Field trial of end-to-end QoS control based on RACS

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***Abstract*—Quality of Service (QoS) control is a challenge to today's telecommunication world. Guangdong Telecom has been conducting a field trial to demonstrate end-to-end QoS control, which is based on Resource and Admission Control Subsystem (RACS) standardized by ETSI. From the results of the field trial, we have confirmed that RACS architecture and the corresponding end-to-end QoS control trial solution will be of great benefit to operator's Next Generation Network (NGN). The solution adds a service aware, policy based QoS control layer to NGN. It can assist network operators to recapture the missing role in the telecommunication value chain, give necessary QoS support for new services, and grow revenue as a value added service itself.**

Keywords- IP ;QoS;RACS

I. INTRODUCTION

Under pressure of fierce competition, telecommunication industry is evolving to next generation network (NGN) [1], which promises low cost, diversified applications, and etc. Among key features of NGN, a uniform multi-service IP bearer network is the corner stone. Every application will be based on IP including voice, video, and data. But IP network was not designed to carry out these services. To properly deliver the new services, current IP technology needs enhancement in several aspects, such as Quality of Service (QoS), security, resilience, and scalability. Among them the biggest challenge is QoS control.

QoS has been intensively researched in the past decade. Inteserv and Diffserv have been proposed as basic QoS models, but are proved not the ultimate answers. More and more people suggest that promising QoS solution for NGN should be service aware and policy based. Resource and Admission Control Subsystem (RACS) is expected to be the right solution, which is standardized by European Telecommunications Standards Institute (ETSI).

As a leading incumbent network operator in China, Guangdong Telecom has conducted extensive research on IP QoS control and network evolution. In this paper, we present a recent field trial based on RACS. From the results of the field trial, we can confirm that RACS is of great benefit to operator's next generation multi-service IP bearer network.

The rest of this paper is organized as follows. In section II, we present the motivation of the field trial. Section III introduces the architecture, basic principles, and standardization progress of RACS. Section IV describes our field demonstration and discusses key issues to the solution. Then we point out future efforts industry should make for large scale deployment of RACS in Section V. Finally, we conclude the paper in Section VI.

II. MOTIVATION

Like other incumbent operators, Guangdong Telecom mainly relies on traditional services to maintain revenue growth in the past years. These services include PSTN, broadband, and Personal Hand phone System (PHS).

As a fixed voice service, PSTN delivers the majority of revenues for Guangdong Telecom. However, PSTN is being replaced by mobile and new VoIP technology like peer to peer. This results in ever decreasing Average Revenue per User (ARPU). Though consumer volume is still expected to grow in the next few years in China, the service revenue will decrease. Launched as a new service two years ago, PHS has heavily contributed to Guangdong Telecom's revenue growth since then. But it's an outdated technology after all compared with competitor's GSM and CDMA mobile networks. Under the pressure of mobile operators' price competition, PHS revenue growth has been greatly slowed down. Broadband service provides high-speed internet access to customers, and is now becoming the main contributor of the total revenue growth. But the success is not expected to last long. Revenue growth relying on broadband network connectivity service will inevitably slow down as penetration approaches saturation. The only ever growing revenue will be generated by applications sitting on top of the network connectivity. The challenge is that current IP network, as a 'bit pipe', brings almost nothing to network operators while creating service providers tremendous growing opportunities. Operators have lost their leading role in today's broadband value chain.

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Based on the above truths, it's urgent for Guangdong Telecom or any incumbent operator to transform its business strategies including management, service, network, and so on, to create new service opportunities and reduce cost of ownership. And network evolution to NGN will be the base for other transformations to make sense.

A uniform multi-service IP bearer network is fundamental to NGN. To get the proper functionality, current IP technology needs enhancement in several aspects, among which QoS is the most challenging.

