

# Chapter 11

## UMTS All-IP Network

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# Abstract

- This chapter shows a UMTS all-IP approach for the **core network architecture**, and briefly describes an Open Service Access (OSA) system developed in NCTU.
- We introduce the core network nodes, and elaborate on *application-level registration*, *circuit-switched call origination*, *packet-switched call origination*, and *packet-switched call termination*.

# Cont.

- This chapter shows how UMTS can guarantee end-to-end QoS and radio spectrum efficiency.
  - We note that to provide the expected QoS across domains, operators must agree on the deployment of common IP protocols.
- The common IP protocols impact roaming (i.e., the interfaces between core networks) and the communications between terminals and networks to support **end-to-end QoS** and **achieve maximum interoperability**.

# Introduction

- By providing ubiquitous connectivity for data communications, the Internet has become the most important vehicle for global information delivery.
  - The flat-rate tariff structures and low entry cost characteristics of the Internet environment encourage global usage.
- Furthermore, introduction of the 3G and the Beyond the 3G (B3G) mobile systems has driven the Internet into new markets to support mobile users. **As consumers become increasingly mobile**, they will demand wireless access to services available from the Internet.

# Cont.

- Specifically, the mobility, privacy, and immediacy offered by wireless access introduce new opportunity for Internet business.
  - Therefore, mobile networks are becoming a platform that provides leading-edge Internet services.



## Cont.

- To integrate IP and wireless technologies, UMTS all-IP architecture has been proposed by the **3GPP** [3GP04i, 3GP05r, Bos01].
- This architecture evolved from GSM (Second Generation or 2G mobile network), GPRS, **UMTS Release 1999 (UMTS R99)**, and *UMTS Release 2000 (UMTS R00)*.
  - UMTS Release 2000 has been split up into Release 4 and Release 5.
  - **Release 4** introduces a next-generation network architecture for the Circuit Switched (CS) domain.
  - **Release 5** introduces the IP Multimedia (IM) Core Network Subsystem (IMS) on top of the Packet Switched (PS) domain.

# Cont.

- Evolution from UMTS R99 to all-IP network has the following advantages.
  - First, mobile networks will benefit directly not only from all existing Internet applications, but also from the huge momentum behind the Internet in terms of the development and introduction of new services.
  - Second, this evolution allows telecommunications operators to deploy a common backbone (for example, IP) for all types of access, and thus to greatly reduce capital and operating costs.



# Cont.

- Third, the new generation of applications will be developed in an all-IP environment, which guarantees optimal synergy between the ever-growing mobile world and the Internet.

# Cont.

- In a UMTS all-IP network, the SS7 transport will be replaced by **IP**, and the common IP technology supports all services, including multimedia and voice services controlled by the **Session Initiation Protocol (SIP)**.
- In UMTS R99, the PS domain supports data services over an enhanced GPRS network. The CS domain mainly supports voice based services.
- Conversely, a UMTS all-IP network **supports voice applications through the PS domain using SIP**.
  - The CS domain call control mechanism in R99 may be re-used to support CS domain services for a UMTS all-IP network.

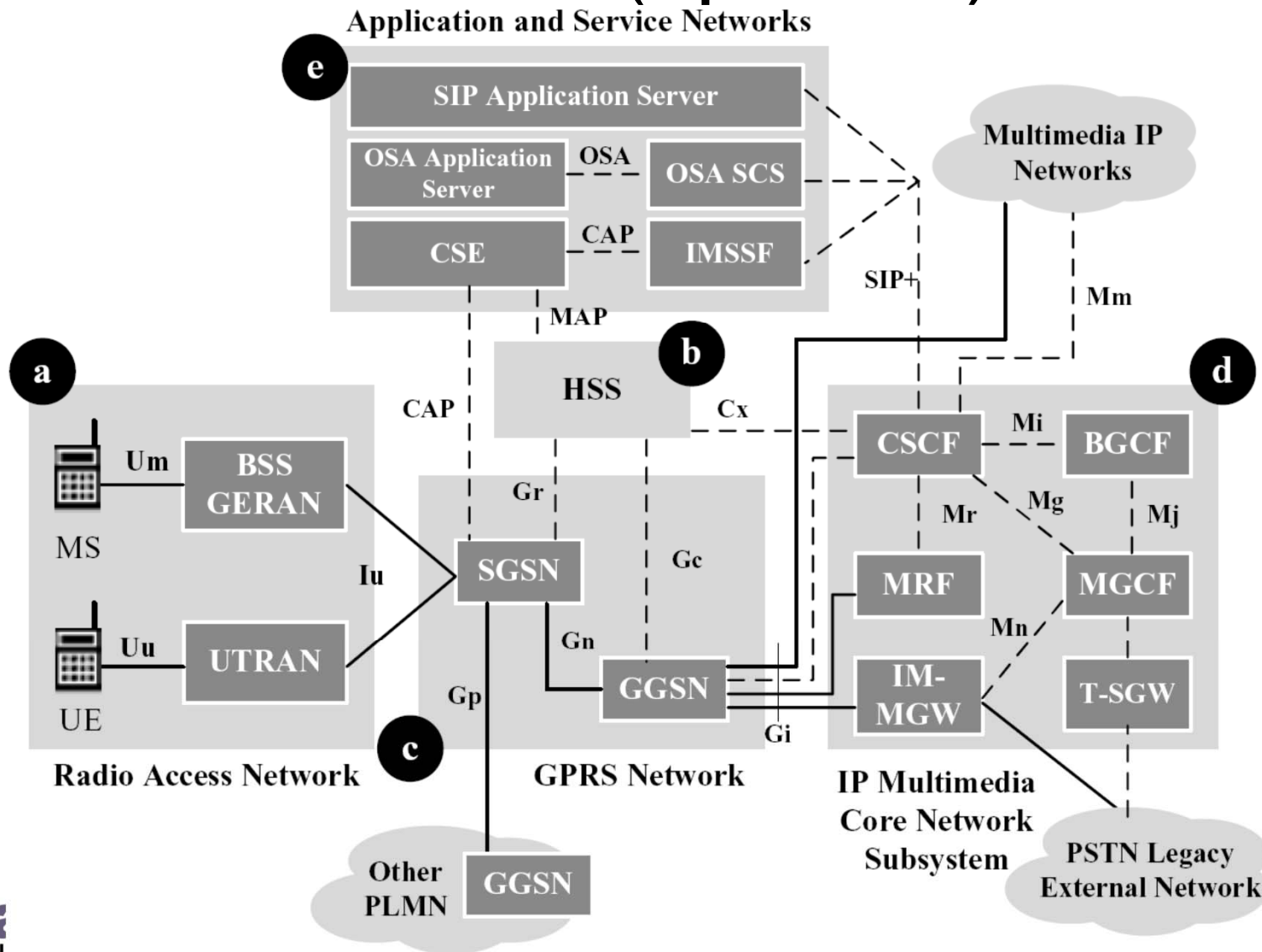
# 15.1 All-IP Architecture

- There are two options for a UMTS all-IP network.
  - The *option 1* architecture supports **PS-domain multimedia** and **data services**.
  - The *option 2* architecture extends the option 1 network by accommodating CS-domain voice services over a packet-switched core network.

