Inter-domain Peering in Content-Aware Networks for Multimedia Applications

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***Abstract* — The Content Aware Networking is an emerging architectural solution, responding to the significant increase in Internet content orientation. This paper is a continuation of a previous work and refines a management framework, for inter-domain peering in overlay Virtual Content Aware Networks (VCAN), QoS enabled, built over multi-domain, multi-provider IP networks. An overlay inter-domain topology service and negotiation protocols are defined in this paper, based on cooperation of the CAN Managers belonging to network domains. The scalability and efficiency is preliminary analyzed. The work is part of the research effort, inside a FP7 European Information and Communication Technologies (ICT) research project, ALICANTE, oriented to multimedia distribution based on CAN approach.**

Keywords — Content-Aware Networking, Network Aware Applications, Multi-domain, Inter-domain peering, Management, Multimedia distribution, Future Internet.

I. INTRODUCTION

The current Internet limitations are recognized, related to the needs of today world and the global spread of this technology. High research efforts are spent to find enhanced architectural solutions or "clean slate" ones, to solve the limitations thus leading to the Future Internet (FI) architectures. Sample of works are presented in [1] - [8]. The work [1] emphasizes the strong orientation of the FI towards content and services and shows the importance of management. Network virtualization is seen as an important "tool" to overcome the ossification of the current Internet [2] - [5]. The overview paper [5], identifies the inefficiency of the current Internet for time-sensitive multimedia content delivery and analyses new solutions based on *Content Oriented Networking* (CON) with decoupling of contents from hosts at networking level. A major trend is the shift from the traditional TCP/IP stack concepts with agnostic network layer to more intelligency in the network layer. New network nodes process the data, based on *content type* recognition or, even more, treating the data objects based on their *name* and not based on *location address*, [6][7]. Inline with this, a new concept is the Content-Awareness at Network layer (CAN) and Network-Awareness at Applications layers (NAA). These new solutions are hopefully able to better support the development of the networked media systems and also the market orientation towards content. The approach is claimed by many studies to bring new benefits for both, Service and Application Layer and Network layer, thus creating a powerful *cross-layer optimization loop* between the transport and applications and services.

The European FP7 ICT running research project, "Media Ecosystem Deployment Through Ubiquitous Content-Aware Network Environments", ALICANTE, [9][10][11], adopted the NAA/CAN approach. It targets to define an architecture, and then to fully specify, design and implements a Media Ecosystem, on top of multi-domain IP networks, to offer a large variety of services for different business actors playing roles of consumers and/or providers.

Architecturally, ALICANTE is a "middle-way" solution: it adopted content-type recognition at network level and light virtualization (separation in the Data Plane of the virtual networks but a single management and control plane). This solution is believed to offer seamless deployment perspectives and tries to avoid the scalability problems (still open research issues) of the full CON approaches.

Several cooperating environments are defined, including several business entities/actors: *User Environment (UE),* containing the End-Users; *Service Environment (SE),* containing High Level Service Providers (SP) and Content Providers (CP); *Network Environment (NE),* where a new CAN Provider exists (CANP - managing and offering Virtual Content Aware Networks- VCANs); traditional Network Providers (NP/ISP) - managing the network elements at IP level. By "environment", it is understood a generic grouping of functions working for a common goal and which possibly vertically span one or more several architectural (sub-) layers.

A VCAN can span several network domains, where each one is managed independently (a realistic business constraint), while offering different levels of QoS guarantees for media flows needs. Therefore an architectural decision have to be taken, on how to manage the peering in the Data Plane (including inter-domain routing) and in the Management and Control Plane (M&C signaling) in order that they cooperate to the realization of a shared VCAN. This is the subject of this paper. Several solutions are analyzed for M&C (cascade, hub, mixed) and finally the so called " hub model" has been selected. A M&C negotiation protocol is proposed to run between domain managers. The scalability aspects are preliminary discussed.

The CANP offers to the upper layers enhanced VCAN-based connectivity services, unicast and multicast (QoS enabled) over multi-domain, multi-provider IP networks. The VCAN resources are managed quasi-statically by provisioning and also dynamically by using adaptation procedures for media flows. The management is based on vertical and horizontal Service Level Agreements (SLAs) negotiated and concluded between providers (e.g SP-CANP). In the Data Plane, content/service description information (metadata) can also be inserted in the media flow packets by the Content Servers and treated appropriately by the intelligent routers of the VCAN.

