CHAPTER 4

SIGNALING DESIGN

The previous chapter discussed the PBQMS architecture and its components with interfaces. This chapter deals with signaling in 4G network using PBQMS, such as pre-negotiation, negotiation, re-negotiation and seamless hand off.

4.1 PROCEDURE FOR POLICY NEGOTIATION/RENEGOTIATION

The purpose of policy negotiation is to determine the final service operating point, by matching the specified user, service, and network parameters. The service operating point refers to the final service configuration to be delivered to the user. The steps involved in a policy negotiation procedure are shown in Figure 4.1. This rather generic procedure is discussed later in terms of possible mapping onto IMS and in the context of a user accessing a service hosted by application servers. Inputs to the negotiation procedure include user policies, network operator policies and network status information. During the registration process the user provides the user policies. Upon a user’s request for a particular service, the client application sends a service request, accompanied by the session policies. A NSIM retrieves the network status information. As per Figure 4.1, specified parameters serve as input to a matching process. The matching process serves to select zero or more feasible service configurations as determined by the input parameters. A service configuration is considered feasible when all the following conditions are met:
- The user’s terminal capabilities support the service processing requirements.
- The user’s access network supports the minimum requirements for all (required) media objects.
- The user’s preferences in terms of acceptable cost, media components, and timing constraints.

![Diagram of Generic policy negotiation procedure]

**Figure 4.1** Generic policy negotiation procedure
A negotiation process follows the matching process. The offered set of potential session parameters from feasible service configurations is returned to the user. The user may then accept or refuse the (subset of) offered parameters. Then network entities authorize resources based on the agreed parameters. The authorization includes limits on data rates and traffic classes for uplink/downlink flows and is based on QoS policy and admission control mechanisms in the network.

Based on negotiated and authorized session parameters, feasible service configurations are ordered according to achievable user-perceived quality into a so-called degradation path, from the highest to the lowest quality configuration. User Preferences determine establishment of a degradation path (for example, a user considers audio to be more valuable than video). This is used when service degradation or upgradation is necessary. The service profile corresponding to the highest quality feasible configuration is passed to the optimization process.

The goal of the optimization process is to calculate the optimal service operating point and respective resource allocation across all media flows. This comprises a multimedia service according to the established objective. The optimization objective can be formulated dynamically, for example, based on user preferences indicating that a user wishes to achieve maximum possible service quality, minimum cost while maintaining acceptable service quality, or the best value for money service. This does not aim to further specify the formulation of actual optimization problem and algorithm(s) to be used. This decision is left to the operator.

After the calculation is completed, the network resource reservation procedures are invoked. If successful, customized multimedia content is retrieved from the application server and delivered to the user.
The previously described cycle may be repeated at any time during service execution, in response to a significant change in relevant factor(s) that affect service feasibility. For scalability and performance reasons, it is not realistic nor desired, to assume re-calculation of the optimal operating point at every change. Instead, thresholds may be established indicating events that to trigger modifications are for re-calculation and subsequently leading to QoS renegotiation. Such triggers may come either from the network (for example, degraded wireless link) or from the applications (for example, a user’s action within the networked game). The important part to note is that triggers coming from the application are related to the semantics of the application and can thus be taken into account during the application design. In this way, the application-level adaptation (for example, multimedia stream buffering) also may be performed to improve the user-perceived quality.

4.2 CASE STUDY: IMS WITH PBQMS IN 4G

This scenario forms the basis for the implementation of the PBQMS concept and achieves improvements in the context of seamless IMS service delivery. A brief description of IMS deployment in 4G networks, highlighting the enhancements made within the PBQMS framework and explaining the use case is given below.

Sam is sitting a cafeteria and currently enjoying a coffee. As an HSDPA subscriber, Sam is registered with his 4G-network provider who hosts an IMS domain for multimedia services. Sam’s HSDPA PCMCIA-based data card is used as a modem for the notebook, which is a multimode device that also includes a WLAN capability. Since, Sam has set preferences for secure connection, the PBQMS module in the notebook detects all available networks (HSDPA and WLAN hot-spot) and automatically selects the HSDPA access. After registration, Sam starts a video-conferencing
application with a friend Rama, who is working at the home. The IMS application consists of voice and video streams. After a while, Sam gets a notice from his notebook of a pending appointment at home. While on the way to home, Sam continues to maintain the video-conferencing session. Since Sam has set the preferences of using WLAN at home, the moment Sam reaches home, the PBQMS module detects the availability of the WLAN and conducts the handover to the WLAN. Because IMS manages the handover process to SIP session transparently and PBQMS governs the process optimally, Sam doesn't notice any service interruption. However, Sam notices an improvement in video quality as the PBQMS informs IMS client about the handover and IMS initiates a change-of-used codecs to cater to higher data rate. Finally, Sam closes the conference by tearing down SIP connection and all network resources are released.

