MULTIMEDIA CONFERENCE OVER SATELLITE

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ABSTRACT
Multimedia conference is one of the important applications in the Internet. To support such an application over satellite networks, one has to address quality of service (QoS) and performance of IP applications over satellite. Research has been carried to study how satellite networks can support efficiently the IP based multimedia applications including voice, video and data and impacts of satellite networks on these applications.

This paper presents the results from the project IP Conferencing with Broadband multimedia over Geostationary Satellites (ICEBERGS), which is within the European 5th Framework IST programme.

The networking architecture is based on Internet protocols, including IP, UDP, RTP and RTCP and the Internet signalling protocols such as SIP and SAP.

A testbed has been developed to demonstrate the concept of multimedia conference over satellite and evaluate the performance of satellite networks and QoS of applications.

The results from this project presented in the paper include IP based multimedia applications over satellite in terms of protocol architecture, satellite network configuration, and performance evaluation.

INTRODUCTION
To take advantage of the satellite’s wide coverage and broadcast capabilities, a lot of efforts have been made on integration of the satellite network into the existing Internet architecture. Multimedia multiparty conference based on IP networks is one of the new applications to take the advantage of satellite networking.

This paper presents the outcomes of the ICEBERGS project (European Commission, EC IST Programme), which has focused on developing integrated satellite multicast systems to support QoS sensitive multimedia conferences. Key issues of establishing an IP multimedia conference via satellite have been studied that included multicast routing protocols, signalling system, conference model and interworking between satellite and terrestrial networks. A demonstrator has been implemented to evaluate all of the study results. It provides many valuable information and results that will benefit to multimedia conference over satellite.

SYSTEM ARCHITECTURE
The whole ICEBERGS system mainly composes of two parts: Signalling and Media. It enables multicast multimedia conferencing over the OBP Geo-satellite with QoS support.

Signalling handles the setup, status changes and termination of the multimedia sessions. In combination with other protocols it describes the session characteristics to potential session participants. The Session Initiation Protocol (SIP) [1] was chosen to be the signalling protocol in ICEBERGS since it is simpler, easier and more flexible to implement and better suited to the support of intelligent user devices comparing with H.323. It should be considered separately from the media because the signalling can pass via one or more SIP proxies while the media stream takes a more direct path.

In a satellite conference system, IP multicast is required to save the expensive satellite bandwidth while take advantage of the satellite wide coverage area and broadcasting property. The ICEBERGS media routing architecture was developed based on both inter-domain and intra-domain IP multicast routing protocols, which are discussed later in this paper. The major constraint is that multicast services offered by the geostationary satellite must be compatible and at the same time competitive with terrestrial multicast real-time traffic services.
The Figure 1 shows that three user groups are communicating using multimedia conference services over satellite. All of these three user groups have unicast end users and multicast end users. They are located in the different satellite spot beams. The groups of Users 1 and Users 2 present two terrestrial domains and Users 3 is a corporation in the satellite domain. Each of these groups has a satellite terminal (SaT) to access the satellite network. The network operation centre (NOC) configures the satellite On Board Switch (OBS) dynamically upon the requests from these user groups to establish the one-to-many bi-directional channels. This function efficiently enables the multicast over satellite. The unicast end users will connect to the Multipoint Control Units (MCU) to join any conferences while the multicast users join the multicast groups by deploying the multicast protocols. The details are presented in the following sections.

The consideration is the confliction between huge bandwidth requirements of the real-time multimedia conference and the expensive satellite bandwidth cost. Congregating a group of end users’ data before sending them to the satellite is a better choice rather than allowing every end user to directly communicate with the satellite, which also needs expensive end media mixing equipments.

Following the Models for Multi Party Conferencing in SIP [13], the ICEBERGS project defined a new conference model that fits both above requirements: the Multiple Media Servers (Multiple-MCUs) Model.

In this model, one or more MCUs exist in the network. Terminals send multimedia streams to the MCUs, which collect the streams, manipulate them and generate multicast flows received by all receivers. This model optimises the satellite bandwidth needed for a multimedia conference in comparison to the simply unicast conference and simplifies the end user equipment requirements. The integrated satellite-terrestrial network and the relatively high satellite delay implies that it is not desirable to send audio/video streams from one terminal to a remote MCU through a satellite hop and then receive the composite signal again through the satellite hop. For this reason, several MCUs are needed, at least one in each corporate/business or ISP network. Therefore, we can find the “Dial-In Conference Servers Model” [13] scenario in each local network, where the conference server mentioned in the draft is now replaced by MCU. In this way, a MCU acts as a normal SIP User Agent (UA): users call it, and it maintains point-to-point SIP relationships with each local-user that calls in. The MCU takes the media from the local-users who dial into the same conference, mixes them, and sends out the appropriate mixed stream to the other participant-MCU's, probably, via one satellite hop.
Regarding scalability and compatibility, the multiple MCU model can also involve multicast end users. This kind of users has to have end-mixable equipments to handle the received mixed media streams from MCUs in the system. It should work as a combination of one unicast end user and one powerful MCU. The difference is multicast end users don’t need aggregate its own media but only anti-mix the received one.

