The DAIDALOS resource optimization framework for converged broadcast and telecommunication mobile technologies

Emiliano Guainella and Matteo Curcetti

Abstract—**This paper describes a platform which allows Service Providers and network operators to optimize network resources and to reduce costs by efficiently and jointly using the broadcast networks and bidirectional data and telecommunication networks. The key element of the framework is the Multicast Manager, a module that is able to maintain a map of multicast subscribers and can order access routers to join multicast groups. An optimization algorithm is then in charge of taking into consideration user profiles, network costs and impacts in order to choose the best suited delivery technology.**

Index Terms—**Multicast, Broadcast, QoS, resource management, inter-technology handover.**

I. Introduction

THE last years have seen a rapid growth of the delivery of new bandwidth consuming services for mobile users such as digital video/audio streaming, file delivery, interactive TV etc., whose typology can be identified as "multicast/broadcast-like" services in the sense that their distribution is better suited with multicast/broadcast technology.

For these reasons, nowadays the research community, network manufacturers and operators are spending a lot of resources to the improvement and realization of broadcast networks.

That is why it's a common idea that traditional telecommunication networks (such as UMTS, WI-FI, etc.) and the above innovative broadcast networks will co-operate and guarantee to the client different technologic interfaces permitting the service provisioning and a more and more complex application interactivity.

The architecture described in this paper assigns a wide sense to the word mobility. The user will be able of receiving the service from different alternative technologies. The choice of which technology is to be used may be derived from users preferences and signal strength, by mobile terminal decision, or from economic reason and resource management optimizations, by network decisions.

In this paper it is shown how this innovative convergence has been considered within DAIDALOS in order to describe a platform which allows to Service Providers (SPs) and network operators to optimize network resources and to reduce costs. Indeed, based on the number of users subscribed to a certain service, a (third party) service providers or the network operator should evaluate the convenience of distributing this service through different technologies and can choose the best one.

This paper is organized as follow: section II describes the technologies that could be exploited by the resource management framework; section III describes why and when is useful to perform a resource optimization; section IV introduces briefly the DAIDALOS general architecture; section V introduces the resource optimization framework; section VI gives an usage scenario and finally section VII gives the conclusions.

II. Involved Technologies

In this work the basic technology considered is the IP Multicast. For this reason, in the IP header, the multicast address refers at the same time to multiple recipients. This means that, in a sub-network, the same stream can be shared by many users without being replicated. As for access technologies, we can group them in:

--unicast networks: when to send the same IP multicast content, in the last hop (from access point to the users), to N users, you need to setup N unicast layer 2 connections. (e.g. GSM, GPRS, standard UMTS, WiFi, etc.)

--broadcast networks: in the same conditions, it's enough to setup only one layer 2 channel.

It follows a brief summary of some of the existing broadcast networks that could be exploited in the process of

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convergent optimization:

A. DVB-H

DVB-H (Digital Video Broadcasting-Handled) is based on the most common DVB-T (Terrestrial). It gives additional features to support handled portable and mobile reception. The main features are: battery saving, mobility with high data rates, single antenna reception, impulse noise tolerance, increased general robustness, support for seamless handover. DVB-H is meant for IP-based services via MPE (Multi Protocol Encapsulation) insertion. [1]

B. UMTS-MBMS

In 3G networks the importance of having a platform which exploits the resource optimizations of multicast and broadcast architecture has leaded to the introduction of MBMS [2] (Multimedia Broadcast/Multimedia Service). UMTS-MBMS aims at offering an efficient way to transmit data from single source to multiple destinations over the existing access radio networks by adding new functional entities in the architecture.

C. DAB

DAB (Digital Audio Broadcast) technology provides a high capacity audio data broadcast network to mobile and fixed users. This technology allows users to receive audio streaming with high quality comparable with CD quality as it broadcasts coded streaming audio at variable bitrate from 64 to 384 Kbit/s and with a very high noise tolerance. Recent extensions allows users to receive also video and data, such as images, web pages, etc (T-DMB, Terrestrial- Digital Multimedia Broadcasting)

D. WiMax

Based on standard IEEE 802.16 WiMAX [3] is a wireless metropolitan area network (MAN) technology. It will connect IEEE 802.11(WiFi) access points to the Internet and provide a wireless extension to cable and DSL for last mile (last km) broadband access. It has the possibility to setup a broadcast channel.