4.3 PBQMS SIGNALING

Considering the example described in section 4.2, various events or triggers shall dynamically occur during the video-conferencing or media streaming session related to the invocation of QoS negotiation/renegotiation, adaptation and handover procedures. This thesis identifies the following five such events to illustrate the procedures and to analyze the corresponding PBQMS signaling flows.

- Terminal Registration and Pre-negotiation
- Negotiation and Propagation of Transport Session
- Re-negotiation
- Tear Down
- Resource Management
4.3.1 Terminal Registration and Pre-negotiation

An end user invokes session establishment. This involves UE registration with the IMS network, and negotiation of initial service parameters. This phase deals with negotiation of session independent policy information’s, which are valid for more than one multimedia session, for example, service configuration. This information can be shared between end systems. During this phase, terminals exchange information on supported codecs, desirable QoS contracts, etc. Having the pre-negotiation information in advance, the end systems can speed up the negotiation process for session establishment. Figure 4.2 presents the summary of terminal registration and pre-negotiation.

![Diagram of Terminal Registration and Pre-negotiation]

Figure 4.2 Terminal registration and pre-negotiation
4.3.1.1 Registration process

UE needs to perform IMS service registration before the pre-negotiation. The following are the steps involved in UE registration process.

1. The UE sends a REGISTER message to the P-CSCF. The message includes the subscriber identity and home networks domain name.

2. Upon receipt of the REGISTER message, the P-CSCF shall examine the “home domain name” to discover the entry point to the home network (i.e. the I-CSCF).
   a. P-CSCF forwards the REGISTER message to the I-CSCF with the P-CSCF address/name, P-CSCF network identifier (e.g., domain name of the P-CSCF network), and subscriber’s identity, etc.

3. The main job of I-CSCF is to query the HSS and find the location of the S-CSCF.
   a. I-CSCF sends a proprietary message to the HSS with the subscriber’s identity and P-CSCF network identifier to check whether the user is registered already.
   b. The HSS shall indicate whether the user is allowed to register in that P-CSCF network according to the User subscription and operator limitations/restrictions.

4. If the user is allowed to register then the HSS will challenge the UE through the P-CSCF for security reason.

5. UE will provide the response to challenge in a REGISTER message.
6. The P-CSCF forwards the REGISTER message to the I-CSCF.

7. The I-CSCF sends OK 200 message to the P-CSCF.

8. The P-CSCF stores the home network contact information, and sends the OK 200 message to the UE.

### 4.3.1.2 Pre-negotiation process

During pre-negotiation the UE will get the PBQMS URI from the IMS. The steps involved during pre-negotiation are as follows:

1. After successful IMS registration the UE sends a SUBSCRIBE message to the P-CSCF. The message includes the subscriber identity, home networks domain name and the PBQMS Id tag.

2. P-CSCF will identify the SUBSCRIBE message with the PBQMS-Id and send 488 (Not Acceptable Here) message to UE with the PBQMS URI.

3. UE will pick the PBQMS URI from the 488 message and contact the PBQMS with a SUBSCRIBE message.
   a. The SUBSCRIBE message includes the PBQMS-Id, PBQMSURI, empty TOKEN tag and the user policies in the form of XML.

4. PBQMS will establish a DIAMETER connection with IMS and verify that the user already registered with the IMS.
a. If the user is already registered with the IMS, PBQMS will accept the SUBSCRIBE message and send the NOTIFY message to the UE.

b. The NOTIFY message contains a result message (accepted, partially accepted, not acceptable) along with the TOKEN tag.

c. If the user is not registered with the IMS, PBQMS will terminate the SUBSCRIBE message with 488 message.

4.3.2 Negotiation and Propagation of Transport Session

The information exchanged during this phase deals with configuration and establishment of a specific multimedia session. If the UE was not able to perform pre-negotiation (due to limited memory or system local policies, etc.) the necessary system configurations can be additionally exchanged during this negotiation phase. Thus, two types of negotiation are defined –

- **Short negotiation**: This uses session dependent policies and a reference to data exchanged in previous pre-negotiation phase.

