Resource Control Architecture in Heterogeneous Networks

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Abstract:
TISPAN, from a fixed access perspective, proposes Resource and Admission Control Subsystem[0] (RACS) as a solution to Quality of Service (QoS) problem for NGN bearer network. In contrast, 3GPP has an approach to this from the perspective of mobile access. In the latest 3GPP R7 draft, integration of Policy Control Function (PCF) with Flow Based Charging (FBC) function of the R6 brought forward policy control and charging. With the development of fixed mobile convergence, the inconsistence in architectures and interfaces of different resource and admission control[0] solutions will have a huge impact on manufacture and network implementation of NGN related equipment. To solve this problem, both 3GPP and TISPAN have been working on the convergence of Gq'/Rx reference points. Harmonized Policy Control and Charging (PCC) proposed by the Next Generation Mobile Network (NGMN) forum, i.e. cooperative resource control architecture for heterogeneous networks, represents an evolutional sign post for resource control technology for heterogeneous network architecture.

The Next Generation Network (NGN) can provide diversified multimedia services, which require the communication network to provide efficient end-to-end Quality of Service (QoS) support. Besides, the subscribers demand higher requirements on QoS of the network. Hence, the end-to-end QoS becomes a core problem of NGN.

The Telecoms and Internet converged Services and Protocols for Advanced Networking (TISPAN), from the perspective of fixed access, proposes the Resource and Admission Control Subsystem (RACS)[1] to solve the QoS problem of NGN bearer network. Being a part of the NGN, the RACS associates resource requirements of the service layer, e.g. IP Multimedia Subsystem (IMS), with resource allocation of the bearer layer, and performs such functions as policy control, resource reservation, admission control and Network Address Translation (NAT). By means of a series of QoS policies, the RACS enables the Application Function (AF) to control the transport layer, thus allowing user terminals to get QoS guaranteed services.

On the other hand, the 3rd Generation Partnership Project (3GPP), based on mobile access, combines Policy Decision Function (PDF) and Flow Based Charging (FBC) in R6, and suggests the Policy and Charging Control (PCC)[2] architecture in its latest R7 draft to enforce resource and admission control. Lying between the service control layer and the access/bearer layer, the PCC is developed based on the characteristics of mobile access networks to achieve certain QoS control.

The "resource and admission control" solutions presented by different standard organizations vary considerably in architecture, network and node type. Having been aware of this point, the international standard organizations have initiated the Gq'/Rx harmonization[3] program to analyze and compare PCC and RACS architectures.

1 TISPAN RACS vs. 3GPP PCC

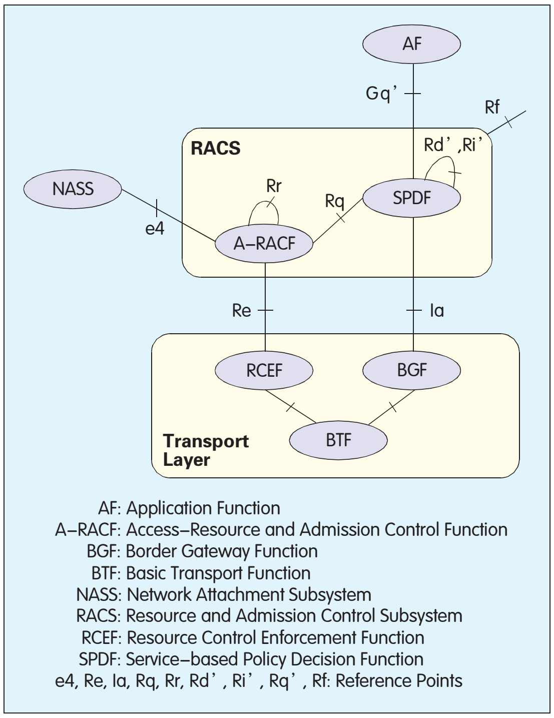
1.1 Functional Architecture

The functional architecture of TISPAN RACS is illustrated in Figure 1. The RACS comprises two elements: Service-based Policy Decision Function (SPDF) and Access-Resource and Admission Control Function (A-RACF). The SPDF provides unified interfaces to the service layer to hide the underlying network topology and particular access technology in use, as well as provides service-based policy control; while the A-RACF controls access networks with two main functions: admission control and network policy assembly.

