Resource Management and Signalling Architecture of a Hybrid Multicast Service for Multimedia Distribution

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Abstract. This paper further develops an architecture and design elements for a resource management and a signalling system to support the construction and maintenance of a mid-long term hybrid multicast tree for multimedia distribution services in a QoS guaranteed way, over multiple IP domains. The system called E-cast is composed of an overlay part – in inter-domain and possible IP level multicast in intra-domain. Each E-cast tree is associated with a given QoS class and is composed of unicast pipes established through Service Level Specification negotiations between the domain managers. The paper continues a previous work, by proposing an inter-domain signalling system to support the multicast management and control operations and then defining the resource management for tree construction and adjustment procedures in order to assure the required static and dynamic properties of the tree.

Keywords: Multicast, overlay, QoS, multimedia distribution, Service Level Specification.

1 Introduction

Efficient real-time multimedia distribution over multiple IP domains with support for the required end-to-end (E2E) Quality of Service (QoS) is still an active area of research. Multicast is a resource efficient transport service for multimedia distribution. The development of such a service with QoS enabled in a multi-domain context requires further research. A hybrid multicast service solution, using Overlay Multicast (OM) and IP multicast, where existent, can be attractive. One can benefit of IP multicast [1], where existent, and use OM outside the IP multicast area. IP multicast, despite its two decade age, is not globally deployed [2] [3] due to problems related to group management, needed router capabilities, and QoS addressing problems. OM

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[4]–[9] presents lower efficiency and speed but eases the implementation of multicast services by not relying on network layer multicast capabilities. Therefore, in this paper, a hybrid solution is considered.

An E2E guaranteed QoS capability over multiple domains infrastructure requires an integrated management system to manage the high level services. On the other side, an important requirement is to still maintain the independency, in terms of resource management, in each network domain. The FP6 IST-507637 project *"End-to-End QoS through Integrated Management of Content, Networks and Terminals"* (ENTHRONE)[1] has proposed an architecture that creates Audio/Video (A/V) service distribution chains [11]-[14] with support for content generation and protection, distribution across QoS-enabled heterogeneous networks and the delivery of content to user terminals.

ENTHRONE's key component is the *Integrated Management Supervisor (EIMS)* [11][12]. The EIMS is built on top of a heterogeneous network infrastructure and manages high level services. Examples of such high level services are Video on Demand (VoD), multimedia streaming, E-learning, and IPTV. The EIMS is also responsible for the E2E IP connectivity, but still maintains independence on network resource management and low level QoS mechanisms.

The EIMS assures E2E QoS provisioning by achieving the required coherence between entities, w.r.t. management and control activities. This is based on *Service Level Agreements/Specifications (SLAs/SLSs)* concepts which are used to express inter-entities commitments [12] [13]. In order to transport the SLA/SLS messages, an appropriate set of signalling protocols have been designed. Each EIMS entity, at a Network Provider (NP), cooperates with the local intra-domain Network Resource Manager (RM) in order to ask for resources in the network.

The architecture is flexible, supporting several business models, including scenarios where different entities cooperate to create value-added services for end-users. The main entities considered are: *Service Providers (SP), Content Providers (CP), Network Providers (NP), Content Consumers (CC), and Access Network Providers (ANP)* [11] [14]. The CPs usually own *Content Servers (CSs)* that are used to generate content for the CCs. The SP provides high level services to the end-users. The NPs role is twofold: 1) to cooperate with each others in the E2E chain and 2) to manage their autonomous network domains. The ANPs manage the Access Networks. In practice, several roles can be played by the same business entity.

The EIMS includes a multicast service, offered by a subsystem called E-cast, which was realised in a hybrid form (OM combined with IP multicast, where existent) and including a special component to manage it. In [10],[12] and [14], the principles of the E-cast have been defined and the architecture of the multicast solution was outlined.

The E-cast main objectives are: to provide a scalable multi-domain solution independent of IP multicast capabilities of the core and access networks; to allow a seamless integration of the E-cast in the existing EIMS framework (which used mid-long term QoS enabled transport pipes called pSLS-links); to address the requirements of new services like IPTV; and to be able to take benefit of the IP multicast in IP domains where it is deployed. The multicast tree construction and maintenance is based on inter-domain resource management and signalling protocols between NPs.

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This work is a continuation of [10]. In Section 2 the general connectivity services framework of ENTHRONE is summarised. The E-cast hybrid multicast service is outlined in Section 3. Section 4 extends the ENTHRONE inter-domain signalling system to support the overlay and IP multicast. The Section 5 introduces the resource management to assure the multicast tree dynamicity. The Section 6 presents the conclusions.