- **Full negotiation**: This contains both session independent and session dependent policy information.

Parameters exchanged during negotiation phase are defined in QoS contexts, like

- Which media streams should be created for a given session.
- How these streams are associated with codecs and basic QoS configurations thereof, and
What kind of QoS and time-synchronization constraints are applied.

The QoS contracts and contexts are applied for multimedia session establishment and for any eventual QoS adaptation process that may take place during a multimedia session. Negotiated information may also be leased between end systems. Figure 4.3 presents the summary of negotiation and propagation of transport session. The steps involved in this phase are: (Assume that UE1 is in UMTS network and UE2 is in the wired network).

1. UE1 sends a SUBSCRIBE message with PBQMS-Id, PBQMSURI and an empty TOKEN tag to the PBQMS.
   a. UE can send two types of SUBSCRIBE message.
      • SUBSCRIBE message for short negotiation
      • SUBSCRIBE message for full negotiation
2. Based on the SUBSCRIBE message the PBQMS will take the necessary action.
3. PBQMSC interacts with the PDP and sends the NOTIFY response message to the UE along with the TOKEN.
4. UE will send a normal SIP INVITE message to the IMS with this TOKEN specified in the NOTIFY message.
5. The IMS will process the SIP INVITE and forward it to UE2.
6. UE2 follows the steps 1 – 3 and sends the 180 RINGING message to IMS.
   a. IMS will forward the same 180 RINGING message to UE1.
Figure 4.3 Negotiation and propagation of transport session
7. PBQMS-PDP will instruct the edge routers (UMTS edge router for UE1 and wire line edge router for UE2) through PEP using the COPS protocol for resource allocation.

8. The resource allocation will take place using the RSVP protocol.

9. After getting confirmation from the RSVP protocol, the UEs will exchange the OK 200 message and the ACK message before transmitting the media.

10. The media transmission will take place using the RTP protocol.

### 4.3.3 Re-Negotiation

The user initiating an audio and/or a video stream causes a change in service requirements. Stream parameters are negotiated and corresponding network resources are authorized and reserved. A change in the user policy is caused by a change in user preferences (for example, the user has chosen to switch to a low cost session). This leads to the re-negotiation and adaptation of service parameters and reserved network resources. The network, leading to re-negotiation and adaptation procedures, detects a change in network resource availability.

This phase deals with enforcement of specific QoS contracts and contexts and the indication of adaptation conditions. If a different QoS contract/context should be enforced due to change in resource availability, then the application, providing the index of new QoS contract to be enforced, invokes the re-negotiation phase. Re-negotiation phase can also be used to specify new configurations PBQMS uses the NOTIFY message for the re-negotiation process. There are two types of re-negotiation messages.
- **Short re-negotiation**: Using references to previously exchanged data. For example, if a dynamic codecs download extends the capabilities.

- **Full re-negotiation**: Enhancing the system/session configurations, whenever system upgrades/downgrades occur.

The short re-negotiation is, thus, an efficient process, since it uses only references to previously negotiated data, and signaling impact is correspondingly minimized. Figure 4.4 shows a simple re-negotiation process.

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**Figure 4.4 Re-negotiation**
4.3.4 Tear Down

During tear down, it frees all the reserved resources and ends the session. When a session is terminated PBQMS-UA should send a unsubscribe message to PBQMS, unless the PBQMS indicates that it does not need to be contacted at the end of the session. This enables a policy server to free all resources it has allocated for this session. Figure 4.5 shows a simple tear down process. The unsubscribe message could be of two types. They are:

- **Short Unsubscribe**: Unsubscribe only the session specific policies and release that particular session resources.
- **Full Unsubscribe**: This Unsubscribe will remove all policies including the pre-negotiated ones.

![Figure 4.5 Tear down](image-url)

Figure 4.5 Tear down
4.3.5 Resource Management

The QoS signaling via PBQMS is out of band and path decoupled. Application-level proxies that can interpret such kind of signaling are in a position to manipulate the QoS configurations exchanged by terminals. However, the original unchanged configurations may be useful for end systems, when planning and performing handovers. Additionally, provider rules applied within one sub network might not be available and/or legal in another sub network when performing a handover. Consequently, network components, which are in a position to enforce provider rules, should add them to the QoS contracts in a way that this information is explicitly visible and recognizable as a provider restriction from the negotiating peers. Terminals can, thus, distinguish between end system constraints and provider rules. The resulting required separation of QoS contracts and provider rules guarantees successful end-to-end application signaling even when components for enforcing provider policies are involved.

