Design of Network Resource Federation towards Future Open Access Networking

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***Abstract*—Various network applications, such as virtual private network, cloud computing and Internet protocol television, are often provided across multiple network operators. One difficulty in managing quality of service across operator domains is the barrier for adoption especially to service level agreement-sensitive and mission-critical cases. Federating network resources among operators is necessary to manage quality of service across operators. To manage network resources of other operator domains, network operator's federation mechanisms aiming at future of open access network model is designed. Mechanisms of the signaling process as well as the capability of the bandwidth broker are proposed for the open access networking, where multiple operators are connected via a common access network operator. Considering both next generation network and non-next generation network architectures coexist in the open access network, the design identifies functional extensions to existing bandwidth broker implementations for the federation signaling. The proposed design is prototyped and the demonstration results show that the federation mechanism can assure the bandwidth of targeted live data stream on demand across trunk and access network operators even under congestion.**

Keywords- QoS; federation; NGN; open access.

I. INTRODUCTION

Network applications, such as virtual private network (VPN), cloud computing and Internet protocol television (IPTV) are often provided across multiple networks operators, such as telecom operators or ISPs. Those applications sometimes have difficulty in ensuring the quality of service (QoS) because of uncertainty condition of networks. Therefore, adoptions of the network applications to SLA-sensitive or mission-critical cases are difficult, which may also block the growth of future network applications. To ensure QoS across operators, network resources across multiple domains must be managed, which requires the capability of federating network resources among operators. The network resource federation denotes the mechanism to negotiate and coordinate network resources, such as bandwidth for a typical example, among operators for inter-operator connections. The bandwidth broker (BB) concept [1] and several solutions for Internet applications [2, 3] and also mobile applications [4] have been proposed as the federation enabler. However, rolling out the federation mechanism to the whole Internet is not likely because of the huge meshed structure inducing also complicated pricing model [5, 6]. Another possible scenario is an open access network (OAN) [7, 8] where the access network operator (i.e., typically incumbent telecom operator) provides access infrastructure to the trunk network operator (i.e., typically competitive telecom operator). Since the OAN has a relatively simple structure, the QoS-managed federation is more feasible than the Internet. Indeed, telecommunication standardization organizations, such as ETSI and ITU-T, have established the architectural framework of the next generation network (NGN) [9], where the capability of the OAN is incorporated in its network to network interface (NNI). A bandwidth broker called the resource and admission control function (RACF) can have NNI for the inter-operator network resource federation. Based on the QoS requests from adjacent NGN, RACF controls an NGN edge router called the border gateway function (BGF) to ensure QoS within the NGN domain. This means that a QoS-managed federation in NGN architecture requires BGFs to be installed in the transport network. Hence, the NGN-based approach cannot be simply applied to the OAN, since BGF has not been widely rolled out yet. Even in the case of inter-NGN domain federation, the signaling procedure has not been discussed yet.

To design a network resource federation for future OAN, this paper proposes a design of signaling mechanisms for QoS-managed multi-domain networks where both NGN and non-NGN operators can coexist. Non-NGN operator assumes to be conventional IP-based transport network, or the other architectures having the BB that is different from the RACF. The design identifies functional extensions to existing BB implementations for the federation signaling. The design is prototyped and the demonstration results show the feasibility of bandwidth-assured services for QoS sensitive cases in the OANs.

Section II describes structures of the network resource federation using the open access network model. Section III introduces existing technical approaches related to the network resource federation. Considering the remaining issues of the related works, Section IV proposes design of network resource federation. Based on the proposed framework, Section V demonstrates basic signaling procedure of the network resource federation.

II. SERVICE MODEL OF NETWORK FEDERATION

As an example, users of VPN, cloud computing and IPTV services connect to remote offices, data centers and application servers, respectively. In the OAN-based service model, ethose services are provided via a common access network operator and multiple trunk network operators, as shown in Fig. 1.