## 15.1.1 Option 1 for All-IP Architecture

- The UMTS all-IP network architecture option 1 consists of the following segments (see Figure 15.1):
  - **Radio Access Network** (RAN; see Figure 15.1 **(a)**) can be UMTS Terrestrial Radio Access Network (*UTRAN*) or *GSM Enhanced Data Rates for Global Evolution* (*EDGE Radio Access Network* (*GERAN*)). The UTRAN is basically the same as the R99 version (see Chapter 2).

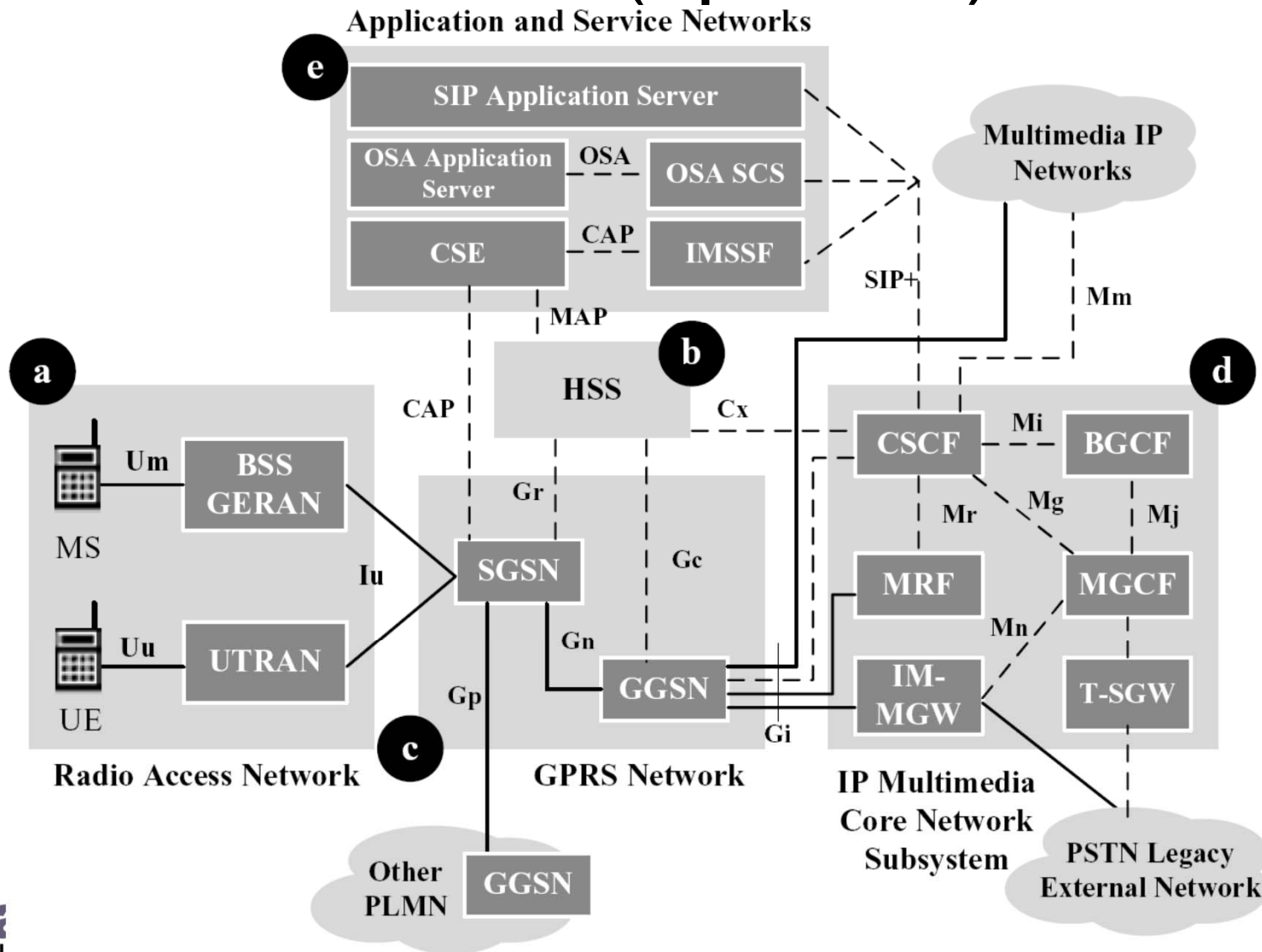
# Fig. 15.1 UMTS All-IP Network Architecture (option 1)



# Cont.

- **Home Subscriber Server (HSS)**; see Figure 15.1 (b)) is the master database containing all 3G user-related subscriber data.
- The HSS consists of the **IM functionality** (that is, IM user database), a subset of the Home Location Register (HLR) functionality required by the PS domain (that is, 3G GPRS HLR), and a subset of the HLR functionality required by the CS domain (that is, 3G CS HLR) to provide support for call handling entities. We will briefly describe these functionalities in Section 15.2.