Figure 2 shows a simple layout of this model. In this figure, two MCUs are located in the terrestrial network and each of them has two downstream unicast users. The 4 unicast users have to send and receive data through their upstream MCUs, MCU1 and MCU2. They don’t need to mix or anti-mix media streams. The USER_E is a multicast enabled user. The USER_E, MCU1 and MCU2 communicate with each other using multicast and handle the media streams.

**SIP Signalling**

In the Multiple MCU model, all end users and MCUs are SIP-enabled. They cooperate together as a group SIP UAs. To enable each end user to join or invite others to join a conference, REGISTAR servers and SIP proxies are necessary in the signalling system.

A UA has to register to REGISTAR server before it can establish any SIP relationship with any other UAs. Registration is used to provide location service for routing incoming SIP requests and has no role in authorizing outgoing requests. SIP proxies are responsible to forward any injected qualified SIP messages to the correct next proxy or conference server. They also have the ability to find out their local SIP User Agent Clients (UAC) and forward SIP messages to these UACs addressed as final destination in the SIP message.

The ICEBERGS system allows users to join an existing conference and invite other users to its conference using SIP. A centralized signalling scenario is proposed to enable all SIP request messages to be handled in the central SIP server while billing mechanism can be employed based on the INVITE message and BYE message.

Two approaches were proposed for the ICEBERGS users to join a conference:

**Meet-Me conferences:** For users in the multiple-MCU model, they call a predefined number (the conference number) at a predefined time when the conference is scheduled (advertised in WEB pages typically). The central SIP server redirects the calls to their corresponding MCUs.

**Ad-Hoc conferences:** For users in the multiple-MCU model, users invite other participants to a conference. For example, let’s say that A and B are talking to each other and they want to add C to their conversation. Then A sends a REFER message to C that will trigger that C sends an INVITE message to the conference server addressed in the REFER message. Later, if either A, B or C wish to add D, the same procedure is repeated.
Figure 3 shows how the end users in ICEBERGS system join a Meet-Me conference.

The Figure 3 described that an end user Terminal 2C registered in the centralized SIP server, which is the Vovida Open Communication Application Library (VOCAL) system with full conference control service based completely in SIP architecture, and send its INVITE message directly to the server as well. The server proxies the INVITE message to its local MCU, which is MCU 2 in the figure. After the SIP relationship is established between the Terminal 2C and MCU 2, they can start to exchange media streams using unicast. When Terminal 2C wants to quit a conference, its BYE request has to be forwarded by central proxy VOCAL to MCU 2 to enable the billing on a call basis. However, it should be defined that which MCU the central proxy forwards a user’s INVITE message to. An advanced server is introduced to solve this problem: MCU feature server. This server will handle the information of all MCUs in the conference system to associate the proper end users to each of them.

Hybrid Routing

After the users join a conference using SIP, they will send and receiver media data to and from the network. To seamlessly cooperate with the Multiple-MCUs conference model, a multicast and unicast hybrid routing architecture is proposed for ICEBERGS.

The first consideration to use this architecture is because in the ICEBERGS project, the bandwidth bottleneck is the satellite network. The hybrid routing architecture can minimize the satellite bandwidth consumption. All unicast end users have to establish unicast connectivity with their local MCUs, in which several media streams are mixed into one before transmitted to the satellite. All of the MCUs connect with each other using multicast, which can enable one-to-many communication and save the uplink bandwidth if via satellite.

Another reason for this choice is that the end user may not want to receive what he sent out to his local MCU or different users want to receive from different sources. Therefore, all end users cannot belong to the same multicast group. The ICEBERGS solution enables the end user to receiver the media data that he is interested by unicast.
MCUs and multicast end users communicate with each other using multicast in the ICEBERGS. Multiparty IP conference via satellite implies the possibility of widely geographically distributed participants. Therefore, both intra-domain and inter-domain multicast scenarios were studied in ICEBERGS.

For a single ISP domain, all of the multicast conference users use intra-domain multicast routing protocols to connect them together without interruption to the rest users in the domain. Two classifications of these protocols are considered and compared for the satellite conference:

- **Source-based multicast routing protocols:** including Distance-Vector Multicast Routing Protocol (DVMRP)[4] Multicast Extensions to OSPF (MOSPF)[5] and Protocol-Independent Multicast Dense Mode (PIM-DM)[6]. In all of these protocols, the source in a multicast group initialise the multicast tree using certain mechanism such as packet flooding, which will cause significant bandwidth consumption when there are many sources.