The other key technologies useful for proposed process are the most widespread data and telecommunication unicast network with a bidirectional channel, such as 2G, 2.5G, 3G, Wifi etc.

III. Optimization Rationale

This section describes some of the advantages of using the optimization mechanism described in the following sections, but without giving exact details on the economic impacts and service flexibility that can be achieved. These last variables, in fact, depends deeply on the operator equipment and topology of the already deployed networks.

As for mere resource and cost optimization, the main advantages are:

--to use broadcast technology to have free bandwidth in the interactive network for the unicast exchanges

--to free capacity in a unicast cellular network in an area covered only by one big broadcast network.

--it's possible to initiate a multicast stream in a unicast technology before switching it to a broadcast technology in case it increases in popularity.

As for service flexibility, the possibilities are:

--to propose different QoS, e.g. higher quality in broadcast (high bitrate), lower in unicast (low bit rate).

--more complex scenarios permits to mix the delivery of content by dividing it in (i) popular, to deliver through the broadcast technology, and (ii) personalized, to deliver through the unicast technology.

-- because this mechanism gives the "keys" to service providers and telecom mobile operator to use broadcast capacity (that a broadcast operator sell/hire) in order to optimise its resources (spending less) and to provide new services and application by combining the two networks as it requires.

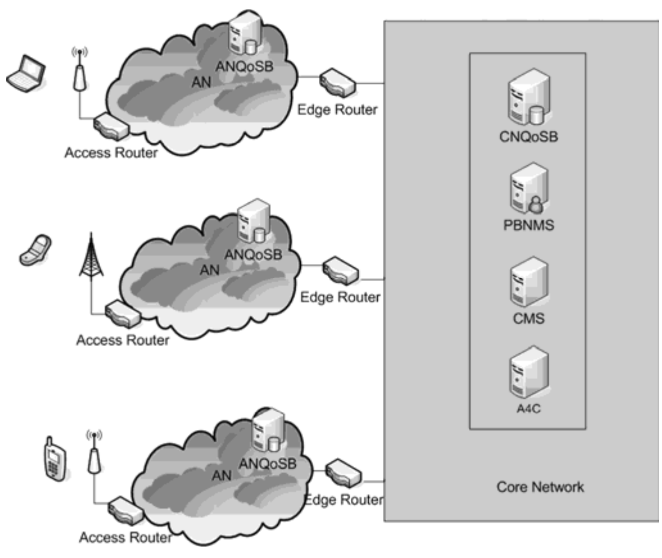
This framework paves the way to intelligent control of the network, thanks to some decision algorithms that, taking into account multiple cost functions, aims at deciding real time what is the best technology to deliver the service (multi objective optimization).

These decisions can be taken a priori, by analyzing market studies about the potential number of users , or a posteriori by considering the actual number of subscriber to the service. Other important cost functions to evaluate depends on network impact and overall cost management.

IV. The DAIDALOS Architecture

One of the main objectives in the vision of DAIDALOS network is to support a full integration of mobility, QoS and heterogeneous technologies. To reach this objective several new network entities have been introduced (Fig.1).[4]

At high level one administrative domain is composed of a Core Network (CN) which acts as a back-bone network, and



several heterogeneous Access Networks (AN). Both the Core Network and the Access Networks are IPv6-based.. The Daidalos network is based on DiffServ-like QoS model in the core, and intserv-like model in the access networks [5][6]. This solution implies scalability of packet forwarding in all areas of a network.

When an Access Router receives a MLD_report message [7] from the user, indicating its will to receive a specific IP multicast stream, it forwards the request to the ANQoSB (Access Network QoS Broker). After its acknowledgements (that implies that the user is authorized, it has correctly paid and the resources are enough), it can send a multicast join to the group according to the PIM-SM protocol [8].