# Fig. 15.1 UMTS All-IP Network Architecture (option 1)

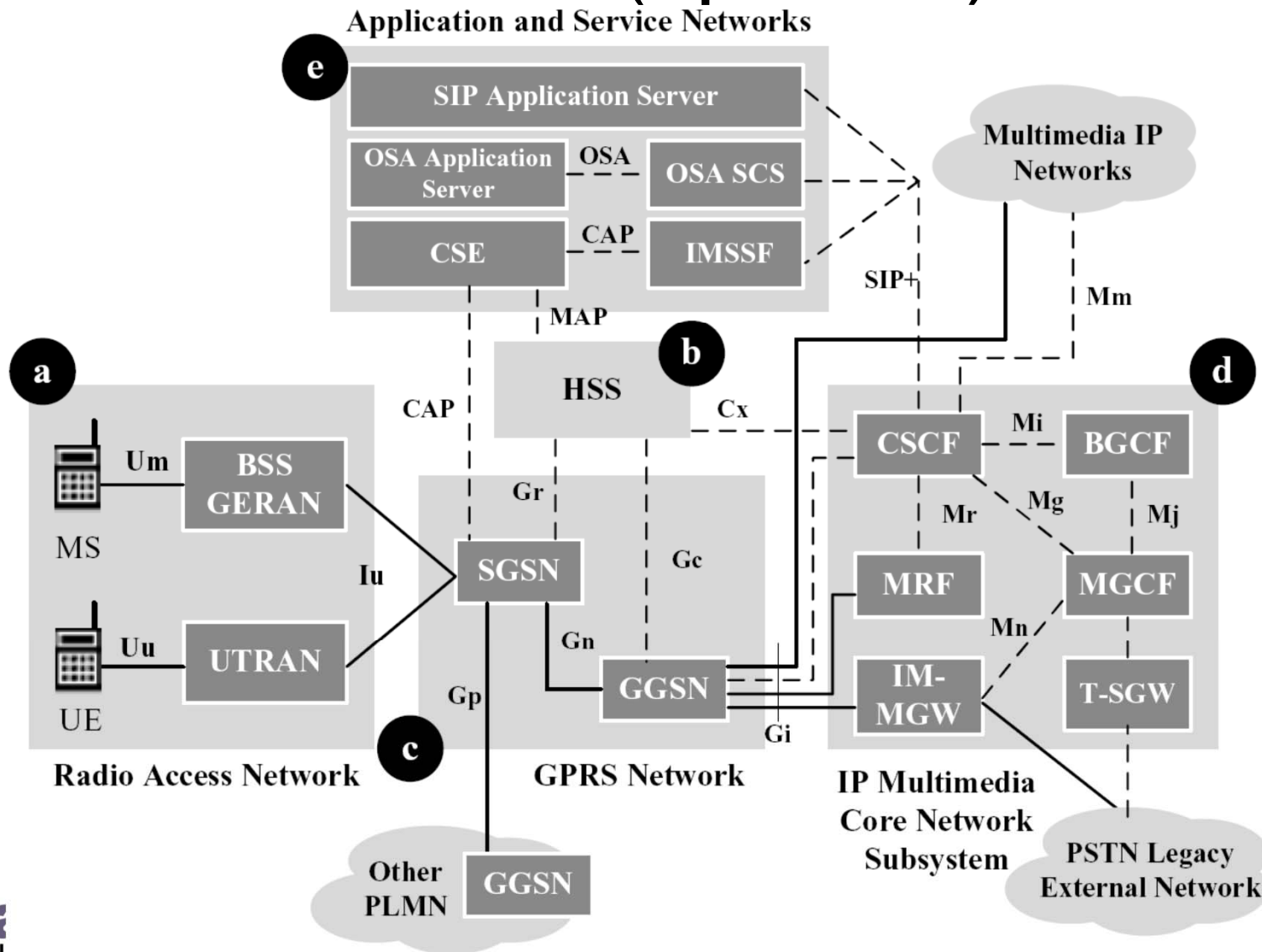


# Cont.

- **GPRS Network** (Figure 15.1 (c)) consists of Serving GPRS Support Nodes (SGSNs) and Gateway GPRS Support Nodes (GGSNs) that provide **mobility management** and **session management**.
- The GPRS network should be able to interface with a variety of RANs such as UTRAN and EDGE. The **Iu** interface between UTRAN and SGSN is IP based.
- SGSN and GGSN communicate with HSS through **Gr** and **Gc** interfaces, respectively. These two interfaces are based on Mobile Application Part (MAP). SGSN communicates with GGSN through the **Gn** interface in the same network, and through the **Gp** interface in the different networks. GGSN interacts with the external PDN through the **Gi** interface.



# Fig. 15.1 UMTS All-IP Network Architecture (option 1)



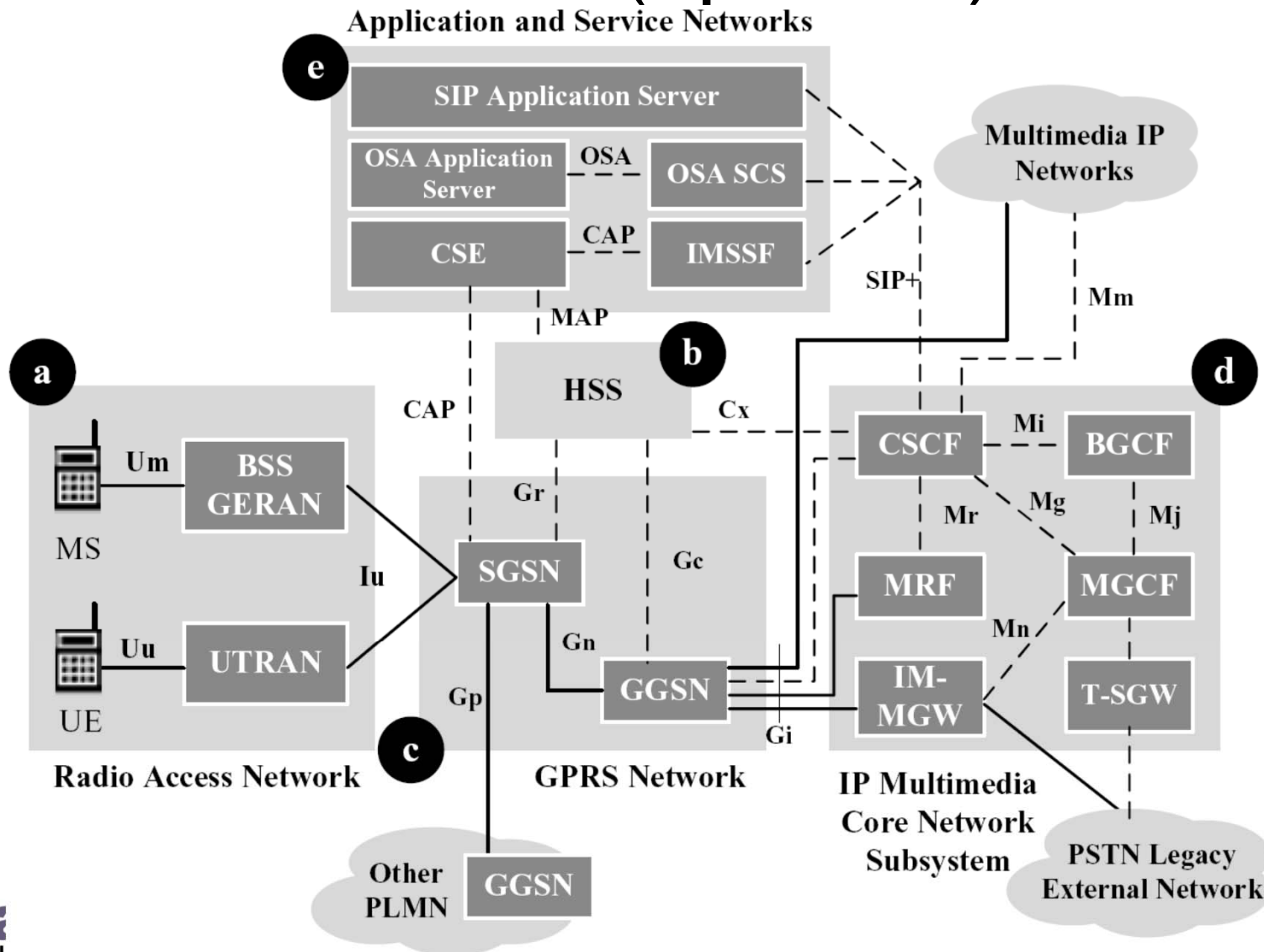
# Cont.