The paper continues the starting work on VCAN presented in [12] [13]. It is organized as follows. Section II presents samples of related work. Section III summarizes the overall ALICANTE architecture. Section IV shortly presents the content awareness features of the system and QoS assurance solutions. Section V is the main one, dedicated to the peering solution selected and associated negotiations aiming to extend a VCAN over several domains. Section VI contains some conclusions and future work outline.

II. RELATED WORK

The paper objective is to develop management solutions to govern the construction of VCANs, QoS capable over several independent network domains which should be peered and assure guaranteed QoS enabled transport of real-time and media traffic.

For inter-domain QoS enabled domain peering, there exist basically two kinds of approaches. The first one [14] [15], proposes QoS enhancements for the Border Gateway Protocol (BGP). The BGP advertises QoS related information between network domains – seen at limit as autonomous systems (ASes), and then a QoS aware routing table is built. However, the notion of content awareness at domains level is absent there.

Other solutions for inter-domain QoS peering and routing are based on the overlay network idea [16] [17] [18]. An overlay network is defined, which first, abstracts each domain with a node, represented by the domain resource manager, or more detailed with several nodes represented by the egress routers from that domain. There exist protocols to transport QoS and other information between nodes and, based on this information, QoS routing algorithms are used to choose the QoS capable path. In [16] a Virtual Topology (VT) is defined by a set of virtual links that map the current link state of the domain without showing internal details of the physical network topology. Then *Push* and *Pull* models for building the VT at each node are considered and analyzed. In the *Push* model each AS advertises its VT to their neighbor ASes. This model is suited for small topologies. In the Pull model the VT is requested when needed, and only from the ASes situated along the path between given source and destinations; the path itself is determined using BGP.

After routes are found, a negotiation protocol should be run [12]-[15] [18], to establish inter-domains Service Level Specification (SLS) agreements (SLS is the SLA technical part) containing clauses for QoS guarantees.

Related to management of inter-domain peering, several solutions are examined and compared (cascade, hub, mixed-mode) [16][17][18]. However, neither solution considers the content awareness capabilities of the multiple domain infrastructure, nor the virtualization aspects. This paper takes these into account. Also, ALICANTE architecture realizes parallel Internet planes as in [19], but mapped onto VCANs, and additionally achieves cooperation between the network layer and applications and services layers, thus realizing a traffic optimization loop (OL), similar to [20].

III. ALICANTE SYSTEM ARCHITECTURE AND VCAN MANAGEMENT

A. General Architecture

The general ALICANTE architecture is already defined in [9][10][11]. A set of business actors is defined, composed of traditional SP, CP, NP - Providers and End-Users (EU). New business actors are introduced: CAN Provider (CANP) offering virtual layer connectivity services and the Home-Box (HB)- partially managed by the SP, the NP, and the end-user, located at end-user's premises and gathering content/context-aware and network-aware information. The HB can also act as a CP/SP for other HBs, on behalf of the EUs. Correspondingly, two novel virtual layers exist: the CAN layer and the HB layer. The novel CAN routers are called *Media-Aware Network Elements (MANE)* to emphasize their additional capabilities: content and context - awareness, controlled QoS/QoE, security and monitoring features, etc.

The CAN layer M&C is partially distributed; it supports CAN customization to respond to the SE needs, including 1:1, 1:n, and n:m communications and also allow efficient network resource exploitation. The interface between CAN and the upper layer supports *cross-layer optimizations* interactions, e.g., offering network distance information to HBs to help collaboration in P2P style, [20]. A hierarchical monitoring subsystem supervises several points of the service distribution chain and feeds the adaptation subsystems with appropriate information, at the HB and CAN Layers. Figure 1 presents a partial view on the ALICANTE architecture, with emphasis on the CAN layer and management interaction. The network contains several Network Domains (ND), belonging to NPs (they can be also seen as Autonomous Systems - AS) and access networks (AN). The ANs are out of scope of VCANs. One *CAN Manager* (CANMgr) exists for each IP domain to assure the consistency of VCAN planning, provisioning, advertisement, offering, negotiation installation and exploitation. Each domain has an *Intra-domain Network Resource Manager* (IntraNRM), as the ultimate authority configuring the

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network nodes. The CAN layer cooperates with HB and SE by offering them CAN services.