2 Connectivity Services Management in ENTHRONE

The EIMS manages an overlay connectivity service based on forecasted information (there exists a Service Planning function) about future users. The SP decides on the construction of logical multi-domain, uni-directional, QoS-enabled aggregated pipes (pSLS-links established prior to real data flows transport). They span over IP core domains crossed by the path from known content servers (CSs) to forecasted regions of expected CCs, which are seen as destination [11], [12]. Each pSLS-link belongs to a given QoS class of service.

The pSLS-link is composed of segments. Each pSLS-link is negotiated and agreed between SP and the first NP placed in the path towards the regions that contain CCs. In its turn, each NP must negotiate and agree on a new segment with the following NP in the path, until the CCs region is reached (*provider pSLS subscription phase*). Each request from a domain is subject to Admission Control (AC) by the requested domain. The EIMS entities performing negotiations and AC are called Network Service Managers (NSM). They are distributed in SP (NSM@SP) and also in the NPs (NSM@NP). Below each NSM@NP there is an Intra-domain Network Resource Manger (RM) whose task is to manage the domain's resources and their links to its neighbours. A negotiation protocol EQoS-pSLS-S/I-NP has been designed [13] to transport the negotiation messages between NSMs.

To avoid inter-domain routing awareness by SP, the forward cascaded mode for inter-domain peering has been selected. Therefore the task of inter-domain path selection from the CS to the CCs regions is performed by each NP. The pSLS request contains all QoS parameters desired (bandwidth, delay, jitter, loss rate). Each NSM@NP is aware of QoS capabilities of its internal paths and also of QoS capabilities of inter-domain links towards the neighbour domains. These capabilities are expressed at overlay level as Traffic Trunks (TT), in terms of bandwidth available, delays, etc. This information has been previously communicated to the NSM@NP by its "lower layer" (RM).

To increase the dynamicity of connectivity services management, the ENTHRONE distinguishes two operations on SLSs [11]-[14]: subscription, by which the necessary resources are logically reserved, and invocation, by which the network resources are actually allocated. The subscription allows EIMS to abstract network resources in terms of end-to-end virtual pipes. After pSLS subscription, SP may later decide on the installation of pSLS-links in the network (*pSLS invocation phase*), by instructing its NSM@NPs to request to the NRM of each domain to perform resource allocation.

After pSLS-link invocation, several individual pipes (cSLS-links), i.e. slices of the pSLS-links, can be agreed and allocated for CCs at their request. The cSLS-links are established by the NSM@SP at request of an EIMS subsystem called *Customer*

Service Manager at SP (*CustSrvMngr@SP*) on behalf of a CC. The cSLS parameters are a mapped version of an agreement established between the *CustSrvMngr@SP* and a CC to reserve the required resources. The cSLS-links pass through the pSLS-links and are extended ("last mile" segment) to the CC's Access Network (AN). Thus, the ENTHRONE solution avoids *per flow* inter-domain signalling. The NSM@SP should communicate with AN Resource Manager to request resource reservation (cSLS subscription phase) and then allocation (cSLS invocation) in the AN for each individual flow.

3 Hybrid Multicast System

The E-cast system is built on existing ENTHRONE management infrastructure [10], [12]. E-cast uses overlay multicast (E-cast(o)) for multi-domain multicast and, if available, IP multicast (E-cast(ip)) in the IP core of the leaf domains of the overlay multicast trees. In such leaf domains, numerous branches are expected and thus the E-Cast(ip) trees are grafted on leaf nodes of E-cast(o) trees. The E-cast tree branches are actually the QoS enabled pSLS-links. The set of unicast pSLS-links used to setup an E-cast(o) is named *mcast-pSLS-tree* and is used to transport multiple streams in multicast. The associated multicast pSLS is the group of underlying individual pSLSs contracts. A *mcast-pSLS-tree* holds a set of *mcast-cSLS-trees*, each one representing a subset of the resources available in the *mcast-pSLS-tree*. The *mcast-cSLS-tree* is composed of a set of unicast cSLS-links, each one associated with a single multicast stream (e.g. an IPTV channel). The E-cast system may include intra-domain IP multicast (E-cast(ip)), based on Protocol Independent Multicast - Sparse Mode/Single Source Multicast (PIM-SM/SSM) [16]. Additionally to standard PIM-SM/SSM, the E-cast(ip) provides QoS guarantees by creating at IP level, a single domain tree based on pSLSs.