The ANQoSB is in fact the network entity within an AN that is in charge of managing all the operations referring to QoS. It performs: admission control, sends configuration messages to the routers and guarantees QoS for end to end connections involving other ANs (by co-operating with the peering ANQoSBs). The ANQoSB is primarily composed of two parts: a Broker Engine and a set of Databases. The first is a set of modules that perform the QoSB functionalities; the databases are: the *Network Status Database*, containing information about network available resources; the *Policy Database*, containing rules for handling QoS requests; the *Topology Databas*e, containing the network topology; the *Profile Database*, containing information about the users. Within the ANQoSB, the Multicast Manager Module and the related databases, described in Section V are the key elements of the resource optimization process proposed in this work.

Also in the Core Network lies a QoS Broker, the CNQoSB, whose functionality is to control the resources on a "per-aggregate basis". It configures the core network routers and edge routers in order to guarantee QoS constraints from an AN to another.

The Central Monitoring System (CMS) is the network entity that is in charge of performing measurement test all over the network assisted by the Monitoring Entities running in the ARs.

The Policy-Based Network Management System (PBMNS) is the system in the network that enables administrator an easy configuration of the network. This means that a single administrator, by applying policies, will be able to configure many devices at the same time, enables administrator reconfiguration of the network (by changing already applied policies) and deals with problems, which may occur in the network, in a proactive or reactive way.

The A4C is the network entity that performs the operation of Authentication, Authorization, Accounting, Auditing and Charging. It registers user information about contracts and preferences. The A4C is invoked before admitting a user to receive a QoS based service.

V. EXTENSIONS ALLOWING RESOURCE OPTIMIZATION

This section describe the Multicast Manager Module, part of the QoS Broker Engine, and the Multicast Database. Its architecture is shown in Fig. 2.

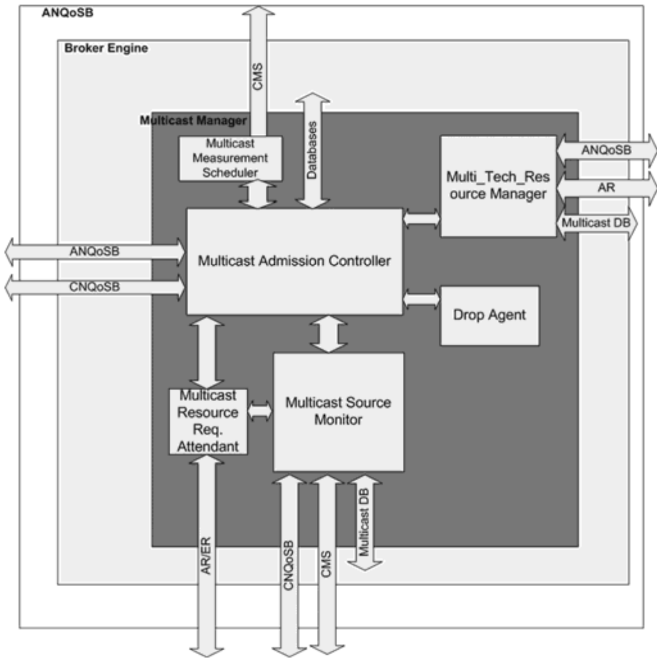


Fig. 2 Multicast Manger Architecture

The *Multicast Resource Request Attendant* receives from the AR the request to admit or not a new multicast user. This action is performed each time a new user sends a MLD_Report to join a multicast group. The AR waits then for a positive or negative decision from the resource request attendant interface. The admission control process and the mapping of the multicast group with the QoS requirements are performed by the *Multicast Admission Control Module* and the *Multicast Source Monitor* module. The detailed description of these two processes are out of the scope of this document.