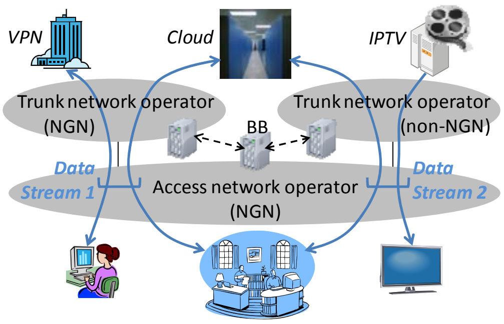

Figure 1. An example scenario involving multiple network operators based on the open access network (OAN) model.

In those scenarios, data streams passes across multiple network operators, as shown in data stream 1 and 2 in Fig. 1. To ensure QoS of those network applications, the BB of each network operator needs to cooperate with each other for managing end-to-end bandwidth resources of the relevant data streams. Several cases must be considered to address network resource federation. Aiming at future OAN scenarios, we focus on two federation cases, that are the federation between NGN operators and the federation between NGN and non-NGN operators. The latter case is indispensable to migrate into the future OAN environment. In Fig. 1, data Stream 1 requires the federation between two NGN operators, while Data Stream 2 requires the federation between NGN and non-NGN operators.

III. RELATED WORKS

Several BB implementations have been proposed for the Internet architectures as we discussed in Section I. On the other hand, BB solutions recently developed for NGN [10] and future Internet architectures [11] may also be applicable to the OAN. In the NGN architecture defined by ETSI TISPAN and ITU-T, BB called RACF has a standard inter-NGN federation interface, shown as "Ri" interface, as shown in Fig. 2. NGN architecture has been developed especially for telecom operators, and thus is suitable for the OAN. Policy decision functional entity (PD-FE) is responsible for federating resources with other NGN, as well as resource reservation based on the availability information residing in the transport resource control functional entity (TRC-FE). Although the Ri federation interface has been defined, the resource reservation procedure (i.e., signaling mechanism) has not been defined yet. Moreover, interworking with a non-NGN domain or resource reservation of a non-NGN by RACF is currently beyond the scope of standardizations.

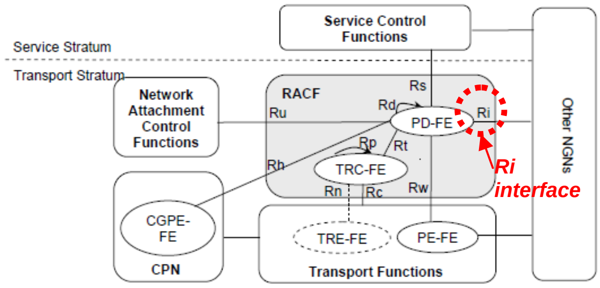

Figure 2. RACF as a BB for inter-NGN resource federation via "Ri" signaling interface [10].

While in the current Internet architecture it is difficult to ensure end-to-end network resources, research testbeds towards the future Internet architecture are developing several control frameworks incorporating a BB mechanism called as "clearinghouse" for resource reservations of both intra- and inter-domains [11]. Although the architectural design of the clearing house is based on the existing BB, the clearing house handles both network and computing resources. However, there are a few demonstrations showing its feasibility of multi-domain resource federation [12]. Since the standardization of the federation interface has not been sufficiently discussed, the control framework often requires complicated interface wrappers (i.e., converters of interface protocols) as shown in Fig. 3. Hence, the applicability of standardized resource federation interfaces needs to be assessed to simplify the signaling design. Especially for the OAN case, the applicability of the telecom federation standard (i.e., "Ri" interface) is attractive not only for the NGN operator but also for the non-NGN operator.

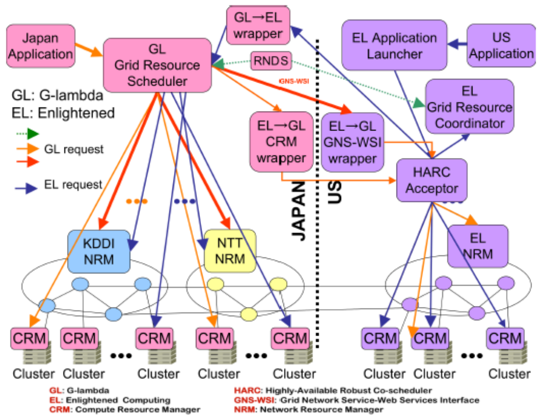

Figure 3. Inter-domain resource federation involving interface wrappers (i.e., protocol converters) [12].