- **Receiver-based multicast routing protocol** such as Protocol-Independent Multicast Sparse Mode (PIM-SM)[7] and Core Based Trees (CBT)[8] protocol. This kind of multicast protocols allow receivers to initialise the multicast tree by sending explicit JOIN message to join a multicast group.

The second kind of multicast routing protocols are more attractive for a satellite conference system for its ability to avoid packet flooding. The proper consideration of a satellite conference is that the conference member will distribute sparsely in a very large area with respect to the satellite coverage. Therefore, a sparse mode multicast tree is needed for each conference. By using receiver-based multicast routing protocols, only the JOIN messages should be carried over satellite from the beams containing the receivers to the beams where the sources located instead of the sources flood packets to all satellite spot beams. Comparing the PIM-SM with the CBT, all of the receivers can receive data from sources directly using source specific multicast tree in PIM-SM while the CBT needs all of the data flows in a multicast group go through the core first that may be located one satellite hop away from the sources and receivers. Thus, the PIM-SM is the best choice of the intra-domain multicast routing protocol for a satellite conference system.

To enable different ISP domains to communicate with each other using multicast, the concept of inter-domain multicast routing protocol has to be introduced. This is required especially for satellite conference systems, like ICEBERGS. It is quite possible that different ISPs located in different satellite spot beams and they have to use inter-domain multicast routing protocols to establish multicast tree via the satellite. Two solutions were considered:

- **Short-term solution:** Multiprotocol BGP (MBGP)[9] and Multicast Source Discovery Protocol (MSDP)[10]. The MBGP is an extension of the widely used Border Gateway Protocol (BGP). It carries multiprotocol routes by adding the Subsequent Address Family Identifier (SAFI) to BGP4 messages. With MBGP, instead of every router needing to know the entire flat multicast topology, each router only needs to know the topology of its own

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**Figure 4 ICEBERGS multicast and unicast hybrid routing architecture**
domain and the paths to reach each of the other domains. The MSDP is based on the deployment of intra-domain PIM-SM. It exchanges the source information between each domain based on MBGP to enable receivers to send JOIN message to the domain containing sources.


The key advantage of the short-term solution PIM-SM/MBGP/MSDP is that it’s a functional solution largely built on existing protocols. Furthermore, it is already being deployed with a fair amount of successes. The key disadvantage of the short-term solution, the PIM-SM/MBGP/MSDP protocols suite, may be susceptible to scalability problems since the flooding function used by MSDP. Considering the deployment of ICEBERGS, the short-term solution is a better choice because it can be compatible with many existing systems and supported by many ISPs while a very large scale IP conference is not that demanded in current market.

Therefore, this multicast and unicast hybrid routing architecture is proposed to enable the end user, without expensive media mixing equipments, to efficiently communicate with others in a multiparty conference via satellite using a Multiple-MCU’s model.

Figure 4 shows this hybrid architecture. It shows a scenario where a conference is holding between one ISP domain and one satellite domain. The ISP has both unicast domain, where unicast users and unicast routers are located, and multicast domain, where MCUs, multicast end users, multicast routers, PIM Rendezvous Point (RP), MSDP peer and MBGP peer are located. All unicast sources in the ISP unicast domain send their data to the MCU where all data for the multicast group are mixed and transmitted to all the receivers in the unicast domain using unicast to enable different receivers to receive only the data they are interested. The MCU also transmits the mixed data to the PIM RP. In the satellite domain, the satellite sources unicast their data to their local MCU that mixes the data and unicasts to each local receivers. The inter-domain multicast happened between the ISP MCU and the satellite MCU. The satellite one-to-many channel establishments are based on the inter-domain multicast protocols: MSDP and MBGP.

**DEMONSTRATOR**

The ICEBERGS has set up a demonstrator for multimedia conference to completely validate the proposed technologies. The innovative aspects of this project, and the advancements in the state of the art in the major research areas will be demonstrated via a fully representative configuration of the hybrid satellite/terrestrial network architecture. The overall demonstration of the functions, signalling service, multicast media transmission and performance, using satellite terminals and a representative Internet, including core and edge routers sub-networks, will allow the full characterisation of the system choices, with possible feedback at system and element design level. A comprehensive evaluation of the trials’ results will also be carried out systematically. The following paragraphs are going to describe the demonstrator in terms of the validation plan.

