SERVICE PROVIDER AND CONTENT AWARE NETWORK PROVIDER CROSS-LAYER OPTIMISATION OF MULTIMEDIA DISTRIBUTION

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ABSTRACT

This work is a part of complex multi-domain eco-system specification and design aiming to deliver multimedia Quality of Services (QoS) enabled services. A cooperation framework is proposed between a high level Service Provider (SP) - managing high level services - and a Content Aware Network Provider (CANP), managing an overlay, multi-domain, transportation network. The virtual CANs are requested by a SP, negotiated with, and realised by the CANP. This cooperation, through online Service Level Agreements, creates a cross-layer optimization loop between the transport, application, and services layers. Inside the VCANs the resources for QoS assurance are assured by static and dynamic provisioning, service differentiation and media flow dynamic adaptation.

Index Terms— Content aware networking, network aware applications, multimedia, quality of services, cross-layer optimisation

1. INTRODUCTION

The architectural solutions for the Future Internet constitute a hot research topics today [1-5]. One new concept is the Content-Awareness at Network layer (CAN) and Network-Awareness at Applications layers (NAA). This idea is defended by the increasing development of the networked media systems and the market orientation towards content. This approach can create a powerful cross-layer optimisation loop between the transport and applications and services.

The new European FP7 ICT research project, "Media Ecosystem Deployment Through Ubiquitous Content-Aware Network Environments", ALICANTE, [11], adopted the NAA/CAN approach, while acting to define, design and implement a multi-domain Media Ecosystem.

Several cooperating environments are defined in which different business actors can be found: User Environment (UE), containing the End-Users; Service Environment (SE), containing SPs and Content Providers (CP); Network Environment (NE), where we find the new CAN Provider and the traditional Network Providers (NP) managing the network elements, in the traditional way at IP level. The "environment", is a generic grouping of functions working for a common goal and which possibly vertically span one or more several architectural (sub-)layers.

This paper defines and specifies a cooperation framework between a SP - which manages the high level services - and a CANP, managing an overlay, multi-domain, transportation network. The Virtual CANs (VCANs) are requested at the SP initiative and negotiated with, and realised by the CANP. This cooperation based on complex Service Level Agreements (SLA) creates a cross-layer optimization loop between the transport and application and services layers. Inside the VCANs the resources for QoS assurance are assured by several mechanisms: static and dynamic provisioning, service differentiation and media flow dynamic adaptation. The paper continues the work presented in other related paper such as [14][15]. It is organized as follows. Section 2 presents related work. Section 3 provides an overview of the ALICANTE architecture. Section 4 defines the CAN services and resource management. Section 5 proposes a template for a complex SLA/SLS between the SP/CANP. Section 6 presents some use cases to illustrate how, based on the SLS clauses, the CAN resources are managed. Conclusions are outlined in Section 7.

2. RELATED WORK

The ALICANTE approach is based on strong trend related to Future Internet architectural solutions to consider the content, services and management as main characteristics [1-5]. The work in [1] shows the importance of management while [2] emphasize the user-centric characteristic of the FI and new telecommunication services. The content and context awareness at network level are analysed in [3][4], showing that they can be powerful approaches to solve the content-related need of the market and can offer a way of evolution of networks beyond IP. The architecture can be still richer if we add context-awareness to content-awareness.

While traditional approaches focus on QoS, the end user is much more interested in Quality of Experience (QoE); the links between QoE and x-awareness is explored in [5]. Apart of provisioning and service differentiation in network nodes the flow adaptation, based on scalable layered codecs is a flexible method to customize the media delivery, depending on the user preferences, context and network conditions [6]. The implementation of VCANs can be naturally supported by virtualization which is also considered as a strong method to overcome the ossification of the current Internet [7-9]. The partial virtualisation – in the data plane – is considered in this paper as the method to achieve VCANs. The CAN/NAA approach can also help to solve the current networking problems related to the P2P traffic overload of the global Internet [10]. The *Application Layer Traffic Optimization* (ALTO) problem can be solved by the cooperation between the VCAN layer and the SE layer.

The references [11-12][14], define the overall ALICANTE architecture, while [13] deals with service/content adaptation framework. These works constitute the background of this paper. The paper [15] outlines the CAN management problems, while this work is a continuation of it. Solving the QoS problems at VCAN level involves implementation of QoS classes in multi-domain context. Here, some significant results elaborated in [16-17] concerning the Meta-QoS classes and inter-domain peering have been used. Also the concept of Parallel Internets as defined in [18] is applied in realising parallel VCANs. The additional contribution of the ALICANTE and also of this paper consists in parallelizing the network, but based on CAN/NAA approach.