IV. DESIGN OF RESOURCE MANAGEMENT FRAMEWORK

A universal BB implementation both for NGN and non-NGN domains has been proposed [13]. That concept extends the standardized RACF architecture to scope not only NGN resource (i.e., BGF in transport network) but also non-NGN resources (e.g., PON, MPLS, etc.), and such the implementation can be an enabler of the federated signaling operation proposed in this Section. However, to find resources residing in other domains, two functional extensions are required in addition to the existing works.

As the first extension, the capability of finding BB for the federating domain must be added. For inter-domain operation, the function that judges whether the request can be processed within own domain or the request needs federation with other domains is defined, but such functionality has not been defined in the current RACF [10] and BB [13]. To identify an appropriate federating BB requires address resolution capability, such as domain name system (DNS) function, when receiving incoming requests. In the NGN control framework, addressing information is incorporated in the network attachment control function (NACF). However, the standard NACF has only knowledge of its own domain.

As the second extension, the capability of resolving hidden addresses must be added. Considering inter-operator federation scenarios, a connection termination point specified by an IP address in other domains may be hidden by the peer BB (e.g., using NAPT) for concealing its topology. Therefore, termination points of the service may be specified using terminal ID, which is a relative value specifying a termination point rather than specifying an absolute IP address value. Ri protocol [14] has introduced "user identifier" to describe media flow, and the parameter can be identical to the terminal ID. Using the terminal ID, the BB must resolve the IP address inside own domain in order to control relevant resource accordingly. The resolution may be done by the user profile database such as NACF, and thus NACF is required to have a table of correspondence between terminal ID and IP address.

Considering the aforementioned extensions with the basis of the Ri interface, the federation signaling is designed using Diameter protocol [15], which provides authentication, authorization and accounting framework for roaming, network access and IP mobility applications. To cover scenarios based on Fig. 1, both cases are discussed. The first case is federating inter-NGN domains, and the second case is federating NGN and non-NGN domains. As for the interface between the service control function (SCF) and BB, standardized "Rs" interface, which is depicted in Fig. 2, is used as a candidate of the common interface. SCF may be a cloud provisioning system, application server, and so forth.

Fig. 4 shows the proposed signaling procedure of the first case (i.e., federation between NGN domains), and the procedure describes the BB of Domain 1 receives a resource request from SCF and negotiates with BB of Domain 2 to reserve resources between two terminals. Two domains are inter-connected by border BGFs, and two end terminals are connected to access BGFs in each domain. In the reservation phase, based on the standard procedure of Rs interface, SCF sends Diameter AA request (AAR) for two ends of the stream with upstream and downstream, and thus totally 4 AAR messages are sent from SCF to BB. In accordance with the AAR sent from SCF, 4 AAR messages are sent from BB of Domain 1 to BB of Domain 2. This AAR messaging process plays the role of reserving the TCP/UDP port resource as well as bandwidth resources at the termination point of BGF. AA answer (AAA) message informs the result of resource assignment with the information of the assigned TCP/UDP port resource at BGF. Since the standard Rs procedure is designed for one domain and SCF has no knowledge of other domains, the inter-NGN process must be masked by BB of Domain 1, whose process is not defined in standards. BB of Domain 1 conceals the existence of TCP/UDP port termination points at two BGFs in Domain 2. From the SCF's perspective, terminal in Domain 2 can be understood as the one accommodated to the border BGF of Domain 1. When receiving AAR, the BB of Domain 1 needs to perform the capability of finding BB of the federating domain, and the process is depicted as (1). The capability of resolving hidden address also needs to be performed by the BB of Domain 2 when controlling BGF, as depicted (2). BBs also reserve resources of standard BGFs using the Megaco protocol [16], which is designed to control transport equipment for managing gateway of each media stream. To finalize the federation, the BB of Domain 1 sends AAR messages to indicate the commitment of the federation. Extending the signaling procedure only of the BB with Ri interface, SCF and BGF do not have to be aware of the existence of the inter-NGN operation.