3.1 Overlay Multicast (E-cast(o))

An E-cast tree is composed of several entities called EN nodes. Each one may assume one or more of the following roles [10], [12], [14]: *E-cast root node* - multicast streams entry point for the E-cast(o) tree; *E-cast intermediate nodes* - located in different Autonomous Systems (AS); *E-cast(o) proxy nodes (EPN*) - leaves of the E-cast(o) trees, usually located at the ingress of ANs; *E-cast cross-layer nodes (EXN)* - which terminate the E-cast(o) and act as IP multicast sources by introducing group addresses in the data packets and delivering them to the IP multicast tree. An EN may belong to different E-cast trees, playing different roles in each tree. The number and placement of E-cast nodes are determined by the service planning activities. The management entities for multicast are Multicast Manager at SP (McastMngr@SP) and Multicast Manager at NP (McastMngr@NP). The E-cast(o) tree construction [14] is shortly described next.

Initially, an E-cast(o) mesh is setup by logically interconnecting ENs. To perform the E-cast(o) tree construction, the McastMngr@SP , gets as input information the root and leaves IDs of the tree and also information on the E-cast(o) mesh. The construction of the mesh is based on the "*Locate, Cluster and Conquer"* principle described in [10], and in [15]; this phase is not in the scope of this paper. The algorithm used for the tree construction is a variation of the Dijkstra shortest path algorithm (SPF) that also considers constraints and a composite metric based on delay. Then, the McastMngr@SP subscribes the multicast pSLS to NSM@SP. The invocation of the multicast pSLS may happen at a later time, but never before using the E-cast(o) tree to transport a multicast stream. The subscription and invocation of individual unicast pSLSs that compose the multicast pSLS, and the actions required in each AS, are performed by NSM@SP and NSM@NPs.

Then McastMngr@SP subscribes and invokes the appropriate mcast-cSLS-tree associated to a stream, prior to any packet being replicated and forwarded along a branch of the E-cast(o) tree. Consequently, the McastMngr@SP instructs all EN nodes (root, intermediate, proxies, cross-layer) on how to replicate the packets of the stream along the tree. The E-cast proxy nodes send the packets to access networks. The E-cast cross-layer nodes cooperate with an IP multicast agent to translate unicast address to IP multicast group address, and forward packets to the PIM-SM/SSM tree.

3.2 IP Multicast (E-cast(ip))

The ENTHRONE selected PIM-SM/SSM as a significant and largely used protocol at IP layer. In our case it is used in an extended mode, based on multicast pSLSs, to provide IP multicast with QoS guarantees within a leaf domain. The construction of E-cast(ip) tree is performed by the NSM@NP of the leaf domain, upon request of the NSM@SP. At its turn NSM@SP has been requested to do that by the McastMngr@SP. The request parameters are: the QoS class, the stream source (E-cast(o) cross-layer node), and the access networks IDs of prospective consumers.

The E-cast can, in principle, support deployment variations regarding the distribution of flows in the AN. If each AN connected to the leaf AS comprises an E-cast(o) proxy node, then they may receive flows from the egress multicast routers of the leaf AS and distribute them into ANs. If not, the egress routers of the leaf AS can directly distribute the flows in multicast mode, using a group address as destination, into the AN.

4 p/cSLS Signalling for Multicast

This section proposes the E-cast(o) signalling support. The identified requirements are: to use ENTHRONE's existing unicast negotiation protocols; to scale in terms of the amount of signalling used per tree branch; to have parallel transaction capability; to support both the E-cast(o) and E-cast(ip).

The solution extends the ENTHRONE signalling framework [13] to enable multicast management. The multicast tree is controlled by McastMngr@SP and is composed of unicast point-to-point pSLS links between E-cast nodes (EN). The McastMngr@SP first determines all the tree elements, namely the root node, the intermediate nodes, the leaf nodes (i.e. topology) and QoS class. Then, it requests NSM@SP to trigger the mcast-pSLS-tree construction. Each negotiated pSLS establishes a virtual link with specific QoS guarantees between two ENs. The NSM@SP reports on the success of the pSLS-links establishment to the McastMngr@SP. Then the McastMngr@SP instructs the ENs to act as root/intermediate/proxy/x-layer nodes on the E-cast tree.