A Demonstrator Network Prototype (DNP) has been specified and designed to fulfil the network architecture proposed in the ICEBERGS. In this framework also a suitable validation strategy has been defined to suggest the right methodologies and to synthesise the main test/measurement parameters and applications to be considered to plan and perform a whole system test and validation campaign. Figure 5 shows the general layout of the demonstrator based the outcomes from the project study phase.
The demonstrator layout is based on an ESW emulator working with real satellite links:

- SESAT satellite belonging to Eutelsat will be used as satellite access, which having Ku band transponder in transparent mode. The Eutelsat is one of the world’s leading providers of satellite infrastructure. It provides capacity on 23 satellites that offer a broad portfolio of services. The SESAT satellite is one of their GEO satellites at 36° East. It provides a widebeam coverage, extending over a very wide geographical area with enhanced coverage of Western Europe, and a Steerable coverage positioned over the Indian Sub-Continent.

- ESW emulator will emulate the ESW satellite network, which contains the NOC and the On Board Switch system. It has the functionalities to establish the one-to-many satellite channels.

The demonstrator is going to use real satellite network to interwork with terrestrial network to demonstrate and examine the performance of ICEBERGS results for general satellite systems. Then the ESW emulator can be implemented to cooperate with the satellite, which has all necessary functionalities of real ESW satellite for the demonstrator including interwork, transmission parameters, on board fast switching system and so on. This scenario will show the performance of the ICEBERGS system via ESW system.

In the demonstrator, the terrestrial network are represented by the following entities:

- Two Corporate/Business Sub-network with satellite terminal.
- One Federated ISP with the satellite terminal.
- Two terrestrial Federated ISP.
- A core network.
- Some terrestrial user connected to the federated ISP.

On the described physical infrastructure the SIP protocols philosophy will be demonstrated, using suitable multiparty videoconference applications. Unicast end users can use the Windows XP messenger and the multicast users can use open-source MBone tools.

To evaluate the ICEBERGS system, we have made a test plan to measure the network performance on the demonstrator. The measurements of the demonstration mainly focus on network level, where a metric of parameters needs be measured and calculated. All of these measurements are aimed to collaborate with the work of the IP Performance Measurement Working Group in IETF.

- One-way delay: the time needed for packets travelling from a source host to a destination host.
• End-to-end delay: the mean of one-way delay.
• One-way delay variation (jitter): the difference in the One-way delay of selected packets.
• End-to-end delay variation: the mean of one-way delay variation.
• Round-trip delay: the time needed for packets travelling from a source host to a destination host and then immediately being sent back to the source host.
• One-way packet loss: the number of packets lost from a source host to a destination host during a measurement interval time.

For ICEBERGS, each parameter can be measured in four ways:
• Unicast end user to local MCU,
• MCU to MCU,
• Local MCU to end user,
• End-user-to-end-user.

Different measurements need to be studied to clarify the effect of each segment of the network on the performance of ICEBERGS systems. For instance, unicast end user to local MCU delay reflects the QoS of the local ISP network in terms of delay that has impact on the end-user-to-end-user delay. Another example is if all of the four delays are known, the delay effects caused by processing packets on the two MCUs in the link can be calculated.

Specifications of end-to-end (mean one-way) delay for TIPHON speech QoS classes are given that the target value for end-to-end delay should be lower than 400ms. However, this “Poor” figure cannot be improved in a geostationary satellite system regarding the physical propagation delay of the satellite link. The results from the ICEBERGS will make a contribution to the TIPHON project to add the satellite affection to the classes of the network parameters.

We also have test cases about subjective test. The overall audio transmission quality Rating (R), E-Model R factor, for TIPHON systems must be used to evaluate and monitor the QoS. The limit values can be found in [14] . The resulting R factor depends on several factors: codec type, packet loss, delay, and advance factor. Perceptual measurements: MOS, PESQ, PAMS, PSMQ+ may also be used to evaluate the perceptual QoS. The ITU-T has the recommendation [15] about the classes of those parameters.

CONCLUSION

After the study of the relevant existing standards, the ICEBERGS consortium had a deep understanding on how a multimedia multiparty IP conference system can work in a complicate environment including both satellite network and terrestrial networks. To take advantage of the wide coverage and broadcast characteristic of the broadband satellite network and realize the real-time communication, one Multiple-MCUs conference model has been developed with separated signalling and media communication parts. Two important technologies, SIP and Any Source Multicast (ASM) routing were studied and fitted into the ICEBERGS for signalling and media communication respectively.

To evaluate this developed multiparty conference system, a demonstrator is under implementation. The demonstrator layout was proposed for both general satellite system and ESW system. The relevant tools and applications has been defined as well as implemented to this demonstrator. A measurement metric has been defined for the ICEBERGS to evaluate its performance in network level with collaboration with the relevant working group in IETF. A subjective test plan has also been made to compare the project results with recommendations from standard organizations.

REFERENCE


[14] Telecommunications and Internet Protocol Harmonization Over Networks (TIPHON) Release 3; End-to-end Quality of Service in TIPHON systems; Part 2: Definition of speech Quality of Service (QoS) classes. ETSI TS 101 329-2 V2.1.3 (2002-01)