As mentioned in the introduction, although under intensive research in the last decade, no ultimate solution to QoS has been found yet. Inteserv and Diffserv are the two popular basic QoS models proposed by the industry. Inteserv is a service aware QoS model which can guarantee the service quality. But it has a fatal disadvantage of poor scalability. On the contrary, Diffserv has excellent scalability but can only deliver relative quality control because it's service agnostic. Besides, both models are edge to edge solutions, i.e. they usually can't provide consistent end-to-end QoS because of the differences between the network topology, QoS mechanisms, and inter-domain management issues. So, a promising end-to-end QoS solution should utilize merits of both models and avoid disadvantages at the same time.

More and more people expect that the promising QoS solution to NGN should has a service aware, policy based architecture. The architecture should be able to transfer service quality requirements to transport layer QoS mechanisms for guaranteed quality control. Meanwhile, the architecture should be policy based. Through loose coupling between service requirements and underlying QoS mechanisms, the architecture thus allows operators to implement the most suitable QoS mechanisms and management schemes in each domain to satisfy the agreed service level respectively.

RACS is the right solution introduced by ETSI, as we will present in the following sections. To successfully carry out network transformation to NGN, Guangdong Telecom has done extensive research and implemented a RACS based end-to-end QoS field trial.

III. BACKGROUND

A. *RACS architecture*

RACS, which is a subsystem of NGN [2], is now being standardized by ETSI. According to ETSI standard [2], the overall architecture of NGN is composed of a service layer and an IP-based transport layer. Service layer is responsible for processing application related issues, while transport layer responsible for IP connectivity. RACS and another subsystem, Network Attachment Subsystem (NASS), make up the control function of the transport layer.

RACS is responsible for elements of policy control, resource reservation and admission control. It also supports for Border Gateway Services including Network Address Translator (NAT). RACS ensures that any existing or future application shall be able to request transport resources appropriate to that service. By offering a loose coupling between applications and the transport resources themselves, RACS also ensures that applications do not need to be aware of the underlying transport networks.

RACS hence provides the means for an operator to enforce admission control and set the respective bearer service policies. It provides the means for value-added services to obtain network resources that are necessary to offer services to the end-user. RACS is resource-reservation session aware but application session agnostic, i.e. it can support transport resource reservations for both session based and non-session based applications.

As an example, RACS allows real-time multi-media services (VoIP, video conference, Video on Demand, on-line gaming) to request some particular bandwidth and/or address mediation capabilities for the service from the network. RACS, as the network element responsible for policy based transport control, evaluates these requests according to the policy rules predefined by the operator. In case that the request passes the policy tests and appropriate resources are available in the transport network, RACS will reserve appropriate resources and admit the request.

B. *Standardization progress*

ETSI has standardized RACS as a high level function block of NGN in [2]. But detailed component function requirements and specific protocols are still in draft status. They are scheduled for publication in NGN release 2 standard series.

ITU, another major Standard Organization (SDO), has adopted ETSI standard output on RACS as the basis for their work in this scope. Basically, the two SDOs focus on the same interests. But compared with ETSI's current efforts on xDSL access network, ITU defines an end-to-end QoS functional architecture including both access and core networks. In addition, the two SDOs name the same function blocks differently, e.g. RACS and NASS in ETSI are called RACF (Resource and Admission Control Function) and NACF (Network Attachment Control Function) respectively in ITU. In order to speed up the standardization progress and guarantee compatibility, ETSI and ITU have established formal tight liaison.

RACS/RACF architecture is defined as function blocks and reference points. ITU draft [3] gives the architecture, as in Fig.1.

The functional description for the two key RACF components, PDF (Policy Decision Function) and TRCF (Transport Resource Control Function) are presented below. Readers interested in the rest function components can refer to ITU draft [3].

PDF is responsible for the final decision of the network resource and admission control based on network policy rules, service information provided by SCF (Service Control Function), and resource availability information provided by TRCF. It also controls the gates in the PEF (Policy Enforcement Function) at per flow level. The PDF is transport technology-independent and is independent of Service Control Functions as well.