- **IP Multimedia (IM) Core Network (CN) Subsystem** (IMS; Figure 15.1 (d)) is located between the GGSN and the PDN (specifically, the IP networks). In this subsystem, the **Call Session Control Function (CSCF)** is a SIP server, which is responsible for call control.
- Other nodes in the IMS include Breakout Gateway Control Function (BGCF), Media Gateway Control Function (MGCF), **IM-Media Gateway Function (IM-MGW)**, and Transport Signaling Gateway Function (T-SGW).

# Cont.

- These nodes are typically used in a VoIP network [Col01, Sch99], and will be elaborated in the subsequent sections. Most interfaces among these nodes (that is, **Mc**, **Mg**, **Mh**, **Mm**, **Mr**, and **Ms**) are IP-based gateway control protocols. We will briefly describe these interfaces in Section 15.2.

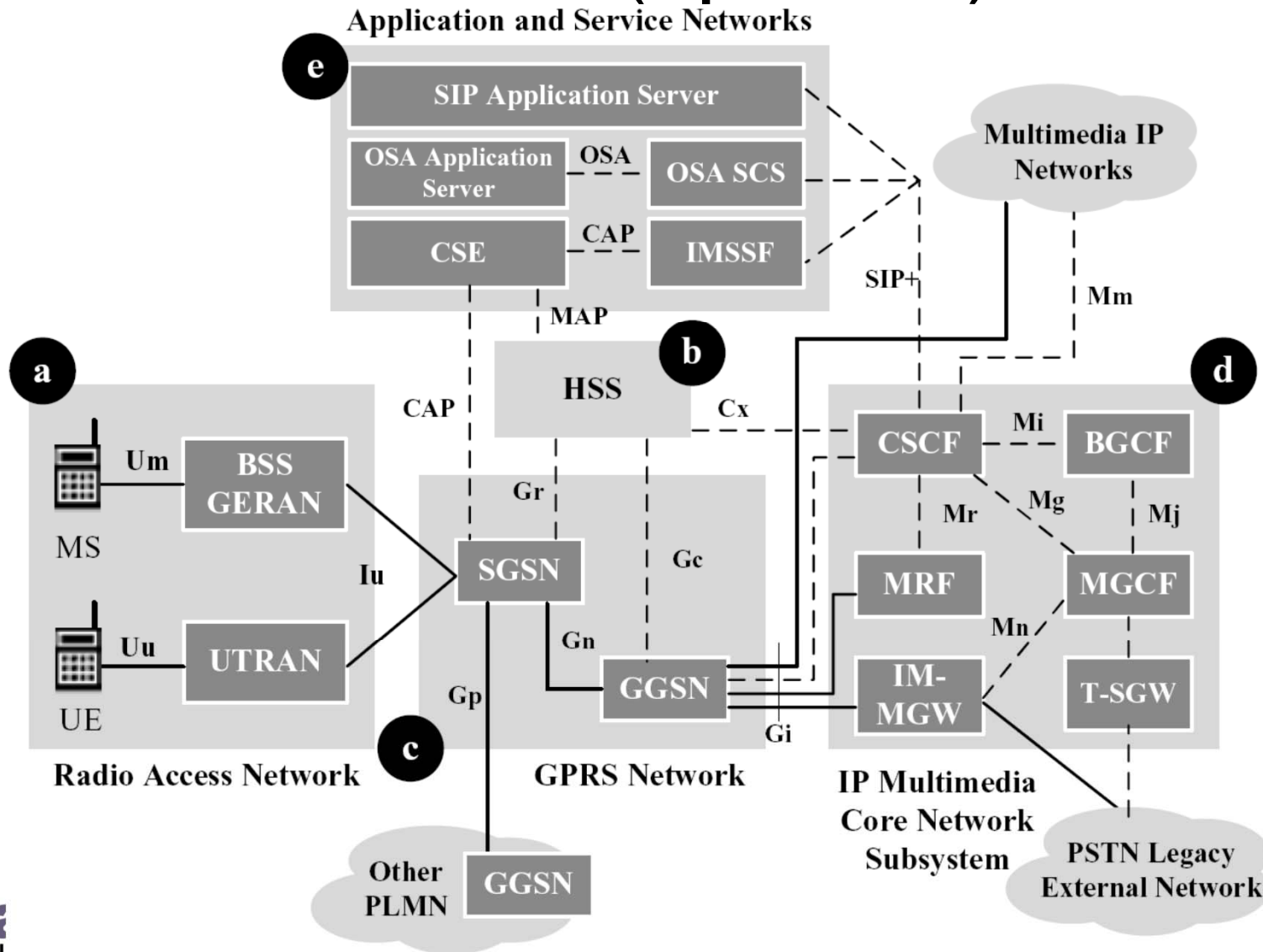
# Fig. 15.1 UMTS All-IP Network Architecture (option 1)



# Cont.

- **Application and Service Network**  
(Figure 15.1 (e)) supports flexible services through a service platform. The all-IP network architecture will provide a **separation of service control from call/connection control**, and the applications are implemented in dedicated application servers that host service-related databases or libraries.

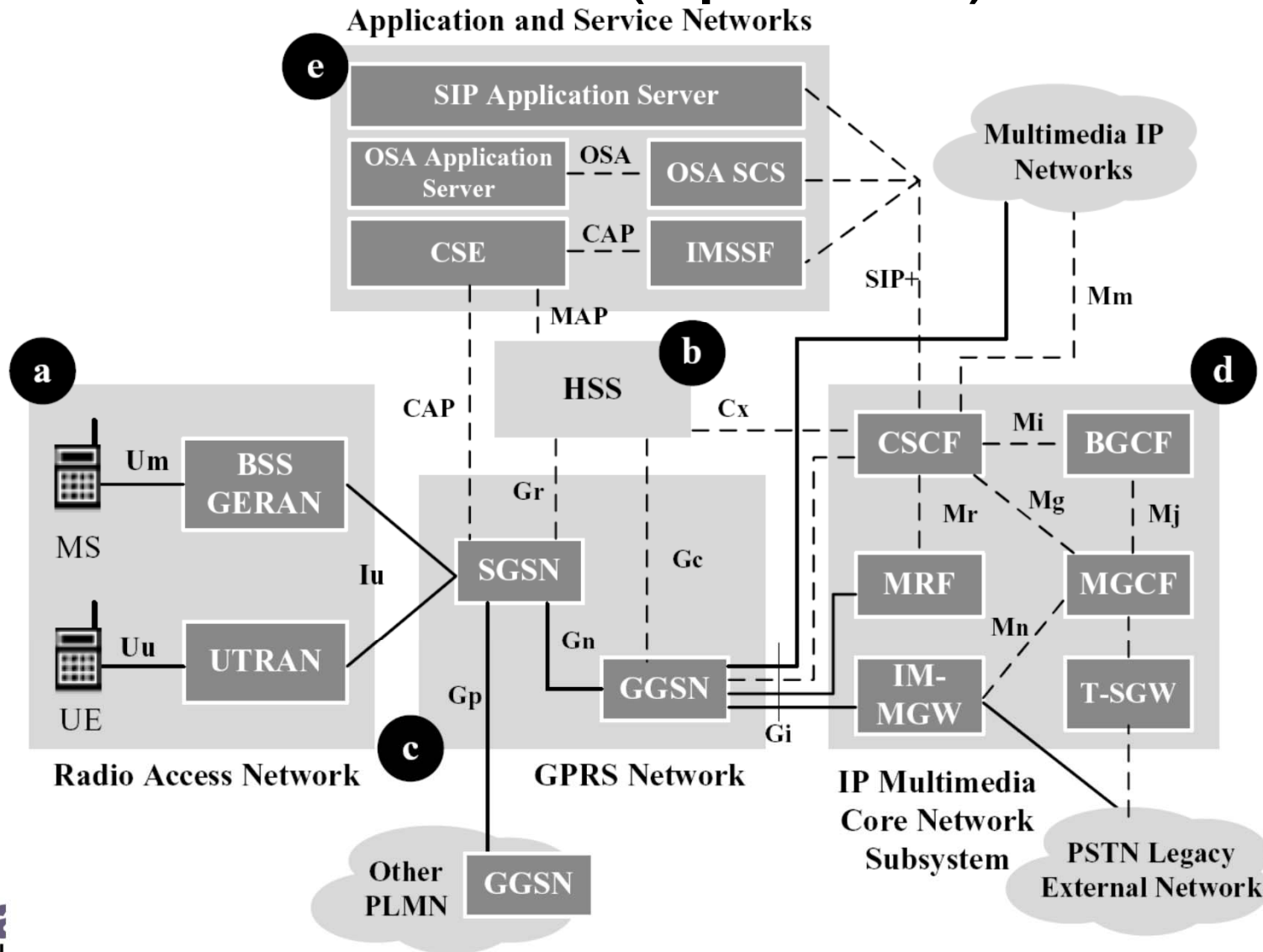
# Fig. 15.1 UMTS All-IP Network Architecture (option 1)