B. *VCAN Management*

The VCAN Management framework has been already defined in [12]. Here only a short summary is recalled for sake of clarity. At the Service Manager SM@SP, the CAN Network Resources Manager (CAN_RMgr) performs all actions needed for VCAN support on behalf of SP. It performs, at SP level, *VCAN* planning, provisioning (negotiation with CANP on behalf of the SP) and then VCAN operation supervision. The *CANMgr@CANP* performs, at the CAN layer, VCAN provisioning and operation. The two entities interact based on the SLA/SLS contract initiated by the SP. The interface implementation for management is based on Simple Object Access Protocol (SOAP)/Web Services. The contracts/interactions of SLA/SLS types performed in the M&C Plane are shown in Fig. 1:

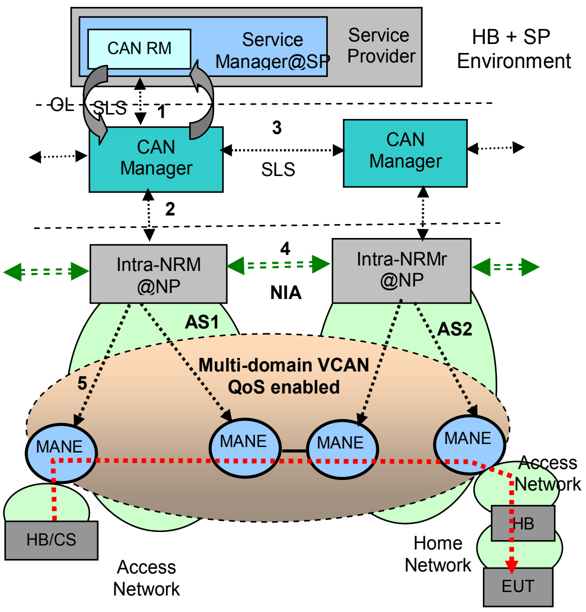

Figure 1. High level ALICANTE architecture: multi-domain VCANs and main management and control interactions

Notations: RM – Resource Management; HB-Home Box; CS- Content Server; EUT- End User Terminal; OL - Optimization Loop; NIA-Network Interconnection Agreements; SP, NP – Service, Network Providers

Interactions in the Fig. 1 are described as follows:*SP-CANP(1)*: the SP requests to CANP to provision/ modify/ terminate VCANs while CANP says yes/no; also CANPmight advertise existent VCANs to SP; *CANP-NP(2)* : CANP negotiates resources with NP;; *CANP-CANP(3)* – negotiations are needed to extend a VCAN upon several NP domains; *Network Interconnection Agreements (NIA) (4)* between the NPs or between NPs and ANPs; these are not new ALICANTE functionalities but are necessary for NP cooperation.

After the SP negotiates a desired VCAN with CANP, it will issue the installation commands to CANP, which in turn configures, via Intra-NRM (action 5), the MANE functional blocks (input and output).

IV. Content Awareness and QoS at CAN Layer

The content awareness (CA) is realized in three ways:

(i) by concluding a SP - CANP SLA concerning different VCAN construction. The content servers are instructed by the SP to insert some special *Content Aware Transport Information (CATI)* in the data packets. This simplifies the media flow classification and treatment by the MANE; (ii) SLA is concluded, but no CATI is inserted in the data packets (legacy CSs). The MANE applies packet inspection for data flow classification and assignment to VCANs. The flows treatment is still based on VCANs characteristics defined in the SLA; (iii) no SP–CANP SLA exists and no CATI. The flows treatment can still be CA, but conforming to the local policy at CANP and IntraNRM.

The DiffServ and/or MPLS technologies support splitting the sets of flows in QoS classes (QC), with a mapping between the VCANs and the QCs. Several levels of QoS granularity can be established when defining VCANs. The QoS behavior of each VCAN (seen as one of the parallel Internet planes) is established by the SP-CANP.

Generally a 1-to-1 mapping between a VCAN and a network plane will exist. Customization of VCANs is possible in terms of QoS level of guarantees (weak or strong), QoS granularity, content adaptation procedures, degree of security, etc. A given VCAN can be realized by the CANP, by combining several processes, while being possible to choose different solutions concerning routing and forwarding, packet processing, and resource management.