The NSM@SP is tree-topology unaware; it receives a list of pSLS links to be established from the McastMngr@SP. The set of all pSLS-links negotiated by the McastMngr@SP define the overlay tree topology, and, in case of some segments failures, the McastMngr@SP decides upon next actions.

Figure 1 presents an example scenario of the E-cast(o) tree construction that comprises several phases..

First, the McastMngr@SP requests to NSM@SP to construct the {EN1-EN2, EN1-EN4, EN1-EN5, EN2-EN3, EN4-…, EN5-EN6, EN5-EN7} pSLS-links. Then the NSM@SP launches several parallel and independent transactions as shown in the Table 1. Note that, for each pSLS-link request, the forwarding cascade mode is still valid. If required, each intermediate NSM@NP will contact other neighbour NSM@NPs to realize the chain. In step three the NSM@NPs respond to NSM@SP. Finally the NSM@SP returns a list of results to McastMngr@SP which proceeds to the next actions.

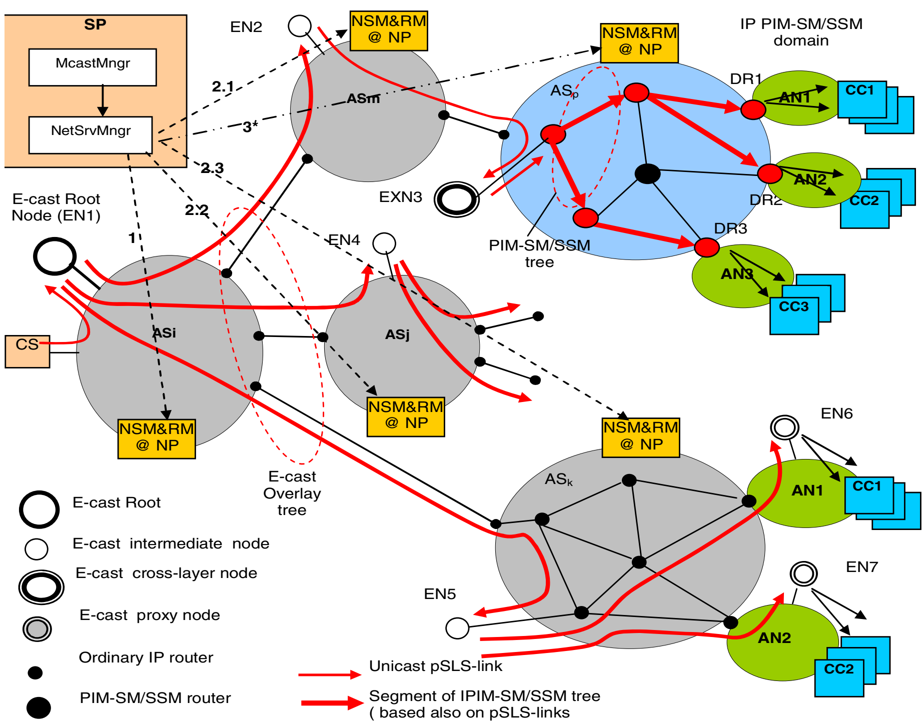

Fig. 1. pSLS signalling for E-cast tree construction. NSM – Network Service Manager; RM – Intra-domain Network Resource Manger.

Table 1. pSLS requests to construct an example E-cast tree

pSLS request from NSM@SP #	NSM@NP to solve the pSLS request	pSLS link origin	pSLS-link end	Notes
1	NSM_i	EN1	EN2	Requests for E-cast(o) tree only
			EN4	
			EN5	
2.1	NSM_m	EN2	EXN3	
2.2	NSM_j	EN4	…	
		EN4	…	
2.3	NSM_k	EN5	EN6	
			EN7	
3*	NSM_p	EXN3	DR1, DR2, DR3	Request for E-cast(ip) tree.

Figure 2 illustrates a Message Sequence Chart of the signalling used in the mcast-pSLS-tree subscription phase.

