bandwidth of routers and hence does not scale good for the entire network. There are [Deering 89] two modes of PIM (Protocol Independent Multicast), PIM – Dense Mode where the dense mode means almost everybody wants to receive and the other is the PIM-Sparse Mode where sparse mode means almost nobody wants to receive. [Diot 00] PIM-SM employed the pull model whereas PIM-DM employed the push model. With PIM-DM all the multicast packets are flooded or pushed to the entire network and the routers which do not have any member for the (S,G) pair will also receive those multicast packets and ultimately the routers have to issue the prune message back up the tree.

Since, prune messages are refreshed periodically therefore, the multicast traffic floods again across the network until a new prune message is received. This makes an inefficient use of the network resources and flooding creates burden on the network. PIM-SM is more efficient as compared to that of PIM-DM as it is based upon the pull model in which traffic floods across the network when it is requested.

Multicast traffic will be distributed across the branch when a join message is being received from that multicast group. PIM-SM follows the shared tree approach in which the receiver joins the shared tree that is rooted at RP. The advantage of shared tree approach is that if the traffic on the shared tree reaches to certain threshold then the last hop router (to which the receiver is connected) can choose a shortest possible path in order to join the source.

This approach will put the receiver in a more optimal path to the source. Core Based Tree (CBT) is a [Ballardie 97] network layer protocol based on the shared tree approach and constructs a single delivery tree that is shared by all group members. Multicast traffic for each group is sent and received over the same delivery tree, regardless of the source. CBT spans to only those networks and links that are interested in receiving multicast packets. In order to achieve this [Fenner 96] a host first show its interest in receiving the multicast packet by sending an IGMP join message across its attached links.

This join request is processed by all intermediate routers that identify the interface on which the join was received as belonging to the group's tree. The intermediate routers continue to forward the join request until it reaches to the core router which is also termed as rendezvous point or meeting point. Like other multicast protocols, it is not necessary for CBT that the source of the multicast packet must be a member of the destination group. Multicast packets delivered by a source which is non-member are simply unicast towards the core router until they found a first router that is member of the group's delivery tree.

When the unicast packet reaches to a member of the delivery tree, the packet is multicast to all outgoing interfaces that are part of the tree except the incoming link. Hence, guaranteed that the packet is forwarded to all the routers on the delivery tree.

CBT is more scalable as compared to that of the other routing protocols discussed above as it makes an efficient use of router resources since it only requires that a router should maintain a state information for each group not for each (S,G) pair. CBT also conserves bandwidth as it does not require that multicast frames are periodically forwarded to all multicast routers in the Internetwork as is the case with PIM-DM.

However, there are certain limitations of CBT as it is used for multimedia applications like TVoIP/VoIP, as it may create an increased delay because of a single shared delivery tree because suboptimal routes will be created. Also, there may be a concentration and bottleneck result at the core router as all the traffic will traverse through the same set of links towards the core router.

Conclusion

In this paper the most important aspects related to the IP multicasting for implementing TVoIP are discussed. The paper mainly emphasizes the important protocols and algorithms used for IP multicasting and give an insight about the advantages and disadvantages each protocol has.

Depending upon the advantages and disadvantages discussed in section 4, DVRMP can be used for Inter-domain routing as it is best suited within an autonomous system but does not scale good within different autonomous system. On the other hand PIM-sparse-dense-mode is suitable for Inter-domain multicast routing.

It is not only efficient but also does not require that special routing messages will be transferred between neighboring routers. PIM-sparse-dense-mode build unicast routing tables within the router for calculations and depending upon that calculation takes decision for the shortest possible path. Although, TVoIP at the moment is at its infancy but can be employed with its full strength by using IP multicasting as IP multicasting opens doors for new applications and hence, provide better usage of network resources. However, it is very important that in order to implement reliable, high performance broadcast TV, which should fulfill all the QoS requirements further improvement is needed to improve IP multicasting.

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ნ. ბორა, ჰ. დე მეერი

IP მარშრუტიზაციის ჯგუფური პროტოკოლი და TvoIP ალგორითმი

რეზიუმე

ფართო დაინტერესება გამოიხატება პირდაპირი სატელევიზიო გადაცემების გავრცელების (Broadcasting) განვითარებისა და მიწოდებისათვის ყველა IP ინფრასტრუქტურაში, ისევე, როგორც ამჟამად გავრცელებულია ტელევიზია სატელიტური ანტენების ან გლობალური ქსელის მეშვეობით. აქ ძირითადად განიხილება IP მულტიშეტყობინება (Multicasting), რომელიც შესაძლებელია გამოვიყენოთ სატელევიზიო გადაცემის პირდაპირი გავრცელებისათვის. ეს ტექნოლოგია მნიშვნელოვანია ისეთი სერვისების განსახორცილებლად, როგორებიცაა : TVoIP/VoIP, VoD/MoD, DSL (ციფრული სააბონენტო ხაზები).

Н. БОРА, Г. ДЕ МЕЕР

IP ГРУППОВОЙ ПРОТОКОЛ МАРШРУТИЗАЦИИ И TVoIP АЛГОРИТМ

Резюме

Существует высокая заинтерессованность в развитии и поставке прямой телевизионной передачи (Broadcasting) по все-IP инфраструктуре, также как и по распространению телевидения посредством спутниковой или глобальной сети. Эта статья в основном обсуждает главные аспекты IP мультивещания (Multicasting), которое может использоваться для прямого телевещания. Multicasting-технология является важнейшей в реализации таких сервисных услуг, как TVoIP/VoIP, VoD/MoD, DSL (Цифровых абонентских линий).