## 3GPP defines three possible alternatives to provide flexible and global services

- **Direct SIP+ link between CSCF and SIP Application Server:** **SIP+** is SIP with extensions for service control, to be defined later.
- This method will be used by mobile operators to provide **new multimedia SIP applications**.
- The SIP application services are either developed by the mobile operators or purchased from trusted third parties.

# Fig. 15.1 UMTS All-IP Network Architecture (option 1)





# Cont.

- **SIP+ link between CSCF and *IM-Service Switching Function (IM-SSF)*** followed by a *Customized Application Mobile Enhanced Logic (CAMEL) Application Part (CAP)* link between IM-SSF and *CAMEL Service Environment (CSE)*:
  - This method will be used by the mobile operator to provide CAMEL services (for example, prepaid service) to the IMS users.
- Note that similar CS domain services have already been provided via the CAMEL platform.

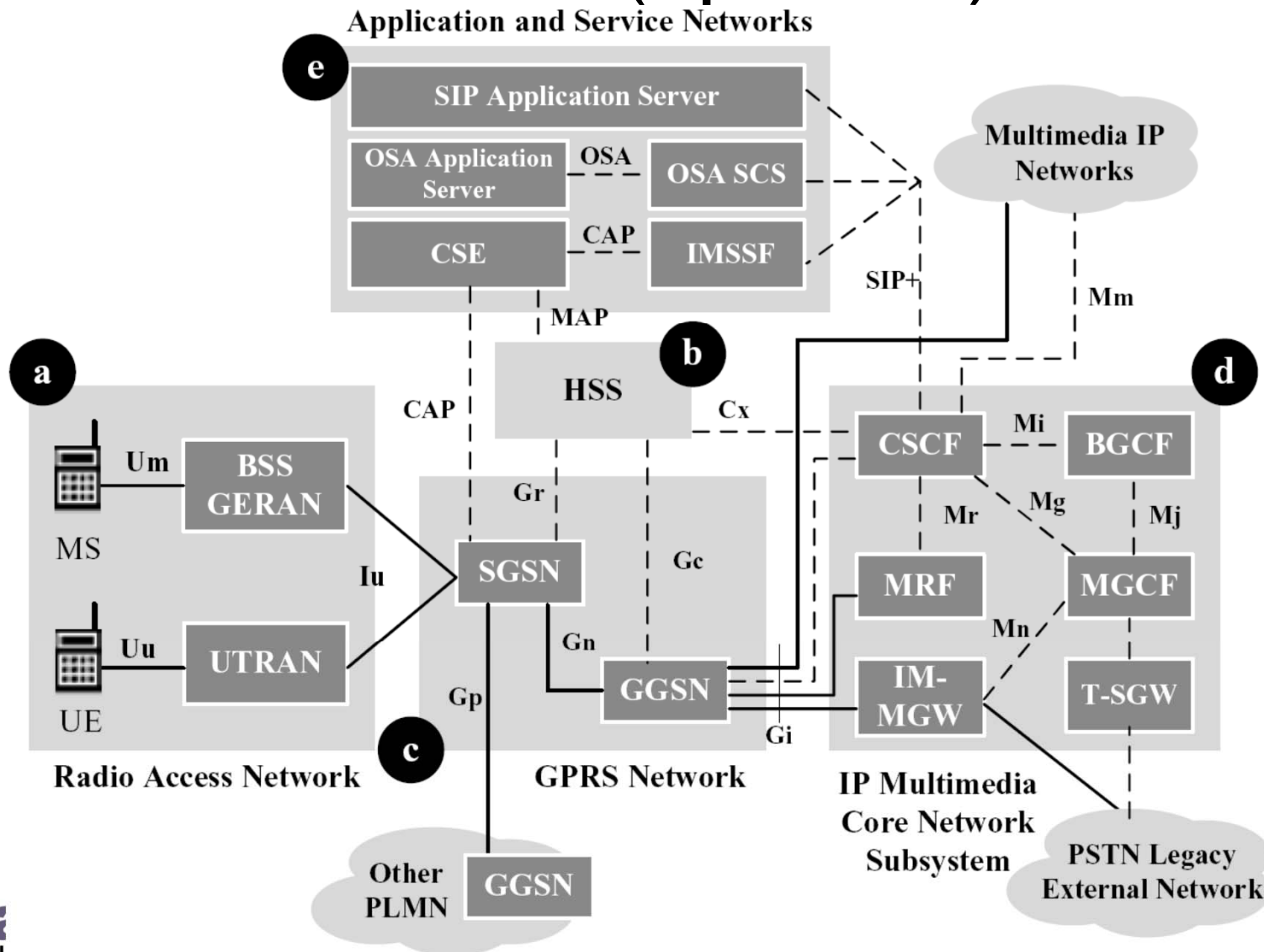
# Cont.

- **SIP+ link between CSCF and Open Service Access (OSA) Service Capability Server (SCS)** followed by an OSA link between OSA SCS and OSA Application Server:
  - This method will be used to give third parties controlled access to the operator's network, and enable third parties to run their own applications (in the third-party application servers) using the IM capabilities of the operator's network.
  - See Section 15.4 for the details of OSA.