The definitions of local QoS classes (QC) and extended QCs and meta-QoS classes were adopted in ALICANTE, [14][15][18][19] to allow capturing the notion of QoS capabilities across several domains. Each domain may have its local QoS classes and several local QCs can be combined to form an extended QC..The types of VCANs defined for different QoS granularities based on QCs are described in [12]: VCANs based on meta-QCs, [14], VCANs based on local QC composition and hierarchical VCANs based on local QC composition. The last case is the most efficient but also the most complex. Inside each VCAN, several QCs are defined corresponding to platinum, gold, silver, etc. In such a case, the mapping between service flows at SP level and CANs can be done per type of the service: VoD, VoIP, Video-conference, etc.

V. CAN Multi-Domain Peering

A. *Horizontal M&C VCAN Negotiation*

A given VCAN may span one or several IP domains. In a multi-domain context, one should distinguish between two topologies (in terms of how the domains are linked with each others): *Data plane topology* and *M&C topology.* The first

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can be of any kind (depending on SP needs and including the domains spanned by a given VCAN). In a general case, one may have a mesh/graph of domains. The *M&C topology* defines how the CAN Managers associated to different domains inter-communicate for multi-domain VCANs construction. The VCAN initiating CANMgr has to negotiate with other CAN Managers. There exist two main models to organise this communication at management level: *hub* model and *cascade* model [14][15][18][19].

The *hub model* was selected; it has the advantage that initiating CANMgr can know, each VCAN component (network) and its status. A drawback is that each CANMgr should know the inter-domain topology (complete graph) of network domains. They could be of lower tier grade or be Autonomous Systems (AS), involved in a VCAN. Given the tiered hirarchy of the Internet, the number of Network Domains (ND) involved in an E2E chain is not too high (actually is lower than 10, [8]), scalability problem is not so stringent. Two functional components are needed: (1) inter-domain topology discovery protocol; (2) overlay negotiation protocol for SLA/SLS negotiations between CAN Managers.

The *cascade* model, [15], [18] is more advantageous for initiating CAN Manager if a chain of domains is to form the VCAN. However, for an arbitrary mesh topology of the NDs composing the VCAN, and for multicast enabled VCAN, this model offers less efficient management capabilities.

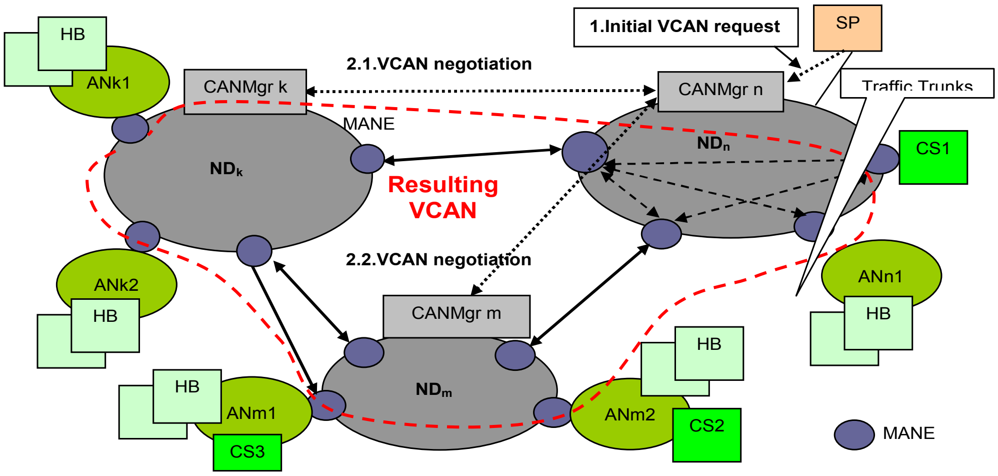

Figure 2 Example of a multi-domain VCAN (hub model for management plane)