In the transport layer, three functional entities are included: Border Gateway Function (BGF), Resource Control Enforcement Function (RCEF) and Basic Transport Function (BTF).

The RACS interfaces with the Network Attachment Subsystem (NASS) via e4 reference point, and interacts service information with the AF via Gq' reference point. The NASS provides independent subscriber access management for the upper service layer.

Figure 2 shows the functional architecture of 3GPP PCC. In this architecture, the Policy and Charging Rules Function (PCRF) encompasses



▲Figure 1. Functional architecture of TISPAN RACS.

policy control decision and flow based charging control functionalities, providing network control regarding the service data flow detection, gating, QoS and flow based charging (except credit management) towards the Policy and Charging Enforcement Function (PCEF). The PCEF encompasses service data flow detection, policy enforcement and flow based charging functionalities. Located at the Gateway, the PCEF provides service data flow detection, user plane traffic handling, triggering control plane session management, QoS handling, and service data flow measurement as well as interaction with charging systems. The Subscription Profile Repository (SPR) stores information needed for subscription-based policies.

The main function of both RACS and PCC is to control the QoS of the network, but their architectures differ in the following aspects:

(1) Control over Access Network

The RACS controls the RCEF of access network via the A-RACF. For example, in Asymmetric Digital Subscriber Line (ADSL) network, the RACS needs to control the access network node Digital Subscriber Line Access Multiplexer (DSLAM). On the contrary, 3GPP PCC does not handle access networks, but focuses on IP Connectivity Access Network (IP-CAN), which can be set up in various access networks.

(2) Gateway Node

In the PCC, the PCEF functions to handle QoS and policies; while 3GPP PCC is only responsible for resource authorization, and resource reservation is taken charge of by the IP-CAN. Specifically speaking, the PCRF first computes the resource requirement of a service and authorizes the service to use resources. Then it sends related information to the PCEF. Upon receiving such information, the gateway node where the PCEF resides works with other nodes to set up an IP-CAN. Different kinds of access technologies have different IP-CAN signalling.

(3) Support to Access Technology

The typical feature of heterogeneous networks is the diversity of its underlying network access technologies. Among these technologies, the RACS R1 only supports fixed access, for instance, xDSL. In RACS R2, the access types are extended, allowing the RACS to be applicable to any type of access, but research on its support to other access technologies is still in progress. In contrast, 3GPP PCC is independent of access technology, so it is applicable to any access technology that complies with 3GPP IP-CAN definition, including General Packet Radio Service (GPRS), Wireless Local Area Network (WLAN) and Worldwide Interoperability for Microwave Access (WiMAX).

(4) Mobility Support

To guarantee the QoS in the case the subscribers move, the resource and admission control system is required to support the mobility. Currently, the RACS does not support the mobility, but its next release, which is under development, has included mobility as an important research subject. With application scenarios and flows of nomadism and roaming being fully discussed, the PCC supports the mobility quite well.

(5) Requirement for Terminal

3GPP PCC requires its terminals to support QoS signalling. The signalling can be explicit. For instance, in GPRS, the terminal must support Packet Data Protocol (PDP) context and the Universal Mobile Telecommunications System (UMTS) QoS parameter should be carried in the PDP context activation message. The signalling can be also implicit. For example, in WLAN, the bearer is an IPSec tunnel from the terminal to the Packet Data Gateway (PDG), so the terminal is just required to support IPSec. The RACS does not have any strict requirement on the terminal's

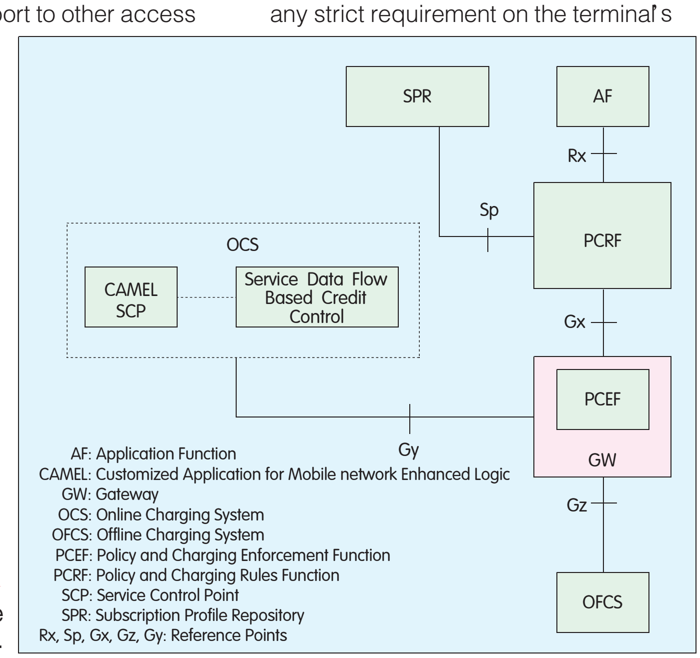


Figure 2.▶
Functional architecture of 3GPP PCC.