# Cont.

- The designs of Mobile Stations (MSs) or User Equipments (UEs) are strongly influenced by the Internet and content availability.
  - For advanced mobile services and applications, content needs to scale to various display sizes of UEs and requires interoperability to ensure wide end-user acceptance. Thus, a large variety of UEs targeted at different market segments will emerge.
- **Multi-mode** and **multi-band** UEs will be the first step in the transition to 3G and B3G. This migration phase means that initial service quality may not be globally consistent [UMT00a].

# Fig. 15.1 UMTS All-IP Network Architecture (option 1)



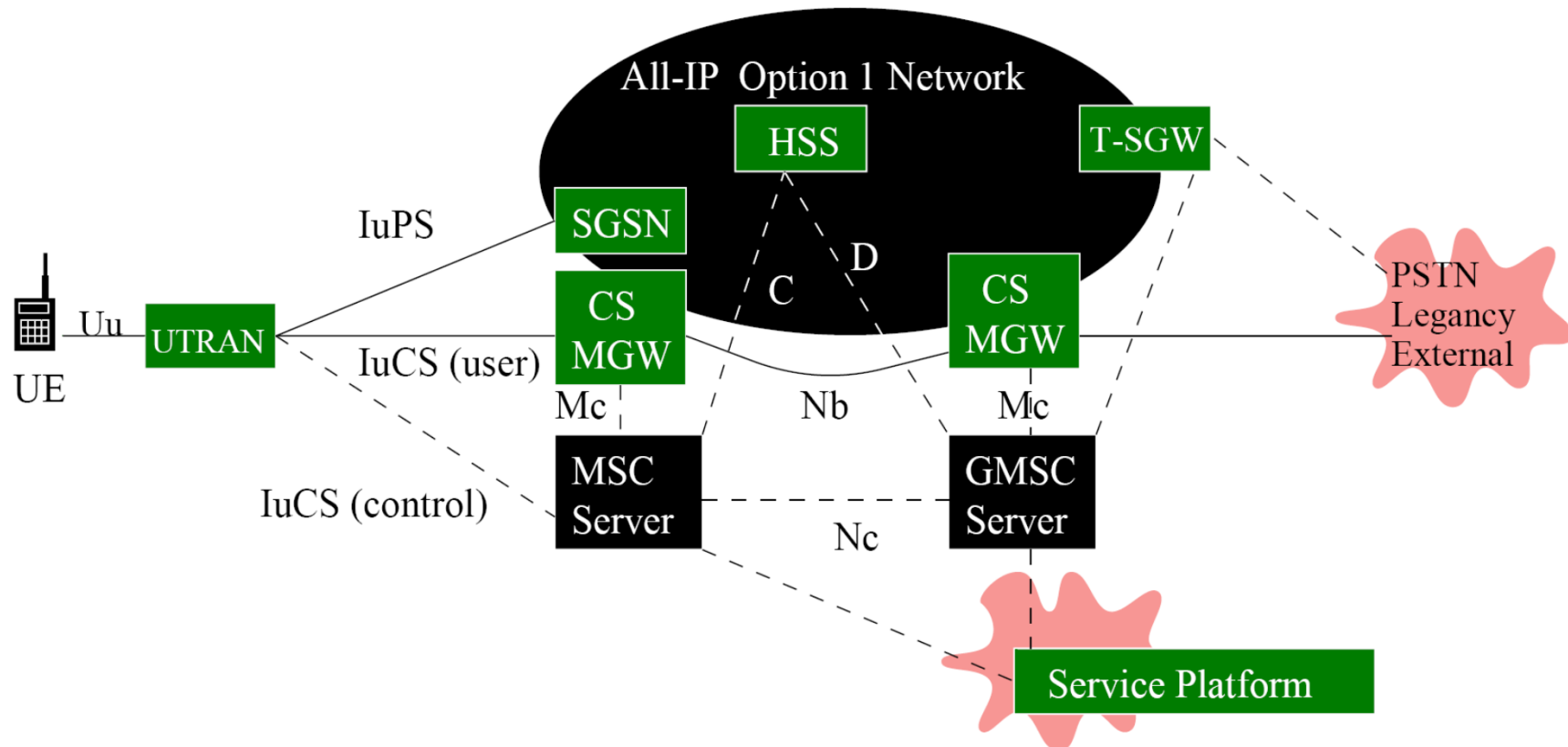
# Cont.

- In this all-IP network architecture, the GGSN is considered as the border of the network toward the public IP network.
- The GGSN and MGW together are the network border toward the Public Switched Telephone Network (PSTN) and legacy mobile networks. Note that an MGW is basically a PSTN gateway, described in Section 12.3

## 15.1.2 Option 2 for All-IP Architecture

- All-IP network **option 2** (Figure 15.2) supports R99 CS UEs, which enables the R99 CS and PS domains to evolve independently. Two control elements, the MSC server and the GMSC server, are introduced in option 2.
- The MSC servers and the HLR functionality in HSS provide an evolution of R99 telephony services. MAP is the signaling interface between HSS and the MSC server (or the Gateway MSC server).