From the above process the Multicast Manager can maintain a map of the current users associated to the IP multicast groups. Moreover, the ANQoSB is able to have access to the user profile from the A4C server present in the network. From these pieces of information is possible to build the database depicted in Fig. 3. The detailed description of the attributes for the *MulticastUse*r data is:

-- *VID*: Is the Virtual Identity of the user. (Home

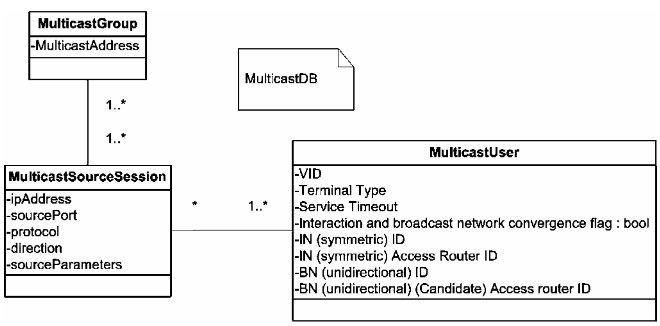


Fig. 3 UML description of Multicast Database

Address)

-- *TerminalType*: It includes terminal capabilities, e.g. available interfaces, screen size and resolution.

-- *ServiceTimeout*: It indicates for how much time the user is authorized to use the resources

--*InteractionAndBbroadcastNetworkConvergenceFlag:* It indicates if the interaction network is different from the multicast network (e.g. multicast packets received from DVB-H and interaction channel by means of UMTS Network); They could be the same in case of UMTS MBMS network.

--*IN_Symmetric_ID:* It identifies the symmetric network in which the user is connected. If InteractionAndBbroadcastNetworkConvergenceFlag is set, this represents the interaction network.

--*IN_Symmetric_AR_ID:* It identifies the access router where the terminal is attached.

--*BN_Unidrirectional_ID*: If *InteractionAndBbroadcastNetworkConvergenceFlag* is set, it identifies the asymmetric broadcast network in which the user is connected. If the flag is not set, this represents the broadcast network ID that covers the area.

--*BN_Unidrirectional_ID_Candidate_AR_ID:* If *InteractionAndBbroadcastNetworkConvergenceFlag* is set, it identifies the AR address where the terminal is attached. If the flag is not set, this represent the address of the candidate access router of the broadcast network. This information must be sent by the terminal.

The *MulticastSourceSession* and *MulticastGroup* data, identify specific sources, within the same multicast group, that the user has subscribed. The attributes mean:

-- *ipAddress :* The IP address of the Source

-- *sourcePort*: the source port of the source

--*protocol*: transport protocol used by the session

--*direction:* Specifies the direction in the AR (ingoing/outgoing)

--*sourceParameters*: Specifies the traffic parameters of the source (bandwidth , RSpec, Tspec)

The Multi Technology Resource Manager is the module that is in charge to perform all the operations related to the management of multicast/broadcast connections via different technology interfaces. It is the main module invoked to harmonize the operations when there is the contemporary presence of different technologies (broadcast unidirectional and telecommunication bidirectional) for optimization purposes. It's here the actual intelligence of the system, where optimisation algorithms discussed in section III can run, using the information of the Multicast Database.

Once the decision of using the broadcast channel is taken, the MulticastManager of the telecom domain A can contacts the broadcast AR of domain B in order to enforce it to send a join to the multicast service. This is possible thanks to a special interface with, e.g. in case of DVB technology, the IP Encapsulator. This interface can be defined the "access key" of

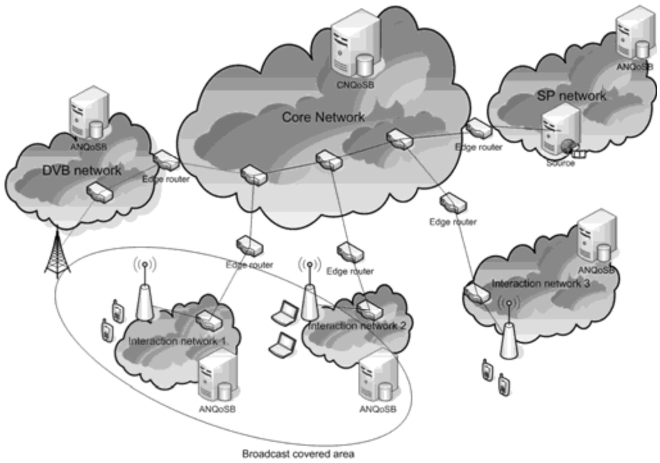


Fig. 4 – Broadcast and telecommunication coverage scenario

the broadcast network. Special agreements should subsist among operators to permit this.