3. ALICANTE ARCHITECTURE

The main functional characteristic of the ALICANTE architecture is the network-awareness at the service/application level and content-awareness at the network level. The architecture and main concepts are defined in [11-14] and we will give a brief summary only.

The business actors are SP, CANP, NP, Content Providers (CP), End Users (EU). An additional entity is the Home-Box (HB) - linking the EUs through some Access Networks to the core multi-domain VCAN. The HB manages the EU terminals and gather content/context-aware and network-aware information. It can also play the role of CP/SP for other HBs. The HB layer hosts the service adaptation, service mobility, security, and overall management of services and content.

The overlay VCAN layer is built on top of the IP layer. The VCANs offer virtual connectivity services in modes 1-1, 1-n and n-m communications. The main VCAN elements are virtual *CAN routers* also called *Media-Aware Network Elements (MANE)* performing: content-aware (CA) and context-aware packet classification, labelling, forwarding, controlled QoS, security and monitoring features, etc., in cooperation with other elements of the system. VCAN resources may be *provisioned at request of the SP*, with several levels of QoS guarantees. Additionally, *dynamic adaptation (aggregated or per flow)* can be enforced at both HB and CAN layers, as additional means for QoS, by making use of scalable media resources. The SE uses uploaded information from the CAN layer in its NAA operations, in addition to user context-aware ones. The rich I/F between CAN and the upper layer allows cross-layer optimizations interactions, e.g., including offering distance information to HBs to help working in P2P style. The management and control of the CAN layer is partially distributed and it supports CAN customization conforming the SP request. A hierarchical monitoring system supervises the services at upper layer, including evaluating of the Quality of Experience (QoE) at SE level and the VCAN functioning at CAN layer. The monitoring information is used both to determine network resource re-adjustments and to trigger per flow adaptation.

Figure 1 presents a part of the ALICANTE architecture with focus on the VCAN-related management entities. The network may contain several NP domains (e.g., autonomous systems - AS). Each domain has an Intra-domain Network Resource Manager (IntraNRM@NP), having authority on the network nodes. The CAN layer offers CAN services to HB and SE layers. One CAN Manager (CANMgr) exists for each IP domain to do CAN planning, provisioning, advertisement, offering, negotiation installation and exploitation. Additionally, autonomous MANE CA behaviour is possible without a specific contract SP-CANP.

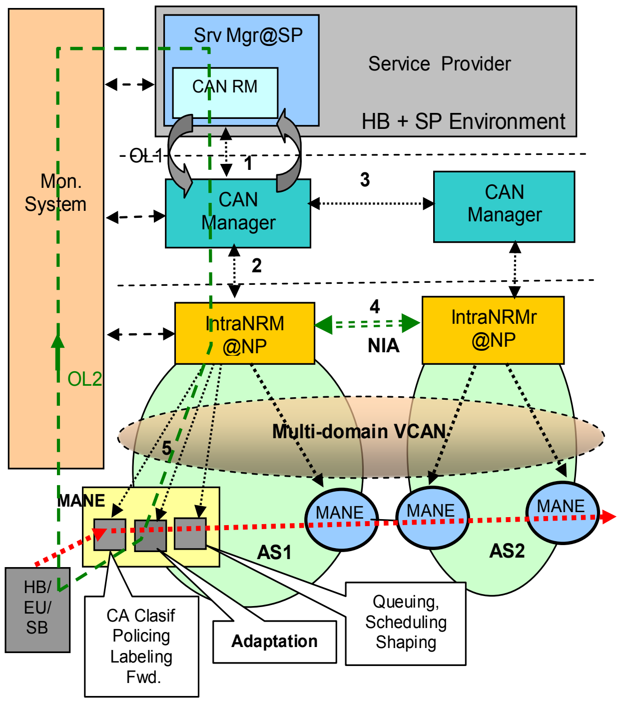

Figure 1. ALICANTE architecture: VCAN management part.