# Fig. 15.2 UMTS All-IP Network Architecture (option 2)

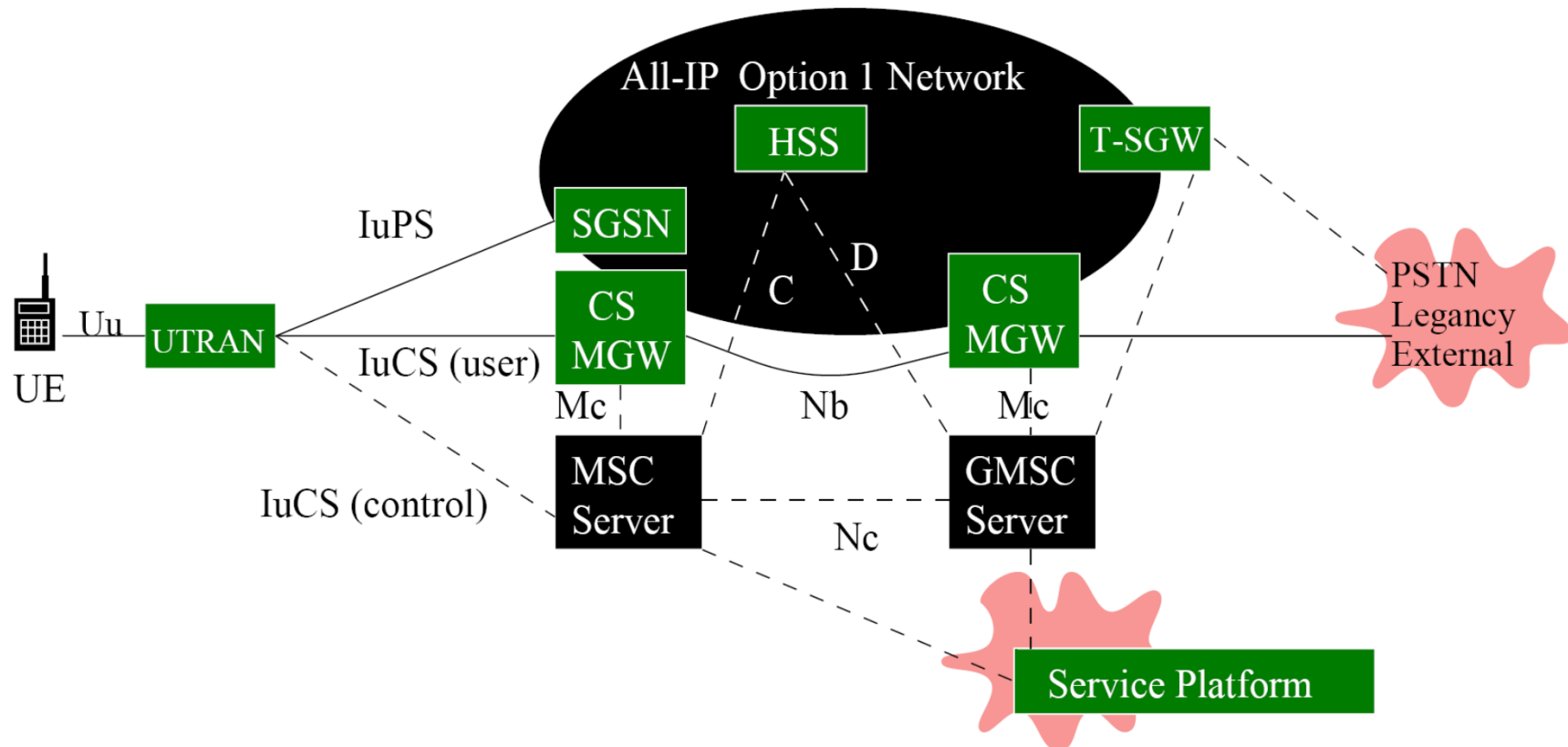


# Cont.

- The R99 Iu interface separates transport of user data from control. Evolving from this interface, option 2 UTRAN accesses the core network via a **CS MGW** (user plane) separated from the **MSC server** (control plane).
- UTRAN communicates with an MSC server using the Radio Access Network Application Part (RANAP) over the Iu interface.



# Fig. 15.2 UMTS All-IP Network Architecture (option 2)



# Cont.

- The Iu interface between the UTRAN and the CS-MGW is based on the *Iu User Plane* protocol [3GP05I]. Notice that there are one or more CS-MGWs in the option 2 network.
- If two or more CS-MGWs exist, then they communicate through the *Nb* interface.
  - In our example, there are two CS-MGWs in the all-IP option 2 architecture:
  - One is connected to PSTN and the other is connected to UTRAN via the Iu-CS interface.
  - These two CS-MGWs are responsible for voice format conversion between PS and CS networks.

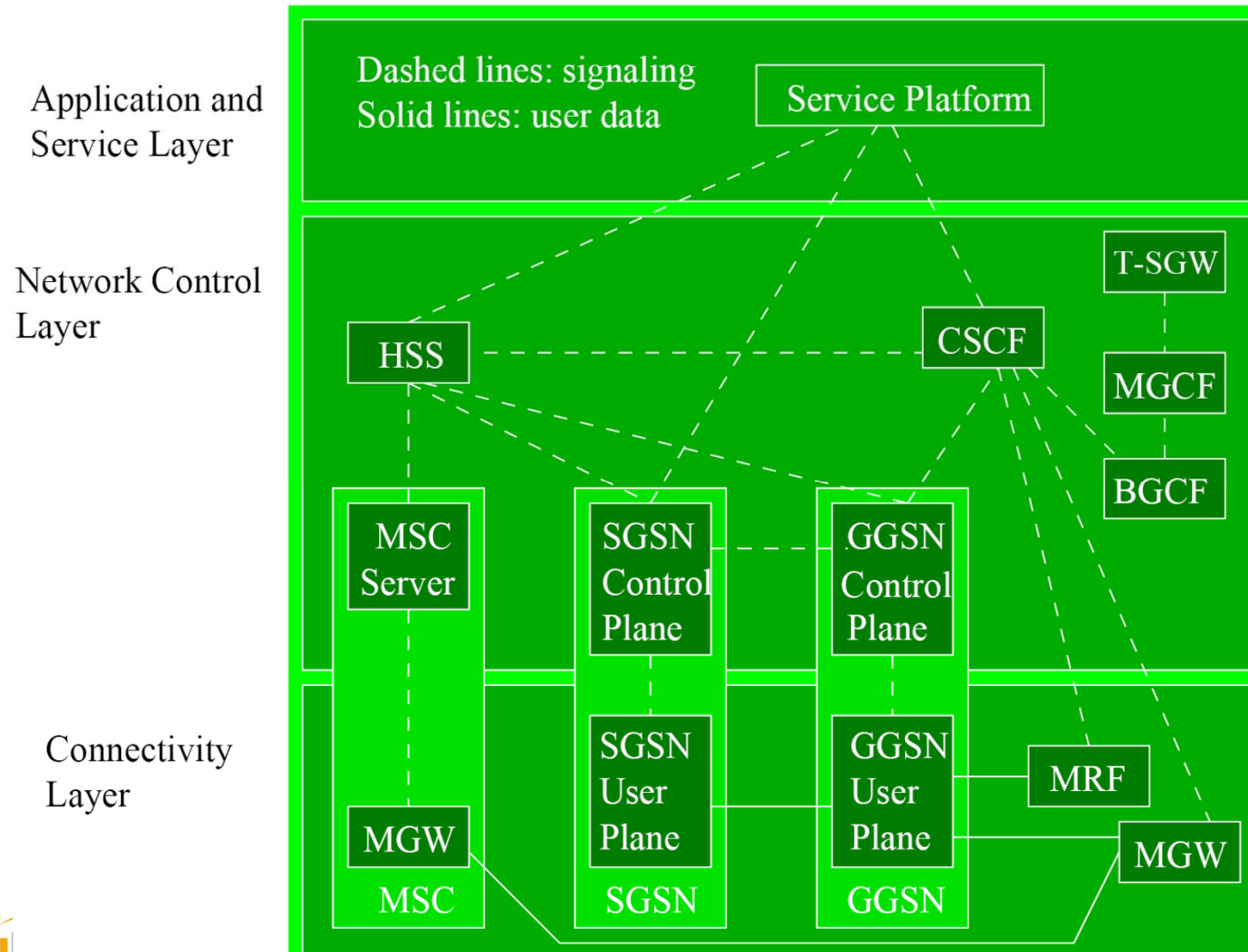
# 15.1.3 Partitioning of All-IP Architecture in Horizontal Layers

- The all-IP network architecture can also be partitioned horizontally into three layers (see Figure 15.3):
  - **Application and Service Layer** consists of service nodes and service platforms such as OSA (same as Figure 15.1 (e)):
  - **Network Control Layer** is responsible for control signaling delivery, consists of the MSC server, HSS, CSCF, BGCF, MGCF, SGSN (control plane part), GGSN (control plane part), and T-SGW. In this layer, CSCF, MGCF, the MSC server, and BGCF can serve as call agents.