QoS signalling capability.

(6) Support for Charging

This is an important function in resource control systems. The RACS only supports offline charging. Moreover, the architecture and flow of the charging system are still under further study, and related signalling specifications have not been released. By contraries, the PCC supports several charging modes: online charging, offline charging and flow-based charging.

(7) Network Address Translation (NAT)/ Network Address Port Translation (NAPT)

The RACS has included NAT/NAPT into its research. As a result, it supports these functions. The main mechanism of NAT/NAPT works like this: The BGF completes NAT/NAPT traversal under the control of the SPDF. NAT/NAPT is not a research subject of 3GPP PCC, so it has to be processed by other systems. For IMS, the NAT/NAPT traversal is handled by its access network gateway and the Proxy-Call Session Control Function (P-CSCF).

1.2 Interface

In TISPAN RACS architecture, the main reference points are Gq'[4], Rq, Re and Ia. Gq' is used for interaction of service-based policy making information between the SPDF and the AF. Rq resides between the SPDF and the A-RACF, and enables the SPDF to send QoS parameters to the A-RACF. Re is between the A-RACF and the RCEF, through which the A-RACF issues the policies of transport layer. Located between the SPDF and the BGF, Ia allows the BGF, under the control of the SPDF, to perform NAT and gating.

The reference points involved in 3GPP PCC architecture mainly include Rx[5], Sp, Gy and Gz. Rx enables transport of application level session information from the AF to the PCRF. Such information is regarded by the PCRF as a part of inputs for PCC decision. Sp allows the PCRF to request subscription information from the SPR based on such parameters as subscriber ID. Gy resides between the Online Charging System (OCS) and the PCEF, allowing online credit control for service data flow-based charging. Gz lies between PCEF and OFCS, used for transport of service data flow based offline charging information.

As both Gq' and Rx are reference points connecting to the AF, their harmonization is of great significance. Currently, 3GPP and TISPAN have started research on Gq'/Rx harmonization. The comparison results of the two reference points show that the basic procedures over them are very similar, which no doubt creates favorable conditions for their harmonization.

The following is a comparison of basic procedures over the two reference points.

1.2.1 Initial Admission/Reservation Procedure

Rx reference point supports AF session setup procedure. When a new AF session is being established and media information for this AF session is available at the AF, the AF shall open a session with the PCRF. That is to say, it sends initial request message via Rx reference point. Gq' reference point supports initial reservation procedure of a session. The comparison of the initial admission/reservation procedure is mainly made with operations of related entities, i.e. SPDF and PCRF.

Both the SPDF and the PCRF perform the following operations: execute policy decision according to the operator policy; open/close the gate of the BGF; and install policy/PCC rules on the BGF/PCEF upon receiving initial admission/reservation request from the AF.

Their different operations include: The SPDF does not decide transmission resources corresponding to IP session and subscriber IP address, and does not associate the request with subscription profile, which are both processed by the A-RACF. By contraries, the PCRF determines IP-CAN session and bearer, and associates the request with subscription profile.

Moreover, both the subscriber's IP address and the globally unique address are sent over Gq'. On Gq', the AF does not display service information negotiation phase, but indicates the valid period of reservation and supports hard-state/soft-state reservation; while on Rx, the AF displays service information negotiation phase, but does not indicate the valid period of reservation and does not support hard-state/soft-state reservation.

1.2.2 Modification Procedure

During the modification procedure over Rx, the AF can modify such information of a previously created session as service information, indicator of service information negotiation, and PCC rules. In the modification procedure over Gq', the information of existing session that can be modified by the AF includes service information, gating control, transport policy rule and duration of reservation.

Gq' supports refresh of an existing session. Therefore, the AF is not required to include service information. However, Rx does not support this function.