Next section describes a usage scenario in which the multicast manager module plays an important role. This usage scenario can be considered an example of multicast extension of the network initiated handover which is being specified by the group IEEE 802.21 [9].

VI. Use case and Signaling scenario

In this scenario a Telecommunication Operator 1 (TO1) sells to its customer some multicast services (bundle of content and bearer services) through the UMTS network (in general, because it's bidirectional, we can call this network IN, Interaction Network). TO1 also owns some broadcast networks, such as UMTS MBMS and DVB-H. It also hired some extra broadcast capacity (DVB-H) from a DVB broadcast operator. The TO1 calculates that the amount of users subscribed to the service in some cells reaches such a limit to consider profitable distributing the same services through a broadcast channel. (see Fig. 4)

In a most general case, two players are candidate to decide when is economic to switch a service to a broadcast network:

--IN operator: any IN ANQoSB must have full knowledge of users subscribed for a certain service within its own network.

--Service Provider network: the SP ANQoSB could have aggregate information about service recipients (which INs have users and the number of users).

When the switching decision is taken, the Interaction Network ANQoSB (IN_ANQoSB) triggers a network initiated handover sending a message to the target Broadcast ANQoSB enclosing the broadcast ARs involved (Fig. 5) . The knowledge of the broadcast ARs involved per user derives from the MulticastDB.

Since the broadcast AN could still not have joined the multicast tree the Broadcast ANQoSB orders the ARs to join the group. After that the AR advises it is ready for handover. Thus the Broadcast ANQoSB sends a positive decision.

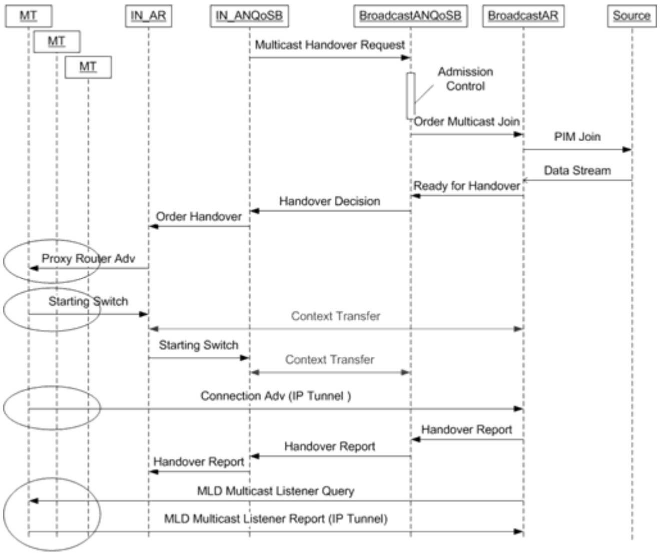


Fig. 5 – Network initiated handover scenario

The IN_ANQoSB in turn teaches the IN_AR to make the mobile terminals (MTs) start the handover by advertisement of the target AR (the Broadcast AR) on a different interface.

For efficient performance, the two networks exchange each other users information by means of Context Transfer Protocol [10]. It's important that when the handover process ends the IN won't drop definitively the connection with MTs, but only reservation for the multicast data flow. The IN will in fact provide MTs with signaling interactive channels to let them utilize IP tunnel mechanism toward the broadcast access router and for application interactivity.

When connected to the broadcast network, the MTs send MLD_reports to the Broadcast AR (via IP tunnel)[11].

VII. Conclusion

The work described in this paper offers a valid perspective of the next generation network management. It provides a simple platform to business operators that want to distribute services through heterogeneous networks, either being owner or tenant, while keeping attention on costs. The framework is so flexible to permit to select the best suited technology on a priori considerations (market study) before service starts, or on real time conditions, that may led to a network initiated multicast handover.

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