All VCAN operations are performed in MANE nodes, installed at the edges of the domains (for scalability). One or several VCANs with different capabilities can be defined, installed and offered by each domain. They also can be chained in order to obtain multi-domain spanned VCANs. The MANEs perform processing according to the content properties, described by: content-aware transport information (CATI) optionally inserted in the data packets by the servers; or packet header-based on-the-fly content-type analysis. Also the MANE processing depends on SLA concluded between SP-CANP and on current network properties and status. The MANE basic set of functions are [11-12]: content-aware intelligent routing and forwarding, QoS and resource allocation, flow adaptation, filtering, specific security functions, and data caching.

The SP can offer (via CAN layer) QoS guaranteed services, realized at CAN level, by constructing appropriate virtual (unicast or multicast) single or multiple-domain pipes in the network, with or without resource reservations, based on Service Level Agreements (SLA). Then, as a second level of actions, adaptation actions will be performed, e.g., adapting flows proactively if we have Scalable Video Codec sources.

Figure 1 shows also the two main optimisation loop of the system: *provisioning loop* (OL1) based on CAN/NAA approach including mainly the SP and CANP; *adaptation loop* (OL2), which is more complex, including the network, HB, terminals, QoE probes the monitoring system and the Adaptation Decision Taking Framework (ADTF) sub-system present at CAN management level and MANE level. The description of these latter topics will be subject of a future dedicated paper.

4. CAN SERVICES AND RESOURCE MANAGEMENT

In the Management and Control Plane (M&C) the SP may request VCANs by negotiating following SLA/SLS with CANP. The Figure 1 shows the simplified management interfaces and actions related to this.

SP-CANP(1): SP requests and negotiate with CANP to provision/modify/terminate VCANs and the CANP to inform SP about its capabilities (note that this is a cross-layer loop). *CANP-NP(2)*: NP offers or commits to offer resources to CANP (these data are topological and capacity-related). *CANP-CANP(3)*: to extend a VCAN upon several NP domains. Also there are *Network Interconnection Agreements (NIA) (4)* between the NPs or between NPs and ANPs. These are not new **ALICANTE** functionalities but are mandatory needed for NP cooperation. After SP negotiates a desired VCAN with CNAP, it will give the installation commands to CANP and at its turn IntraNRM configure (5) the MANE functional blocks (input and output).

The types of ALICANTE services supported by VCANs are: Fully Managed Services (FMS); Partially Managed Services (PMS); Un-Managed Services (UMS). This split captures two point of views: services defining the degree of how strict the services QoS requirements are and the CANP showing the degree of the CAN layer freedom to perform autonomic actions.

The FMS are high priority services in ALICANTE, i.e., they are delivered by the SP and the in some cases EU's HB. The SLAs are agreed between SP and CANP. The CANP should respect fully all clauses of the contract limits. The services requirements are to get guaranteed: (low) packet delay, bandwidth, (low) packet loss, possible secure, private connectivity. The VCANs are provisioned by the CANP to answer the requirements. Different levels of guarantees are possible. However in this contract we still might have several categories (priorities). Flow adaptation may be performed - if necessary - in HB and/or MANE (here at aggregated or individual level) - but only in the limits allowed by the SLA.

For PMS, the CAN layer has more freedom (to act upon flows) than in FMS case. Still one may have a contract SP-CANP specifying two cases: PM1, some minimum QoS guarantees (quantitative) – plus some extra, or - PM2, only statistical/qualitative (weak) guarantees. The CAN layer may apply adaptation if necessary. In the PM1 case, by applying adaptation it should not violate the contract (assuming a context for a normal network operation cases). In PM2 case, any adaptation operation in the network is allowed to CAN layer in order to do "its best".

The UMS assumes no contract between SP and CANP. Still the CAN layer may offer QoS but based on CANP policies and NP policies. Adaptation may also be applied.

The types of ALICANTE QoS guarantees for services supported by VCANs are: Hard Guarantees (HG), Statistical Quantitative Guarantees (SQnG), Statistical Qualitative Guarantees (SQlG); No guarantees (Best Effort – BE).

Figure 2 shows in a bi-dimensional diagram the FMS, PMS, UMS and the adaptation approach. The notations are: BQ1, BQ2, etc. - different sets of bandwidth requirements (put in the picture in decreasing QoS order); DLJ-Q1, DLJ-Q2, etc. - different sets of *Delay, Jitter, Loss* requirements also shown in decreasing QoS order. It is seen that the freedom of applying adaptation at MANE/CAN layer is greater when the contract between SP and CANP is weaker or even absent. This philosophy offers to ALICANTE a high flexibility.