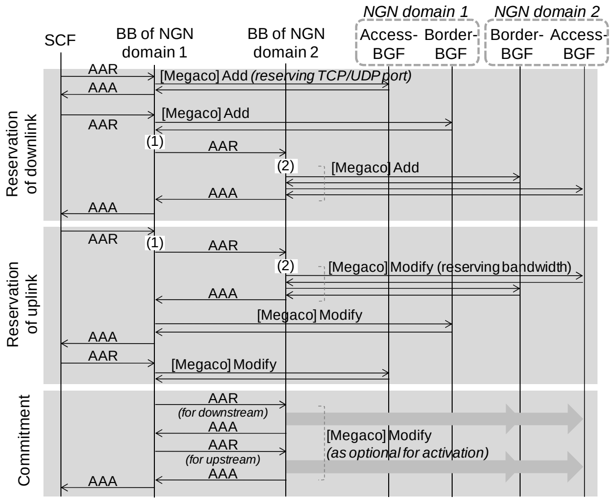

Figure 4. Signaling procedure of resource federation between NGN-domains.

Next, Fig. 5 shows the proposed signaling procedure of the second case (i.e., federation between non-NGN and NGN domains). Although the base procedure for SCF and Ri interface are not dramatically changed, the internal process of BB needs to be modified deriving from non-NGN does not have the TCP/UDP port reservation mechanism. BB operation within the non-NGN domain follows the existing procedure [13] using SOAP protocol message "NetResourceReservation" to reserve bandwidth

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resources of logical links at passive optical network (PON) and MPLS segments, etc. SOAP [17] is a protocol for exchanging extensible makeup language (XML)-structured information of Web services. To manage multiple segment resources, the non-NGN domain has multiple network resource managers (NRMs) that locally manage the resources of each segment. For the purpose of synchronizing reservation states of the resource segments, two-phased commitment is effective for the reservation. In addition, since non-NGN equipment does not have the capability of reserving any TCP/UDP port resource at the equipment. The BB of the non-NGN domain proxies BGF's role supplying terminal port values of the stream since any network address port translation (NAPT) [18] is performed within the non-NGN domain. The port proxy function is performed at Diameter AAA messages marked as (3). Hence, the two-phased SOAP operation and the port proxy function is the third additional extension to BB. Based on those mechanisms, SCF, BB in the NGN domain and BGF do not have to be aware of inter-domain operation.

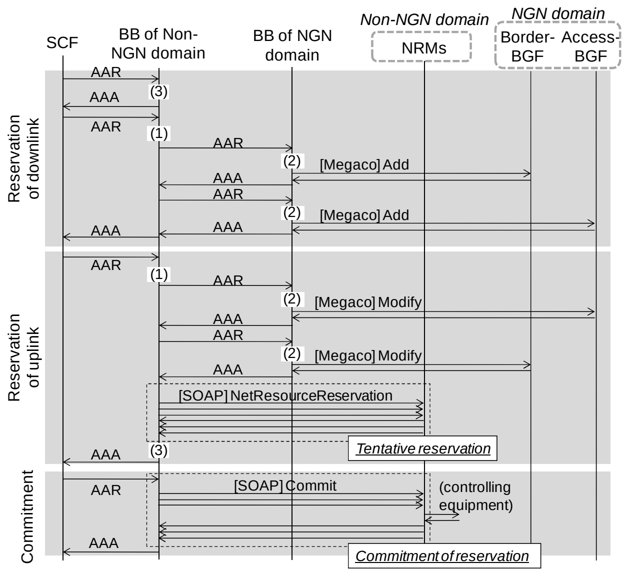

Figure 5. Signaling procedure of resource federation between non-NGN and NGN domains.