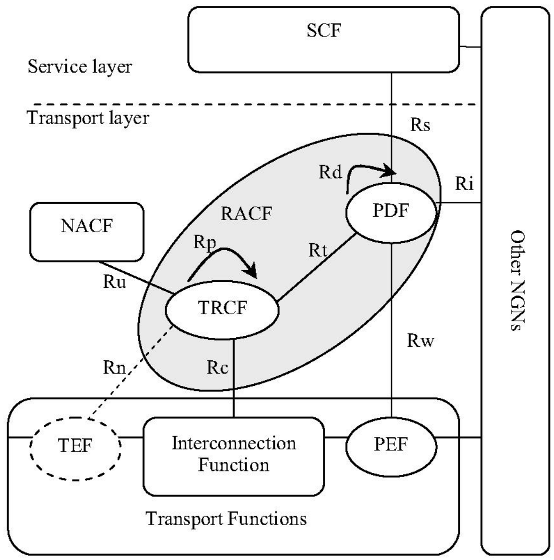

Figure 1. Generic RACF architecture in NGN

TRCF is responsible for the resource control of a specific transport network based on network information such as topology and/or connectivity, network and element resource availability. The TRCF is service-independent but transport technology-dependent, and is located within a single network provider's domain. The policy rules used by TRCF are transport technology specific. Multiple TRCF instances may co-exist in core transport network for the control of different sub-networks.

ITU and ETSI are now evaluating existing protocols and adding necessary features to adopt them as the standards of RACS. Several main protocols have been making progress, and are targeted for publication in 2007. But others are still left untouched. The proposed protocols are shown in Tab. I.

TABLE I. PROPOSED PROTOCOLS

Reference point	Supporting Entities	Protocol proposed
Rs	SCF, PDF	Diameter
Rp	Between TRCF	RCIP
Rd	Between PDF	To be determined
Rw	PDF, PEF	COPS
		H.248
Rc	TRCF, Interconnection Function	COPS
		SNMP
Rt	PDF, TRCF	To be determined
Ri	PDF to PDF (inter-domain)	To be determined
Ru	NACF,TRCF	To be determined
Rn	TRCF, TEF	For further study

IV. FIELD DEMONSTRATION

The field trial is part of the project sponsored by Guangdong provincial government of China. It's a joint program conducted by operator, vendor and research institute. Guangdong Telecom, as an operator, supplies the trial environment and studies the function and performance requirements based on its business and network evolution strategy. Huawei Technologies Co., Ltd, as a vendor, develops and supplies trial equipments. Sun Yat-Sen University provides necessary support on research.

The field trial was implemented from 2005 to 2006. It follows the RACS architecture principles defined in ITU and ETSI. The trial is an end-to-end solution for QoS delivery, including the access, metro, and core networks. The details are presented in the following.

A. Key issues to trial solution

ITU and ETSI define RACS in a logical function manner. Most of the protocols have not been finalized yet. Therefore many issues should be carefully considered when implementing these functions in a real network. Several key issues are given below.

1) Implementation of RACS functions

Recall that RACS function blocks are composed of TRCF and PDF. In our field trial both function blocks are implemented in one box called RM9K, therefore reference point Rt becomes an internal interface. RM9K is a bandwidth broker for its related IP domain, and holds the information of network topology, connectivity, and available resources for the IP domain.

RM9K follows the following steps to detect and determine available resources. It checks if there are sufficient resources available in the IP network by comparing the total capacity and used bandwidth. If there are sufficient resources, RM9K updates the resource status information database to include the new application request, and responds to the SCF with a positive reply. If the IP network does not have the required resources, the RM9K responds with a negative reply.