1.2.3 Termination Procedure

In 3GPP PCC architecture, when the AF receives an internal or external session release request, it sends a session termination message to the PCRF. The PCRF then identifies related AF session or IP-CAN session and bearer, instructs the PCEF to remove any PCC rule related to the IP streams of the AF session, and replies to the AF.

In the RACS architecture, once session release is triggered, the AF sends a session termination request to the SPDF. If the related session has been set up, the SPDF shall instruct the A-RACF to perform related operations and ask the BGF to close the gate. Upon receipt of acknowledgements from the A-RACF and the BGF, the SPDF replies to the AF.

2 Evolution of Resource Control Architecture of Heterogeneous Network

As fixed and mobile networks converge and heterogeneous networks converge, a unified resource control architecture is needed to satisfy the subscribers' service experience. For example, in heterogeneous networks, the continuity and QoS of services should be ensured during moving and handover. Therefore, the Next Generation Mobile Network (NGMN) forum suggests the concept of Harmonized PCC, i.e. the cooperative resource control architecture for heterogeneous network. This architecture represents the evolution direction of resource control technology and system in heterogeneous networks.

The evolution of resource control technology and architecture can proceed in three steps: harmonization of service layer interfaces of different resource control architectures, coordination of PCC and RACS, and possibly, integration of PCC and RACS.

2.1 Harmonization of Service Layer Interfaces

Gq' is the interface between the RACS and the service layer, while Rx is the interface between the PCC and the service layer. The harmonization of the two interfaces means that a unified resource control service interface can be provided for the service layer, allowing the service layer to shield differences between heterogeneous networks without perceiving differences between the RACS and the PCC.

The harmonization of Gq' and Rx is the first step of Harmonized PCC, but it is of great value. In November 2007, TISPAN and 3GPP held a joint meeting. And after the meeting, the Gq'/Rx harmonization program was initiated by 3GPP with the document No. 23.822 (Framework for Gq'/Rx Harmonization), where ZTE Corporation is one of the initiators. In TISPAN 16bis meeting held in March 2008, MI2054 was approved, which is a Gq'/Rx harmonization program of TISPAN. So far harmonization solutions for globally unique address, NAPT control and soft-state model have been worked out.

- Globally unique address: Rx reference point is extended to use the globally unique address on Gq' to replace its original subscriber IP address. To ensure backward compatibility, it is suggested to add domain description.
- NAPT control: NAPT binding setup and modification procedures are added on Rx reference point, and Rx can use the same binding parameters as Gq'.
- Soft-state reservation model: The duration of reservation is proposed to be added on Rx reference point to support soft-state model.

2.2 Coordination of RACS and PCC

Currently, several RACS systems can interact with each other, although related communication interface specifications are to be further improved. However, no interface is available for communications between the RACS and the PCC. Consequently, they cannot coordinate with each other. When a subscriber is handed over between heterogeneous networks, continuous QoS control has to be implemented among the heterogeneous networks to satisfy the subscribers' service experience. That is to say, the RACS and the PCC have to interact and negotiate with each other in order to finish the operations required for continuous QoS guarantee, for instance, resource reservation. To achieve coordination between the RACS and 3GPP PCC, it is necessary to study and standardize the interactive interface between them, which is a focus in next stage standard research, following the Gq'/Rx harmonization program by 3GPP and TISPAN.

2.3 Integration of PCC and RACS

The integration of PCC and RACS is a possible development trend of resource control technologies of heterogeneous network. The need and feasibility of this integration is still under study, but the cross reference and convergence of these two resource control architectures make this integration possible.

Two proposals of ZTE Corporation have been adopted in the TISPAN 16bis meeting. As a result, in the new version of RACS, mobility support technology and mobile access technology (e.g. WiMAX) will be included. Meanwhile, harmonization of RACS and PCC is another research topic.

3 Conclusions

Resource control can provide various services with guaranteed QoS and dynamic policy control, allowing the operators to achieve differentiated service and good operation. The resource control in heterogeneous networks is surely a research focus, an important topic in network convergence. The significance of the research lies in its provision of QoS guarantee for services across heterogeneous networks.

One important tendency in the development of resource control technologies for heterogeneous networks is Harmonized PCC. The evolution of Harmonized PCC will go on in a step-by-step way: first, harmonization of service layer interfaces; and then coordination of PCC and RACS to meet the QoS requirements of Fixed-Mobile Convergence (FMC) services.

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Biographies

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