V. DEMONSTRATION OF FEDERATION SIGNALING

As a proof of concept of the signaling design described in Section IV, federation-capable BBs for NGN and non-NGN are developed, respectively. The prototype BBs are installed to the OAN testbed, and QoS-managed federation service across trunk operator (i.e., non-NGN) and access operator (i.e., NGN) is demonstrated. Bandwidth-assured content transfer across domains is evaluated using the testbed configuration shown in Fig. 6. A contents server is located in an non-NGN domain, and identical 30 Mbps unicast contents are sent to Terminal X and Y in the NGN domain, respectively. Based on the Rs protocol-based request from a content server, the BB in each domain communicates with each other using the Ri signaling procedure. The BB in the NGN domain controls BGFs using the Megaco protocol, and the BB in the non-NGN domain control NRM for the MPLS router using the SOAP protocol, as described in Fig. 5. NRM performed the call admission control to ensure the bandwidth reservation of the MPLS network. The link capacity of each link is 1 Gbps. Using the federation signaling between the BBs, the bandwidth of only the content stream to Terminal X is reserved, while a bandwidth of the stream to Terminal Y is not reserved. In addition, for both content streams, the background stream of 1.5 Gbps is periodically generated between traffic generator ports within the access operator domain. The background traffic shares an outgoing link of BGF with the content streams, and induces the congestion.

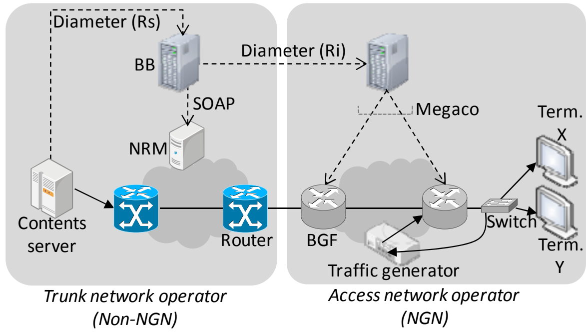

Figure 6. Configuration of concept-proof demonstration for the network federation using proposed signaling method.

Fig. 7 shows the throughput of the content streams and the amount of the generated background traffic. Before activating the federation process, the throughputs of two streams were both affected by the background traffic. Next, the federation signaling was activated to reserve 35 Mbps only for the stream to Terminal X, and then the throughput was stably maintained at 30 Mbps after the federation process. This signaling mechanism assured the targeted live stream on demand without any significant disruption to the targeted traffic.

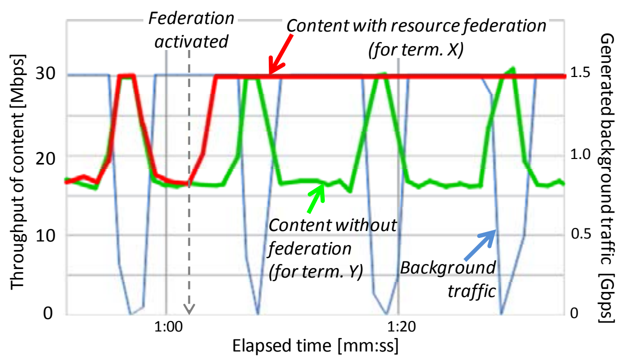

Figure 7. Throughput of contents and generated background traffic.

The signaling operation was captured as Fig. 8. The completion time was about 2.46 sec including configuration of the network equipment.

No.	Time	Source	Destination	Protocol	Info
37	69.229893	BB_of_Non-NGN	BB_of_NGN	DIAMETER	cmd=AARequest(265)
99	69.851988	BB_of_NGN	BB_of_Non-NGN	DIAMETER	cmd=AAAnswer(265)
101	69.872660	BB_of_Non-NGN	BB_of_NGN	DIAMETER	cmd=AARequest(265)
163	70.182833	BB_of_NGN	BB_of_Non-NGN	DIAMETER	cmd=AAAnswer(265)
165	70.614396	BB_of_Non-NGN	BB_of_NGN	DIAMETER	cmd=AARequest(265)
167	70.633962	BB_of_NGN	BB_of_Non-NGN	DIAMETER	cmd=AAAnswer(265)
169	70.648584	BB_of_Non-NGN	BB_of_NGN	DIAMETER	cmd=AARequest(265)
219	71.694199	BB_of_NGN	BB_of_Non-NGN	DIAMETER	cmd=AAAnswer(265)

Figure 8. Snapshot of Ri-based signaling part for the federation process.