In order for the trial network to deliver end-to-end QoS, RM9K must be suitable to access, metro and core networks. While the method to detect and determine available resources for RM9K is the same for different networks, the route selection and enforcement schemes are different. Access network is a simple tree topology L2 switching. The route selection for access network is straightforward. Metro and core networks are MPLS (Multi-Protocol Label Switch) network which is based on complex mesh topology. The route selection and enforcement is more complex in MPLS networks. Our approach is to construct a logical bearer network based on MPLS LSP (Label Switching Path), which can be established manually or automatically with signaling such as RSVP-TE. RM9K keeps track of the label information of the logical bearer network, and uses label stacks to present the selected route. Once the route selection has been decided, RM9K passes the label stack information of the selected route to the MPLS edge node. The edge node will then push the label stack on the packet belonging to the specific flow before it enters the network. Based on the label stack, packets can be switched among the nodes of the logical bearer network. This approach avoids upgrading the huge number of MPLS routers (excluding edge routers) in our existing network to support new features, which may be hard to realize sometimes.

2) Hierachical QoS in access network

Access network usually has a tree based topology, as shown in Fig.2. For the sake of simplicity and economics, switch and access node have no per flow or session based QoS capability. Therefore, Broadband Remote Access Server (BRAS) is the only contact point of access network to RACS (implemented as RM9K in the solution). To enforce the resource allocation along the downstream path and maximize resource utilization, BRAS should be able to support hierarchical QoS capability as proposed in [4].

3) Scalability

Scalability is necessary for a promising QoS solution. RACS architecture supports one independent PDF instance each domain and each PDF can have multiple corresponding TRCF. This assures that RACS solution can grow its capacity smoothly as service volume expands. In our trial network, we have implemented three RM9K to meet the scalability requirement.

4) Protocol selection

Although not published, protocols listed in Tab.1 have been accepted as the base of future work by ETSI and ITU. In our trial network Diameter, COPS and RCIP have been chosen as related protocols, as illustrated in Fig.3.

B. Trial network setup

The field trial network was designed to simulate current network structure of Guangdong Telecom. As shown in Fig.3, the trial network was deployed over 3 cities, Shenzhen, Zhongshan, and Foshan. And it was designed to serve 21,000 subscribers at its full capacity. The services including VoIP, VoD, video conference, and etc. were offered. To the best of our knowledge, this is the first field trial based on RACS to deliver end-to-end QoS.

The trial network can be decomposed into three logical layers, i.e. service control layer, bearer control layer, and data transfer layer, corresponding to SCF, RACF, and TF of ITU standard respectively. Service control layer includes a soft switch (Huawei's SOFTX3000) and some application servers such as VoD (not shown in the figure). The equipments in bearer control layer are RM9Ks, in which the PDF and TRCF function of RACF are implemented. The data transfer layer is an IP network, which has three metro and one core domains. MPLS is used as the transport technology. Each metro network has similar topology. As an example, the details of Foshan metro network are shown in Fig.4.

Foshan MPLS metro network consists of four transit routers NE40, and five edge routers (BRAS) MA5200G. Access network is L2 Ethernet aggregation network constructed by Ethernet switch S3528. Various terminals were deployed including Integrated Access Device, POTS phone, video conference phone (VP8220), NGN Access Gateway (UA5000) and Trunk Gateway (UMG8900).