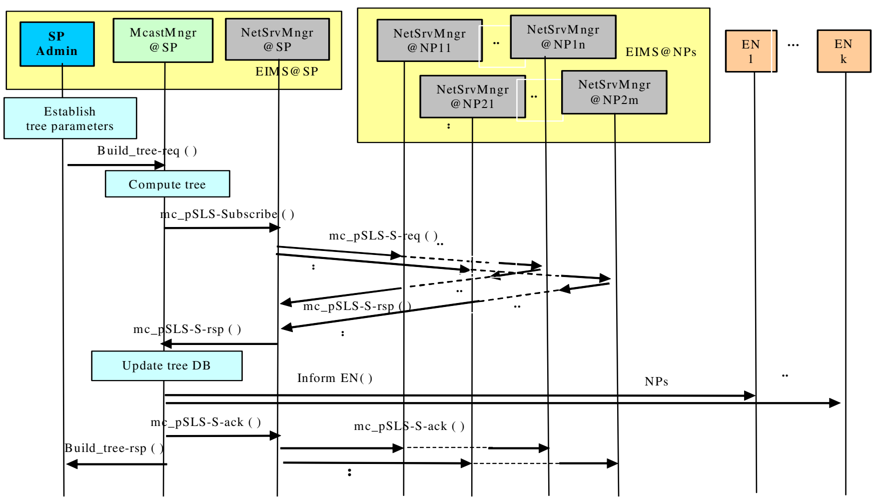

Fig. 2. Message Sequence Chart for Build E-cast(o) or E-cast(IP) tree use case, illustrating communication between EIMS entities and EN nodes

The signalling inside a core IP domain for establishing an IP multicast tree will be detailed in another paper. The key issue is that, using the above signalling, the NSM@NP obtains all parameters required for the IP multicast tree. Enabling it to completely control the subscription and invocation of the tree based on PIM-SM/SSM protocol.

For multicast pSLS invocation signalling, the protocols and interfaces are similar to those used for subscription, except for the quantitative parameters. For multicast cSLS signalling we note that, from the point of view of NSM@SP, this invocation only means AC applied at the entrance of the tree in order to see if a given mcast-cSLS request can be accommodated in the current pSLS-link. The result of AC (positive or negative) is stored. Additionally, the first NSM@NP that owns the ingress router is informed about the flow characteristics, allowing it to configure an appropriate police.

5 Resource Management

In ENTHRONE the pSLS links are constructed after successfully accomplishing Admission Control (AC) in each IP domain. This is the basis of capability to guarantee the QoS. In multicast case also AC is applied. This check can be applied statically (at pSLS subscription epoch) or dynamically (at invocation time).

5.1 Admission Control for E-Cast Tree Subscription

To construct the E-cast(o) tree the list of pSLS-links is asked to be established, by the McastMngr@SP to the NSM@SP. For each pSLS-link the usual AC similar to that applied in unicast case, [13], is performed. A successful multicast tree subscription means that every segment of the tree has successfully passed the AC test.

The NSM@SP response message to the McastMngr@SP indicates a success or a failure. In the failure case, the rejected pSLS links are individually reported by the NSM@SP to McastMngr@SP. The latter may react differently conforming the policies applied by the Service Planning entity of the SP together the McastMngr@SP.

The multicast IP tree is also established at pSLS level but the branches of this tree are intra-domain ones. The intra-domain is governed by an Intra-domain Network Resource Manager at NP (RM@NP). The additional problem in a real deployment is that RM@NP is not always willing to disclose to external parties its internal network topology and traffic load. Such a behaviour will make the AC problem more difficult than in overlay multicast tree case.

In unicast pSLS case AC is performed at NSM@NP based on its knowledge on virtual Traffic Trunks (TT) crossing the respective domain. This information is delivered by the RM@NP to NSM@NP. Performing AC on such a trunk (intra and inter-domain) is sufficient, while it is checked at the entrance of the TT. At NSM level, each TT is independent of other TTs.

In IP multicast tree case the AC should be applied on each branch of the tree. The NSM@NP knows (from the parameters of the request message): the ingress node (router); the list of egress nodes (router); the bandwidth required; the QoS parameters required (e.g. maximum delay).

We make the simplifying assumption that the unicast and multicast pSLS-links are established in two different disjoint “resource planes”, i.e. the RM@NP allocate an amount of resources to create multicast trees and this is separated from the resources for unicast pSLS-links. This choice can simplify significantly the management of resources because it decouples the unicast resource management from the multicast one. The unicast TT framework and AC executed at the level of NSM@NP remains not affected. Therefore the following solutions can be applied. Here policies issues may appear.

A. The RM@NP does not disclose to the NSM@NP the intra-domain topology.
The NSM only knows the tree root and the leaves, so it cannot make AC. The NSM@NP makes a request for a tree to the RM@NP containing the parameters specified above. Then the RM@NP selects an appropriate tree for this request and performs AC on each tree branch in terms of bandwidth (and maybe delay) - depending on policy applied. The RM@NP returns an answer to the NSM@NP, about acceptance/rejection of the request and also updates its matrices of resources.