PBQMS QoS contracts are used for resource-reservation during session establishment and adaptation. PBQMS adopts the “economy principle” to describe the order of reservation processing, i.e., end system local resources should be reserved ahead of network resources, which are the most expensive ones. Resource management within the network may be heterogeneous and end systems may not be allowed to perform network resource reservation signaling; or the signaling may be terminated in the network at a gateway. However, it is the task of the end systems to synchronize session setup with optional network resource reservation.
4.4 SEAMLESS HANDOVER USING PBQMS

The handoff operations should be quick enough to ensure that the mobile station can receive IP packets at its new location within a reasonable period of time and also reduce the packet delay as much as possible. It should also be seamless to the mobile user and at the same time achieve efficient usage of the network resources. Seamless handover means smooth transparent transition, that the user does not notice. This section explains two types of PBQMS based seamless handover. They are:

- Intra PBQMS Inter IMS Seamless Handover
- Inter PBQMS Inter IMS Seamless Handover

The following subsections use the case study explained in section 4.2. Sam is currently enjoying a coffee seating in a cafeteria. As an HSDPA subscriber, he registered to the HSPDA network using the IMS-1. Sam’s HSDPA PCMCIA-based data card is used as a modem for the notebook. After registration and pre-negotiation, Sam starts a video-conferencing application with a friend Rama, who is working at the home. After a while, Sam gets a notice from his notebook of a pending appointment at home. While on the way to home, Sam continues to maintain the video-conferencing session. Since Sam has set the preferences of using WLAN at home, the moment Sam reaches home, the PBQMS-UA module detects the availability of the WLAN and collects the WLAN information.

4.4.1 Intra PBQMS Inter IMS Seamless Handover

Assume that the WLAN network is connected to IMS-2 but within the same PBQMS area. The following steps explain the Intra PBQMS Inter
IMS seamless handover process. Figure 4.6 provides the Intra PBQMS Inter IMS seamless handover sequences.

1. To use the WLAN connection the PBQMS-UA has to register with the IMS2.
   a. PBQMS-UA will send a REGISTER message to IMS-2 and complete the registration process.

2. After completing the registration process, PBQMS-UA sends a dummy SUBSCRIBE message to IMS-2 with the PBQMS-Id.

3. IMS-2 provides the PBQMS URI in the 488 message.

4. PBQMS-UA verifies the new PBQMS URI with the existing one.
   a. Both the PBQMSURI’s are same, hence it sends a re-negotiation SUBSCRIBE message to the PBQMS.

5. PBQMS will check the credentials with IMS-2 using the DIAMETER protocol and provide the NOTIFY message to PBQMS-UA.

6. PBQMS-UA will send a re-invite message to Ram and perform the resource reservation.

7. After successfully reserving the resources the data transmission will takes place in the WLAN network.

8. In the mean time the data transmission takes place in the HSDPA network.
4.4.2 Inter PBQMS Inter IMS Seamless Handover

Assume that the WLAN network is connected to IMS-2. IMS-2 uses the PBQMS-2 network. The following steps explain the Inter PBQMS Inter IMS seamless handover process. Figure 4.7 provides the sequences for inter PBQMS inter IMS seamless handover.

1. To use the WLAN connection the PBQMS-UA has to register with the IMS2.
   a. PBQMS-UA will send a REGISTER message to IMS-2 and complete the registration process.
Figure 4.7  Inter PBQMS Inter IMS seamless handover
2. After completing the registration process, PBQMS-UA sends a dummy SUBSCRIBE message to IMS-2 with the PBQMS-Id.

3. IMS-2 provides the PBQMS URI in the 488 message.

4. PBQMS-UA verifies the new PBQMS URI with the existing one.
   a. The new PBQMSURI is different from the earlier one. Hence PBQMS-UA sends a full negotiation SUBSCRIBE message to the PBQMS-2.

5. PBQMS-2 interacts with
   a. PBQMS-1 using the XCAP protocol and check for the home policies and credentials.
   b. Check the credentials with IMS-2 using the DIAMETER protocol

6. PBQMS-2 provide the NOTIFY message to PBQMS-UA.

7. PBQMS-UA will send a re-invite message to Ram and perform the resource reservation.

8. After successfully reserving the resources the data transmission will takes place in the WLAN network.

9. In the mean time the data transmission takes place in the HSDPA network.