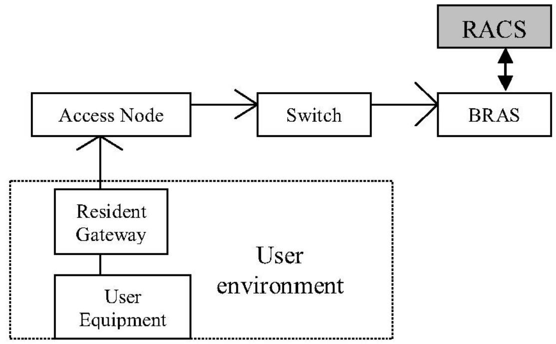

Figure 2. Access network topology

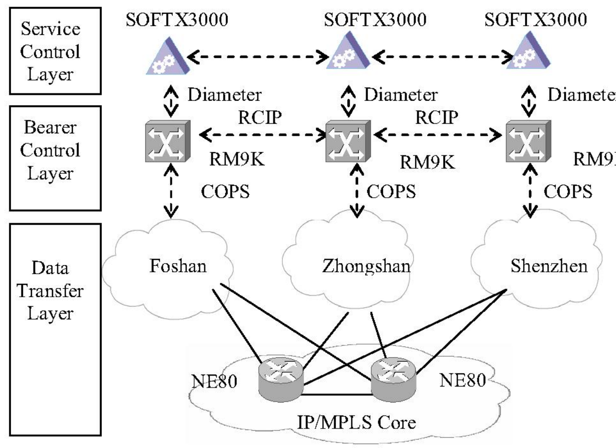

Figure 3. Trial network setup

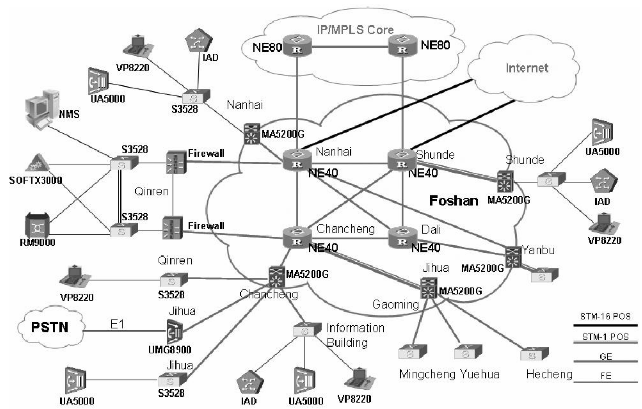

Figure 4. Details of Foshan metro MPLS network

Traffic in IP network is classified into two priorities by MA5200G based on policies. The traffic with different priorities is treated accordingly by routers with Diffserv mechanism. When a critical flow (such as VoIP, video) enters the network, RM9K will first receive a resource request from application servers related to that flow. At the request RM9K will execute resource and admission control procedure. If the request is accepted, RM9K will tell MA5200G to classify the flow as high priority. The QoS of the flow will then be guaranteed. Low priority flows (such as WWW, email application) enter the network directly. RM9K doesn't have to be aware of them. Consequently, these low priority flows get no guaranteed QoS.

To simulate the real network operating environment, we overloaded the network with huge volume of low priority background traffic. No guaranteed QoS led to the poor performance of these low priority flows.

C. Demonstrated applications

Based on the future business models and applications to be delivered, we expect to benefit from the QoS solution in the following three scopes. Fist, it should help us to recapture the leading role in the future value chain. Secondly, it must support new IP-based applications like triple play and video surveillance. Finally, the solution itself should be a value added service to the market.

Based on the above expectations, we have designed many application test scenarios in our trial network. Three representative scenarios are described as follows, each representing one above expectation respectively:

1) Scenario 1: application supermarket

In this scenario, the network operator offers an application portal which aggregates lots of broadband value-added applications developed by the operator itself or third party service providers. Customers can select various value-added applications from the application portal just as they select goods in the supermarket. The owner of the supermarket (operators) gets to share the revenues with the commodity provider (service providers). This scenario will change the operators' current embarrassing role of 'bit pipe seller', and help them to recapture the leading role in the telecommunication value chain.

With end-to-end QoS control introduced in the field trial, the operator offers guaranteed QoS solution to the service providers who join the supermarket to sell their applications and thus differentiates them from best-effort internet players. To other service providers outside the supermarket, their applications will be treated with best effort only and therefore gets no guaranteed QoS. QoS solution in this trial will be a necessary contact point for applications sensitive to network performance. And the application supermarket is expected to be attractive to lots of major players.