While this solution simplifies the task of the NSM@NP, it does not allow it to apply its own policies for AC. In the best case the NSM@NP could pass together with its request, some more additional parameters, to allow RM@NP to apply one of the several options.

B. The RM@NP discloses the internal tree topology to the NSM@NP.
The NSM@NP makes a request for a tree to the RM@NP with parameters specified above. In this case the RM@NP selects a possible tree and returns to the NSM@NP information on the available tree in the form: T(V,E), where V is the node set; E is the edge set and we have weights associated to links. Each cost is expressed as a pair (B, d) where the B= max available bandwidth and d = max delay on that link. The NSM@NP performs AC on each tree branch in terms of bandwidth (and maybe delay) - depending on policy. Upon successful AC, the NSM@NP informs the RM@NP about this reservation. The RM@NP updates its matrices of resources.

This solution still makes the AC at NSM@NP level, but the computation of the tree itself is performed by the RM@NP..The advantages of this design are that still NSM@NP is free to apply different policies to accept/reject multicast services requests, independent on how the RM@NP manages its resources. At its turn, the RM @NP can apply its own policies of network dimensioning because it is this entity which offers a given tree to the request of NSM@NP.

C. The RM@NP discloses the internal graph topology to the NSM@SP.
This is the most open policy of the RM@NP, based on higher degree of trust and cooperation with EIMS. Initially and at each start of a Resource Provisioning Cycle, [11], [13], the RM@NP sends to the NSM@NP information on an available graph to be allocated for multicast services. The graph is expressed in the form: G(V,E); where V is the node set; E – edge set and we have weights associated to links. Each cost is expressed as a pair (B, d) where the B= max available bandwidth and d = max delay on that link.

Then in the event of a new request for a multicast tree NSM@NP computes a feasible tree. First it constructs a constrained sub-graph eliminating those branches which do not satisfy the bandwidth constraint. Then it computes a spanning tree (even if the tree is bigger than required, the computation algorithm is simpler) having the root in the node indicated in the request. This can be computed depending on policy in several ways: *a.* by only using a concave metric of 1/B where B is bandwidth. The tree is a shortest path one (SPT) in terms of bandwidth wideness and the algorithm can be, e.g. Dijkstra; *b.* by using an additive metric, i.e. delay; *c.* by optimising both bandwidth and delay (more complex solution and less scalable). .On each branch of the required tree the NSM@NP applies AC in terms of delay (remember that the bandwidth constraint has been fulfilled). Upon successful AC, the NSM@NP computes an available graph by subtracting the used resources from the initial ones.

At a new request the NSM@NP uses the updated available graph as an input for tree computation. This solution gives the highest degree of liberty to the NSM@NP in applying different policies in the process of tree computation.

5.2 Policy Based Management for Multicast Tree Subscription

The ENTHRONE framework is open and flexible in the sense that it allows the SPs and NPs to apply their own policies for service and resource management. The Policy Based Management related details of ENTHRONE including policy analysis tool and policy decision and enforcement methods are discussed in details in [13].

In multicast service case several policies can be applied at subscription phase. Here are below some examples

Estimated data for future traffic are considered (being generated by the traffic forecast block). Therefore, the tree leaves will be defined only for those AN regions where a given minimum number of future users is estimated.

When receiving the answer from NSM@SP about the multicast tree pSLS subscription, the McastMngr@SP can react in several ways depending on the policy applied: *P1.* McastMngr@SP can be satisfied with the sub-tree proposed by NSM@SP and ask it to consider installed that sub-tree. The amount/percentage of successful branches is also subject of policies; *P2.* McastMngr@SP is not satisfied and in this case it can ask the cancellation of all sub-trees (i.e. all pSLS-links); *P3.* McastMngr@SP might ask the NSM@SP a new tree with different quantitative parameters (e.g. lower bandwidth, lower QoS, reduced number of branches, etc.).

Also different policies may be applied in the process of making tree computation and AC as shown in the section above.

5.3 Dynamic Resource Allocation

The AC for mc_pSLS-tree invocation is performed similarly to that of subscription. The difference is that the tree is already known (computed at subscription phase). Therefore the three cases described in the Section 5 still apply.

In case A, the NSM@NP does not know the tree IP multicast tree topology. The AC should be performed by the RM@ NP.

In case B and C the Admission Control is performed by the NSM@NP because it knows the tree and has the necessary information on previously subscribed trees. Monitoring information can be used in the process of AC if information on the actual load of the tree branches is available.