The definitions of the QoS classes are those of [16-17], i.e., well known "international" Meta-QoS classes (MQC) or local QoS classes (per domain). These are used in ALICANTE in a multi-domain CAN context. Inside each QoS class there may be several priorities defined.

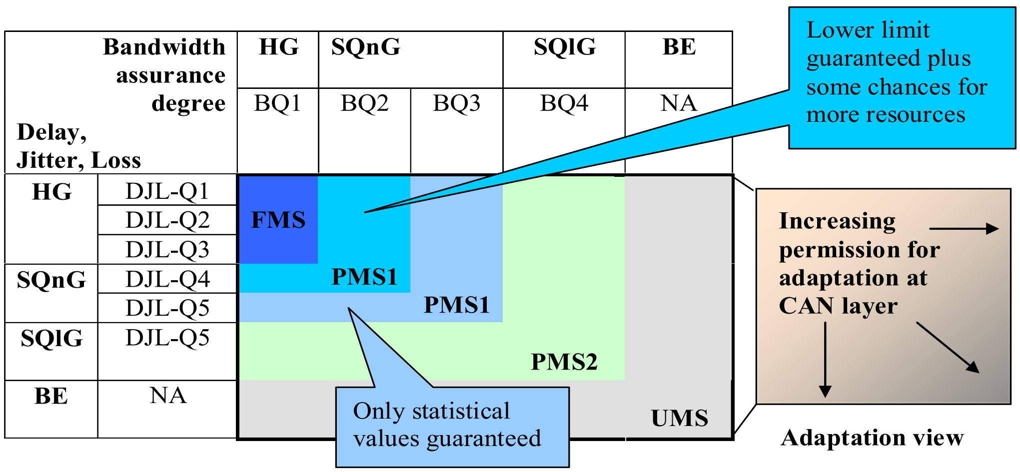

Figure 2. ALICANTE types of services, levels of guarantees and adaptation.

5. SP-CANP SERVICE LEVEL AGREEMENTS

This section outlines the SLA/SLS SP-CAN contracts with more emphasis on QoS aspects. We follow the ideas of [16-18] but with significant modifications to adapt the SLA for the ALICANTE framework. While the SLA usually can contain administrative and business issues, only its technical part, which is SLS, is described here. To establish VCANs the SP should conclude SLS with CANP. Each contract may have one or several partial agreements, each one being described by an SLS instantiation derived from an SLS template. In ALICANTE, a complex template for SLS is proposed here, to cover all aspects of VCAN creation, exploitation, modification and termination. Additionally, the adaptation conditions are specified in these SLSs.

Table 1 describes the SLS clauses and their attributes. A negotiation protocol is going to be built in ALICANTE to allow establishing of the agreements between SP and CANP. The SOAP/XML technology will support these negotiations. The SP management entities which generate the values for the SLS clauses are described in [15].

Table 1. SP-CANP SLS template.

SLS Element/Clause	***Description and Attributes***
SLS Identification	A unique identification key (set by service provider).
VCAN Associated CATI	Information about VCAN-Id, Service Type, Service sub-type, etc. to be optionally inserted in the data packets by the content servers.
VCAN Connectivity Services Req .	
Topology & scope: (pipe, hose, funnel, multicast tree, etc.) and scope (ingress, egress points)	Identifies: the edge points of the topological region over which the QoS applies (IP addresses or layer 2 identifiers); the topology (pipe, hose, etc.). Attributes: Ingress-Egress points (e.g. set of IP addresses of the edge MANE routers where the CAN is ended); Type of topology.
Connectivity class (guarantees): quantitative/qualitative: delay, jitter, loss, availability	Describes the performance guarantees a provider agrees to offer to the packets entitled to this SLS inside the connectivity class. Attributes: delay, loss, jitter, values.