To meet the requirements of the application supermarket, operators need to deploy a service platform with portal technology. When a customer decides to buy a service from the portal, for instance, ordering a VoD film, the portal will first generate a request to VoD server that customer A wants film X. If the request passes predefined policy and the VoD server is still capable to handle the film processing, the server accepts the request. Then the portal will request RM9K to reserve the transport resource from VoD server to customer A. The rest steps will be identical to the example introduced in section III.

Here SOAP (Simple Object Access Protocol), a standard communication protocol in information technology world, was adopted as the protocol between the portal, VoD server, and RM9K.

2) Scenario 2: Triple play

In this scenario, the operator can provide integrated voice, video, and data services to customer with a uniform IP network. Triple play creates new revenue opportunities and helps to keep customers' loyalty to the operator. With decreasing PSTN service margin and competition fierce than ever, triple play will be an important innovative application to incumbent operators like Guangdong Telecom.

Voice and video traffic is sensitive to loss and jitter. To assure quality when delivering these applications the network must guarantee QoS. And the end-to-end QoS solution in our field trial enables us to provide triple play services in carrier grade quality.

3) Scenario 3: bandwidth on demand to VIP business customers

Large business clients usually assemble their own application systems with VPN connectivity leased from operators. These applications include mission critical VoIP, video conference, best effort email, FTP, and etc. They differ a lot in terms of QoS requirements on VPN transport resources. But operators' network has no way to treat them differently because the network doesn't have any knowledge of which application each packet belongs to. Currently, customers only have two choices, either overbooking the VPN bandwidth or relying on complex QoS technologies. Both choices increase the cost and thus are not desirable.

With bandwidth on demand feature provided by solution of our field trial, the customer can now lease the VPN bandwidth appropriate to the volume of less critical data traffic at usual time. When there are mission critical calls coming in, customer's application server can request RM9K to allocate more resources and get bandwidth on demand with guaranteed QoS just for critical traffic. As a value added service, bandwidth on demand can greatly reduce the customer's cost, and grow revenue for operators at the same time.

D. Results

The trial demonstrated the beneficial effects of RACS on telecommunication services. By controlling the usage of bandwidth resources, RACS guarantees the quality of admitted services. We have got excellent service quality on VoIP, VoD and video conference even with heavy background traffic volume at about 100% link bandwidth utilization. In contrast, every service bypassing RACS will be marked as low priority traffic and no service quality is guaranteed.

The field trial has proved us two facts:

- RACS allows us to provide carrier grade diverse service to consumer in a unified IP network.
- As an enabler of service differentiation, RACS can help us join the value chain between service providers and end consumers, not just 'bit pipe seller' any more.

V. FUTURE WORK

Though the field trial has proved our solution is successful and RACS architecture is of great benefit to operators, it doesn't imply that the solution can be deployed in large scale right now. Further efforts should be made toward some unsolved issues.

The most important issue is standardization progress. Most incumbent operator's networks are constructed with equipments from multiple vendors. Multi vendor compatibility is very important to successful RACS deployment, due to the fact that the equipment at service control layer, bearer control layer and transfer layer should cooperate with each other. Up to now, all of the protocols related to RACS are still in draft status. For large scale deployment of RACS in real network, industry should speed up the standardization progress.

Another important thing to consider is how to reconstruct the value chain with the help of RACS. Application supermarket demonstrated in the trial is a good example. In addition, to fully exploit the benefits of RACS, Business and Operating Support System (BOSS) must be upgraded to include new business and applications enabled by RACS.

VI. CONCLUSION

We have deployed the first end-to-end QoS field trial in China based on RACS. Scenarios based on expected business model and applications have been successfully demonstrated. The solution adds a service aware, policy based QoS control layer to NGN. It can assist operator to recapture the missing role in telecommunication value chain, give necessary QoS support for new service to market, and grow revenue as a value added service itself. From the trial we can confirm that RACS architecture and the corresponding trial solution are of great benefit to operator's next generation network.

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