Fig. 2 shows an example of a multi-domain VCAN. It is supposed that the inter-domain discover protocol has already produced its results, so each CANMgr knows about the inter-domain graph and have inter-domain routing information, including link capacities and QoS related capabilities. The SP asks for a VCAN to a CANMgr (Initiator) – see action 1. It was supposed that the SP knew the edge points of this VCAN, i.e. the MANEs IDs where different sets of HB currently are, or they will be connected. The initiator *CANMgr_n* determines all network domains (ND) involved (from the SP information and its inter-domain knowledge) and then negotiate in parallel with all other CAN Managers (actions 2.1, 2.2) to establish the VCAN = {VCANn **U** VCANm **U** VCANk}. The split of the SLS parameters (if it is the case) should be done at the initiator (e.g. for delay). In a successful scenario, the multi-domain VCAN is agreed and then it is later instantiated in the network.

B. Overlay Virtual Topology

Constructing VCAN over one or multiple domains is a main target of the CAN Manager. Each ND has complete autonomy w.r.t its network resources including network dimensioning, off-line traffic engineering (TE), and also dynamic routing. The CANMgr cooperating with Intra-NRM is supposed to know about its network resources.

Given that in ALICANTE each ND has associated the IntraNRM and CANMgr, one could abstract the both under the name of NDMgr. This entity should have an abstract view of its network domain and output links towards neighbors in a form of a set of virtual pipes (called Traffic Trunks). A set of such pipes can belong to a given QoS class. As already stated, a multiple domain VCANs should also belong to some QoS class and therefore inter-domain QoS aware routing information is necessary in order to increase the chances of successful SLS establishment, when negotiating the multi-domain VCAN. The multi-domain VCANs deployment needs knowledge on a virtual multi-domain topology.

Each ND can assure QoS enabled paths towards some destination network prefixes while implementing its own network technology: DiffServ, MPLS, etc. Also, each ND can be seen in an abstract way as an *Overlay Network Topology (ONT)* expressed in terms of *TTs (traffic trunks)* characterized by of bandwidth, latency, jitter, etc. One TT is belonging to a given QoS class QCi.

We define an *Overlay Network Service (ONS)* responsible for getting the ONTs related to NDs belonging to a multi-domain VCAN. The CANMgrs will then inter-negotiate the SLS contracts in order to reserve VCAN resources and finally ask installation of them. The overlay topology can be hierarchised on several levels.

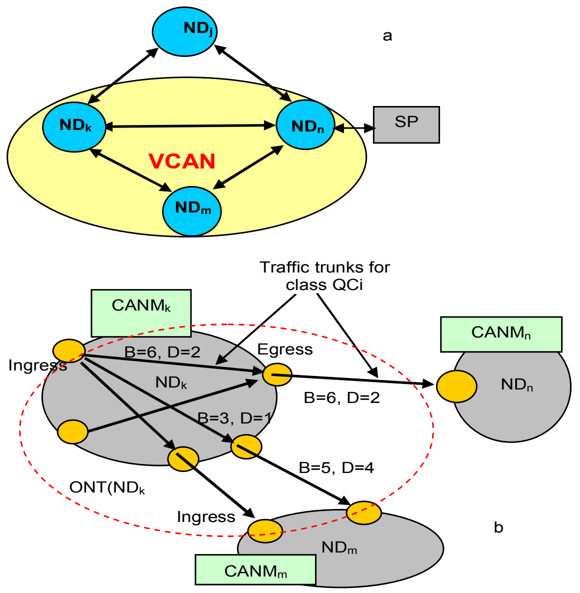

Figure 3. a. Inter-domain level overlay network topology (ONT); b. ONT of the domain NDk (B= bandwidth, D= max delay- generic figures)

Fig. 3.a presents a first level (inter-domain) ONT, in which, each domain ND is seen as a node. The overlay graph of the NDs belonging to the VCAN is composed of the nodes NDk, NDn, NDm. Then, a second order ONT can be defined for one ND. Figure 3.b shows the ONT for the domain NDk, composed of TTs, each one characterized by a bandwidth and a delay. If the initiating CAN Manager knows the ONT graph of the NDs involved, then provisioning of QoS enabled VCANs can be done.

The ONS can be act in two ways: a *proactive* (*push*) mode and a *reactive* (also called *pull* or *on demand*) mode in order to obtain the overlay (virtual) topologies of other NDs.