All policies discussed at multicast pSLS subscription can be applied for invocation also. Additionally policies can be applied for tree maintenance. While not all these policies are included in the current implementation (except some basic ones) the framework is enough flexible to allow different policies to be applied, defined by the SP and also by NPs.

6 E-Cast Implementation

The E-cast system is currently under implementation in the ENTHRONE project framework. Figure 3 presents (as an example) a part of the ENTHRONE system, the

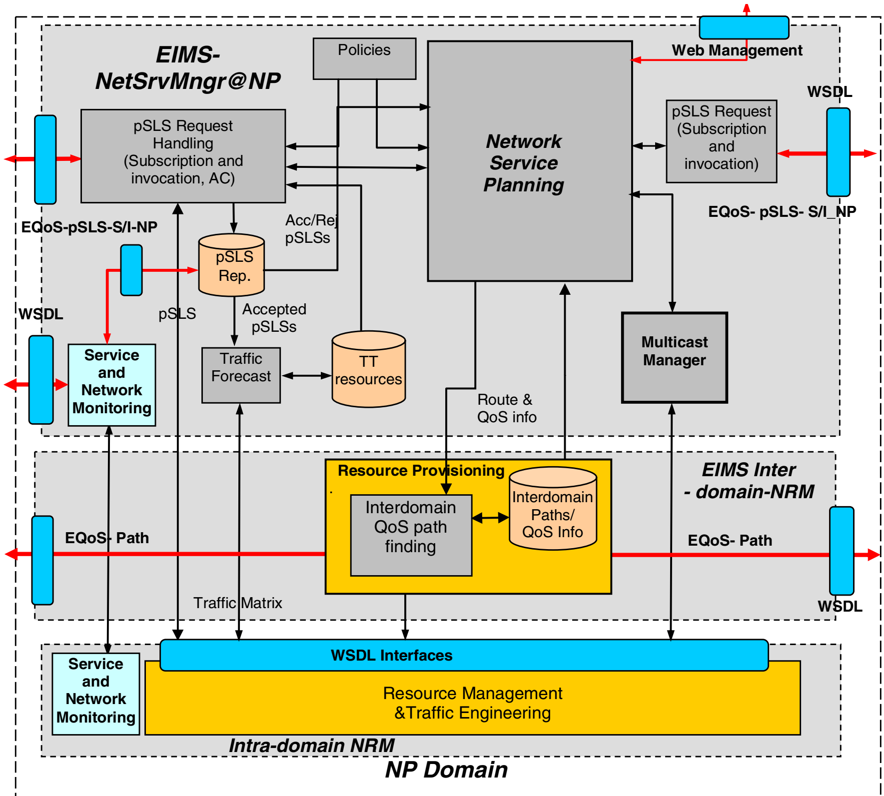

Fig. 3. Architecture of the Network Service Manager at NP

overall view of the implemented architecture of the EIMS-Network Service Manager at NP (NSM@NP).

The EIMS@NP subsystem is composed of: Network Service Manager - responsible for service provisioning and pSLS processing; Inter-domain Network Resource Manager –responsible mainly to find inter-domain paths; The Intra-domain Network Resource Manager (Intra-NRM). The latter does not belong to ENTHRONE EIMS but it is owned by NP.

The details of the NSM@NP subsystem are not given here; they can be found in [13], [14], [17]. In Figure 3 the Multicast Manager is emphasized and its relationships with other entities are drawn. The Multicast Manager at NP is instructed by the Service Planning block to perform low level multicast related functions (e.g. to construct the IP multicast tree, etc.).Its south-bound interface is used to request to the intra-domain resource manager to install the multicast tree.

The implementation solution for the interfaces outside the NSM@NP has been Web-Services based, [17], due to flexibility offered. In particular, ***Multicast Manager WSDL interface*** –used by the IP Multicast Manager to ask to Intra-NRM to construct a multicast IP level tree composed of pSLS links.

Below it is given an example of a set of messages used for the construction of the overlay multicast tree by establishing unicast pSLS agreements between E-Nodes and also for resource invocation for the overlay multicast tree. For example, the first two messages are used to subscribe a pSLS pipe between two E-cast nodes. These messages could be used between EIMS@SP and NSM@NP or between two NPs.