Bandwidth (capacity)	Depending on the topology the capacity is specified abstracted based on the notion of traffic trunks. This is done in the most general case as a traffic matrix. Attributes: Value of capacity assured between edge points.
VCAN Traffic Processing Req.	
Access and transfer rules: Ingress flow Id, Egress flow Id, Ingress point, Egress point	Describe the flows to which the committed treatment in the VCAN is to be done. Attributes: DiffServ Code Points (DSCPs), source, destination, application/content - CATI information.
Access and transfer rules: QoS Guarantees: Class, (dropping, re-marking, shaping)	The former defined class in the Connectivity Service parameters should be specified.
Access and transfer rules: QoS guarantees: Conformance algorithm	Describes the criteria to decide in-profile or out-profile upon input traffic. Only in-profile traffic can get QoS guarantees specified by Connectivity Guarantee clause. Traffic Control (TC) information is needed to configure the traffic conditioners at the edge MANE.
Access and transfer rules: QoS Guarantees: Excess traffic treatment	Describes how the out-profile (excess) traffic will be treated: dropping, re-marking, shaping, adapting.
Routing and Forwarding rules	Describes possible constraints on the way to compute the paths and constraints on forwarding.
Security requirements	Describes details on how to apply security services to the flows. Attributes: Levels of security required at VCAN level and associated parameters.
Adaptation requirements	Describe the condition (thresholds, etc.) under which the adaptation is allowed.
Reliability	Describes the allowed figure of non-availability of the service. Attribute: Mean Down-time per year (MDT) etc.
VCAN Services Assessment Req.	
Monitoring methodology	Describes a selection of procedures for monitoring tasks.
Monitoring tasks	Describes how the monitoring actions to supervise SLS fulfilment at CAN layer is performed. Specific monitoring tasks: time windows, sampling rules, active/passive procedures, entities involved.
Notification and Reports	Describes the details of reports and notification: time, level of information aggregation, etc. There will be regular reports or event-triggered notification.
VCAN Allowed actions	
Availability and VCAN service schedule	Describes possible time intervals allowed for service invocation. Attribute: Timetable for delivery planning.
Invocation methods	Optional attribute used if invocation of the VCAN services is a separate phase w.r.t. the subscription. It describes the conditions of invocation.
Modification permission (of): Connectivity services; Traffic Processing; Service Assessment	Describes modification permissions and conditions for the three categories. Attribute: ranges of modifications allowed for the three categories.

6. USE CASE EXAMPLE

This section briefly presents a dedicated VCAN for multicast, while using the powerful adaptation feature of the ALICANTE (Figure 3). The Scalable Video Codecs (SVC) - generated video flows will be transported via VCANs while adaptation features are present in the MANE and HBs. From the VCAN point of view, multicast trees are needed. The current solution adopted is to construct a multicast channel (each one is a tree) for each SVC layer. The topologies of such trees are subsets of the same spanning tree (i.e., covering all leaves possible). The SLS (simplified presentation) specification is:

VCAN associated Metadata

Connectivity Services: Topology and Scope: Tree model; Quantitative guarantees; Capacity

Traffic processing: Performance Parameter: the guaranteed throughput R = r (token bucket rate). Other parameters are not mandatory necessary to be indicated. For each layer a tree is defined. The *flow specification* comprises a set of source information, destination information, i.e., tree leaves, application information, or a DSCP-value indicating a possible Assured Forwarding Per Hop Behaviour AF-PBH.

Traffic Conformance Parameters: token bucket (b, r) are indicated. These parameters will be used for policing at the ingress points of the trees.

Excess traffic: Remarking is used if necessary; *adaptation* conditions.

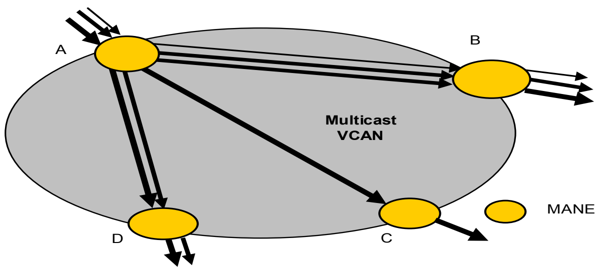

Figure 3. Multicast SVC-oriented VCAN.

6. CONCLUSIONS

This work proposed a framework for cooperation between a High Level Service Provider (SP) - managing and offering high level multimedia services - and a Content Aware Network Provider (CANP), managing an overlay, multi-domain, transportation network. The VCAN services are described, while designed to assure a configurable level of QoS guarantees. Static and dynamic provisioning, service differentiation and flow adaptation are methods to solve the QoS inside VCANs. The top-down initiative has been considered in which the VCANs are requested by SP, negotiated with, and built by the CANP. To achieve this, a complex template for SLA/SLS has been proposed. This cooperation creates a cross-layer optimization loop between the transport and application and services layers. The system is currently in the design phase and implementation will follow inside the FP7 ICT research project ALICANTE.

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