In the *proactive case*, every ND advertises its ONT to other NDs without being requested for. The advantage is the same as in IP proactive routing protocols: the ONTs of other NDs are already available at a given ND because they are periodically or event-triggered advertised among ND managers. The the advertisement can executed at an initiative of each ND manager, so this model allows promotion of some routes to other domains. This can be subject of policies. The dynamicity is high (event driven advertisements), but the complexity is also high. Scalability problems exist, because of high control traffic volume and also flooding the neighbour NDs with (maybe) not needed information.

In the *reactive* (*on-demand*) mode the ONTs are obtained on demand by an ND interested to reach a given destination prefix. The ND will query each domain of a given path to get the ONTs. No advertising mechanism is necessary. The scalability is higher because only the ONTs of the chosen routes will be obtained. Studies [8] show that the mean End to End (E2E) communication in the Internet usually involves few domains (less than 8). Therefore, the number of domains to be queried to obtain the ONTs is small. The pull model latency is higher (need time for queries and calculations). The updates of ONT knowledge is not event driven w.r.t other NDs, because lack of advertisements. For ALICANTE we have chosen the reactive model.

In ALICANTE case if a CANMgr wants to build an ONT it will query its directly linked (at data plane level) neighbour domains (i.e the corresponding CAN Managers). It is supposed that it has the knowledge of such neighbours. There two possibilities of a querry:

a. non-selective querry/demand- the asking CANMgr wants to know all neighbourhood of the asked neighbours

b. selective demand- the asking CANMgr wants to know answers only from those AS neighbours which have paths to a given set of destinations.

In case a. each queried CANMgr can return – in a first most simple approach only its list of neighbours. At receipt of such information, the interrogating CANMgr updates its topology data base. Then it queries the new nodes learned and so on. The process continues until the interrogating node CANMgr learns the whole graph of “international” topology.The extension of such a zone can be determined by local policies. Because the topology structure changes events are not very frequent (weeks, months), the topology construction process could be run at large time intervals (once a day, for example). Consequently the amount of messages used to build the ONT will not overload the significantly the network. In the case b. the query process is similar, but the answers will be selective, i.e., filtered conforming the required set of destinations.

The area of knowledge desired by a given CANMgr can be determined by policies and can be enlarged if needed. The Fig. 4 shows such an area for two levels of extension.

We summarize the ALICANTE design decision: *on-demand model based on overlay network topology service; based on non-selective and selective queries and simple answers* (i.e., no internal ONT information of a domain is made public). Advantages are: less complexity, higher speed, preserving intra-domain information. Drawbacks are: higher probability of failures of QoS enabled paths at first attempt.

VI. Conclusions and Future Work

The paper proposed a management solution for inter-domain peering, in Content Aware Networks for a multi-domain and multi-provider environment. The management is based on horizontal SLAs negotiated and concluded between CAN providers (represented by CAN Managers) the result being a set of parallel VCANs offering different classes of services to multimedia flows, based on CAN/NAA concepts. The inter-domain approach is to develop an overlay topology service to support VCAN construction, thus obtaining several parallel QoS planes. A CAN Manager is initiating the multi-domain VCAN realization by using the overlay topology service. The system is currently under complete design and implementation in the framework of the FP7 research project ALICANTE. Validation and performance evaluation results will be shown in a future work.

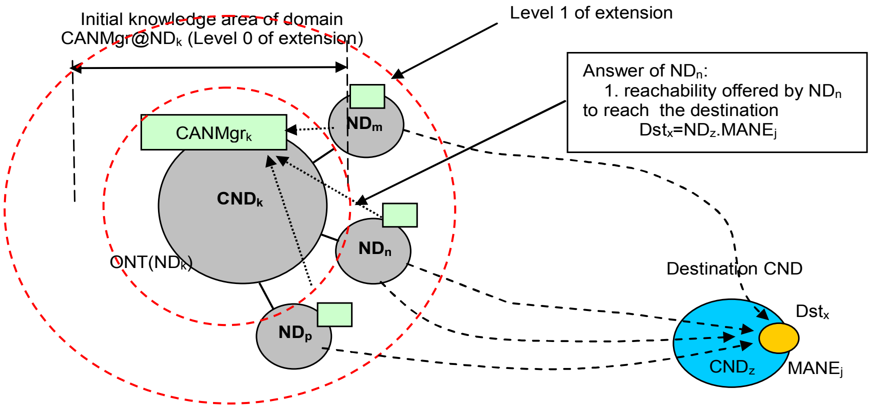

Figure 4 Different areas of ONT knowledge for NDk (Level 0, Level 1, …) in selective –query mode

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REFERENCES

[1] Schönwälder, J., Fouquet, M., Dreo Rodosek, G., and Hochstatter, I.C., "Future Internet = Content + Services + Management", IEEE Communications Magazine, vol. 47, no. 7, Jul. 2009, pp. 27-33.