- ***pslsMcastSubscribeRequest*** (pSLS obj req)
- ***pslsMcastSubscribeResponse*** (status, pSLS obj resp)

- ***pslsMcastInvokeRequest*** (pSLS obj req)
- ***pslsMcastInvokeResponse*** (status)

- ***pslsMcastSubscribeCloseRequest*** (pSLS obj req)
- ***pslsMcastSubscribeCloseResponse*** (status)

- ***pslsMcastInvokeCloseRequest*** (pSLS obj req)
- ***pslsMcastInvokeCloseResponse*** (status)

For IP multicast pSLS establishment in the "leaf" IP core domains a similar set of messages are defined but having different parameters. They are exchanged only between the EIMS@SP and NSM@NP in the "leaf" tree core domains. After NSM@NP receives these messages it will know that it is the "leaf" core domain and consequently it will inform the IP Multicast Manager to subscribe and then to invoke the IP multicast tree.

7 Conclusions

The work on E-cast hybrid multicast service with QoS guarantees over multiple IP domains, presented previously in [10] is continued with new proposals for a signalling system and scalable solutions (both in the data plane and control/management plane) for resource management, both at overlay level and network level. The overlay multicast solution is independent on the existence of IP multicast in the Autonomous Systems but in our hybrid approach one can benefit of IP multicast in those domains where IP multicast is deployed. The inter-domain multicast signalling is done between managers, at aggregated level, thus exposing good scalability. The resource allocation can be done at aggregated and individual level with distinction between operational phases of subscription and invocation. Separation is achieved between the service management at overlay virtual level and actual resource management at network level. The proposed system is currently implemented in the ENTHRONE project. The implementation results will be soon reported in a future work.

References

1. Deering, S.: Host Extensions for IP Multicasting, IETF RFC 1112 (1989)
2. Diot, C., et al.: Deployment Issues for the IP Multicast Service and Architecture. IEEE Network 14(1), 78–88 (2000)
3. Asaeda, H., et. al.: Architecture for IP Multicast Deployment: Challenges and Practice. IEICE Transactions on Communications E89-B(4), 1044–1051 (2006)

4. Biersack, E.W.: Where is Multicast Today? ACM SIGCOMM Computer Communication Review 35(5), 83–84 (2005)
5. Zhang, B., Jamin, S., Zhang, L.: Host Multicast: A Framework for Delivering Multicast to End Users. In: Proceedings of the IEEE INFOCOM 2002, New York, USA, vol. 3, pp. 1366–1375 (2002)
6. Lao, L., Cui, J.-H., Gerla, M., Maggiorini, D.: A Comparative Study of Multicast Protocols: Top, Bottom, or In the Middle? In: Proceedings of the IEEE INFOCOM 2005, Miami, USA, vol. 4, pp. 2809–2814 (2005)
7. Li, B., Liu, J.: Multirate Video Multicast over the Internet: An Overview. IEEE Network 17(1), 24–29 (2003)
8. Androutsellis-Theotokis, S., Spinellis, D.: A survey of peer-to-peer content istribution technologies. ACM Comput. Surv. 36(4), 335–371 (2004)
9. Banerjee, S., Bhattacharjee, B., Kommareddy, C.: Scalable application layer multicast. In: Proceedings of the ACM conference on Applications, technologies, architectures, and protocols for computer communications (SIGCOMM 2002), New York, pp. 205–217 (2002)
10. Mehaoua, A., Fang, L.: E-cast: An Overlay Multicast Service Management System for scalable audiovisual services. In: Proceedings of the IEEE-TTTC AQTR Conference, Cluj, Romania (February 2008)
11. ENTHRONE II Deliverables D01: Overall system architecture version 2 (2007)
12. ENTHRONE II Deliverable D03: EIMS for ENTHRONE 2 (2007)
13. ENTHRONE II Deliverable D18: Service management and QoS provisioning (2007)
14. ENTHRONE II Deliverable D21: Multicast provisioning and multicast service management (2008)
15. Kaafar, M.A., Turletti, T., Dabbous, W.: Locate, Cluster and Conquer: A Scalable Topology-aware Overlay Multicast, INRIA, technical report (2005)
16. Fenner, B., et al.: Protocol Independent Multicast - Sparse Mode (PIM-SM): Protocol Specification (Revised). IETF RFC 4601 (2006)
17. Obreja, S.G., Borcoci, E., Lupu, R., Iorga, R.: Web-service solution for inter-domain QoS negotiation, International Conference on Communication Theory, Reliability, and Quality of Service, CTRQ, Bucharest, Romania (2008), `http://www.iaria.org/conferences2008/CTRQ08.html`