VI. CONCLUSION

To design the network resource federation for future open access networking, signaling mechanisms are proposed for multi-domain networks where both NGN and non-NGN operators coexist. The design has been identified functional extensions to existing BB implementations for the federation signaling. The design is prototyped and the demonstration has shown that the federation mechanism can assure bandwidth of targeted live stream on demand across trunk and access network operators even under congestion. With the proposed federation mechanisms, QoS sensitive services are expected to be provided across multiple domains in future open access environments.

In the next steps of this study, our BB prototype needs to be extended considering scalability of network resources and transaction volume. For the future roll out of the federated OAN model, the federation operations simulating various operators' policies, such as usage of terminal ID, notifying event, and charging, must be examined in the testbed. The proposed OAN model also needs to be discussed in the future Internet communities for the better compatibility with the access infrastructure providers.

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REFERENCES

[1] K. Nichols, V. Jacobson, and L. Zhang, "A Two-bit Differentiated Services Architecture for the Internet," RFC 2638, July, 1999.

[2] X. Xiao and L. M. Ni, "Internet QoS: A Big Picture," IEEE Network, pp. 8-18, March/April, 1999.

[3] M. Günter, T Braun, and I. Khalil, "An Architecture for Managing QoS-enabled VPNs over the Internet," in Proceedings of LCN '99, pp. 122-131, Oct., 1999.

[4] R. Aguiar, D. Bijwaard, B. A. Farshchian, K. Jonas, and A. Sarma, "Pervasive Services for Next Generation Heterogeneous Networks," in Proceedings of WTC '06, May 2006.

[5] K. R. Vemu, D. T Daniel, and Y. Nagappa, "Optimal Multiclass Internet Pricing with Game Theoretical Approach," in Proceedings of ICOIN 2009, pp. 1-5, Jan., 2009.

[6] S. Shelford, E. G. Manning, and G. C. Shoja, "A framework for quality of service control through pricing mechanisms," in Proceedings of NOMS 2006, pp. 24-32, Apr., 2006.

[7] M. Forzati, C. P. Larsen, and C. Mattsson, "Open Access Networks, the Swedish Experience," in Proceedings of ICTON 2010, pp. 1-4, Jul., 2010.

[8] R. Battiti, R. L. Cigno, F. Orava, and B. Pehrson, "Global Growth of Open Access Networks: from WarChalking and Connection Sharing to Sustainable Business," in Proceedings of WMASH 2003, 2003.

[9] ITU-T Recommendation Y.2012, "Functional requirements and architecture of the NGN," Apr., 2010.

[10] ITU-T Recommendation Y.2111, "Resource and admission control functions in next generation networks," Nov., 2008.

[11] GENI project office, "GENI control framework requirements," GENI-SE-CF-RQ-01.3, Jan., 2009.

[12] S. R. Thorpe et al., "G-lambda and EnLIGHTened: wrapped in middleware co-allocating compute and network resources across Japan and the US," in Proceedings of GridNets 2007, October, 2007.

[13] N. Matsumoto, M. Hayashi, and H. Tanaka, "Network Middleware Design for Bridging Legacy Infrastructures and NGN," in Proceedings of NGI 2009, pp. 1-9, Jul., 2009.

[14] ITU-T Recommendation Q.3307.1, "Resource Control Protocol No. 7 – Protocol at the Interface Between Inter-Domain Policy Decision Physical Entities (Ri interface)," Jun., 2009.

[15] P. Calhoun, J. Loughney, E. Guttman, G. Zorn, and J. Arkko, "Diameter Base Protocol," RFC3588, Sep., 2003.

[16] ITU-T Recommendation H.248.1, "Gateway control protocol: Version 3," Sep., 2005.

[17] M. Gudgin et al., "SOAP Version 1.2 Part 1: Messaging Framework (Second Edition)," W3C recommendation, Apr., 2007.

[18] P. Srisuresh and M. Holdrege, "IP Network Address Translator (NAT) Terminology and Considerations," RFC2663, Aug., 1999.