[2] Baladrón, C., "User-Centric Future Internet and Telecommunication Services", in: G. Tselentis, et. al. (eds.), Towards the Future Internet, IOS Press, 2009, pp. 217-226.

[3] Turner, J. and Taylor, D., "Diversifying the Internet," Proc. GLOBECOM '05, vol. 2, St. Louis, USA, Nov./Dec. 2005, pp. 760-765.

[4] Anderson, T., Peterson, L., Shenker, S., and Turner, J., "Overcoming the Internet Impasse through Virtualization", Computer, vol. 38, no. 4, Apr. 2005, pp. 34–41.

[5] 4WARD, "A clean-slate approach for Future Internet", http://www.4ward-project.eu/.

[6] J.Choi, J.Han, E.Cho, T. Kwon, and Y.Choi, A Survey on Content-Oriented Networking for Efficient Content Delivery, IEEE Communications Magazine, March 2011.

[7] V. Jacobson et al., "Networking Named Content," CoNEXT '09, New York, NY, 2009, pp. 1–12.

[8] W.K. Chai, et.al., CURLING: Content-Ubiquitous Resolution and Delivery Infrastructure for Next-Generation Services , IEEE Communications Magazine, March 2011.

[9] FP7 ICT project, "MediA Ecosystem Deployment Through Ubiquitous Content-Aware Network Environments", ALICANTE, No248652, http://www.ict-alicante.eu/ (last accessed: Dec. 2010).

[10] Borcoci, E., Negru, D. and Timmerer, C., "A Novel Architecture for Multimedia Distribution based on Content-Aware Networking" Proc. of. CTRQ 2010, Athens, June 2010, pp. 162-168.

[11] ALICANTE, Deliverable D2.1, ALICANTE Overall System and Components Definition and Specifications, http://www.ict-alicante.eu, Sept. 2011.

[12] Eugen Borcoci, Mihai Stanciu, Dragoş Niculescu, Daniel Negru, George Xilouris, Connectivity Services Management in Multi-domain Content-Aware Networks for Multimedia Applications, " Proc. of. INTERNET 2011, Luxembourg, June 2011.

[13] Borcoci, E. and Iorga, R., "A Management Architecture for a Multi-domain Content-Aware Network" TEMU 2010, July 2010, Crete.

[14] Levis, P., Boucadair, M., Morrand, P., and Trimitzios, P., "The Meta-QoS-Class Concept: a Step Towards Global QoS Interdomain Services", Proc. of IEEE SoftCOM, Oct. 2004.

[15] Howarth, M.P. et al., "Provisioning for Interdomain Quality of Service: the MESCAL Approach", IEEE Communications Magazine, June 2005, pp. 129-137.

[16] Fabio L. Verdi, Maurıcio F. Magalhaes "Using Virtualization to Provide Interdomain QoS-enabled Routing", Journal of Networks, April 2007, pp. 23-32.

[17] 14] Z. Li, P. Mohapatra, and C. Chuah, Virtual Multi-Homing: On the Feasibility of Combining Overlay Routing with BGP Routing, University of California at DavisTechnical Report: CSE-2005-2, 2005.

[18] ENTHRONE, End-to-End QoS through Integrated Management of Content, Networks and Terminals, FP6 project, URL: http://www.ist-enthrone.org/.

[19] Boucadair, M. et al., "A Framework for End-to-End Service Differentiation: Network Planes and Parallel Internets", IEEE Communications Magazine, Sept. 2007, pp. 134-143.

[20] Aggarwal, V., Feldmann, A., "Can ISPs and P2P Users Cooperate for Improved Performance?", ACM SIGCOMM Computer Communication Review, vol. 37, no. 3, Jul. 2007, pp. 29-40.

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