# Cont.

- **Connectivity Layer** is a pure transport mechanism that is capable of transporting any type of information via voice, data, and multimedia streams. The layer includes MGW, SGSN (user plane part), GGSN (user plane part), and MRF.

# Fig. 15.3 Horizontal Structure of UMTS all-IP Network



# Cont.

- In UMTS all-IP option 1, the radio access network (e.g. UTRAN) and the GPRS network together are referred to as the *bearer network*.
- Through the *Gm* interface (which includes radio, Iu, Gn, and Gi), the bearer network provides transport for signaling (control plane) and data (user plane) exchange between the UE and the CSCF/gateways.
- Signaling between the bearer network and the PSTN is interworked through CSCF, BGCF, MGCF, and T-SGW.

# Cont.

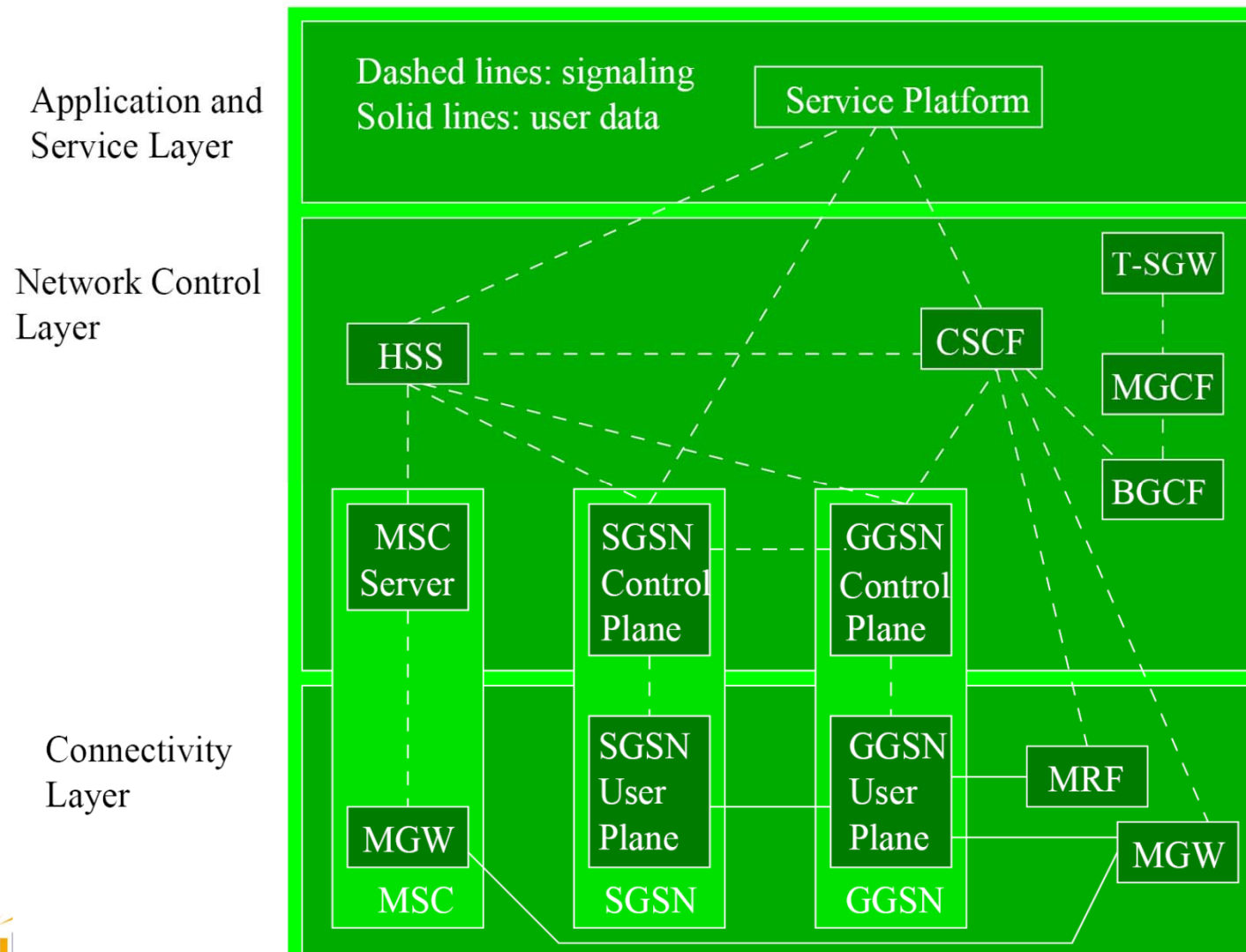
- The user plane bearer is connected to the PSTN via an MGW. The bearer network nodes (RAN, SGSN, and GGSN) are not aware of the multimedia signaling between the UE and the CSCF.
- However, the RAN may optimize radio transmission by supporting specific Radio Access Bearers (RABs) for individual flows of the multimedia user plane.
- These RABs are requested by the UE at Packet Data Protocol (PDP) context activation.

## 15.2 All-IP Core Network Nodes

- This section describes the nodes in the network control layer and the connectivity layer. Among these network nodes, the GGSNs and the SGSNs are basically the same as that in UMTS R99. In all-IP network option 2, an MSC server controls CS services, and an SGSN controls PS bearer services.
- In the connectivity layer, the MGW uses open interfaces to connect different types of nodes.
- Like the MSC structure in Figure 15.3, the SGSN control plane handles control layer functions for PS domain communication.
- The media gateway provides user plane data transmission in the connectivity layer.



# Fig. 15.3 Horizontal Structure of UMTS all-IP Network



## 15.2.1 Call Session Control Function

- *Call Session Control Function (CSCF)* communicates with HSS for location information exchange, and handles control-layer functions related to application-level registration and SIP-based multimedia sessions.
- Through the *Mm* interface, the CSCF processes call requests from other VoIP call control servers or terminals in multimedia IP networks. The CSCF consists of the following logical components:

# Cont.

- **Incoming Call Gateway (ICGW)**  
communicates with HSS to perform routing of incoming calls (see, for example, Step 4 in Section 15.3.4). ICGW may trigger incoming call service (for call screening or call forwarding), and query address handling through the Address Handling component.

# Cont.

- **Call Control Function (CCF)** is responsible for call setup and call-event reports for billing and auditing. It receives and processes application level registration (see Step 2 in Section 15.3.1), provides a service trigger mechanism (service capabilities features; see Step 4 in Section 15.3.3 or Step 5 in Section 15.3.4) toward application and service networks, and may invoke location-based services related to the serving network.
- It also checks whether the requested outgoing communication is allowed given the current subscription (see Step 4 in Section 15.3.3). The CCF interacts with the MRF through the *Mr* interface to support multi-party and other services (for example, tones and announcements).

# Cont.

- **Serving Profile Database (SPD)** interacts with HSS in the home network to receive profile information (see Step 7 in Section 15.3.1) for the all-IP network and may store them depending on the *Service Level Agreement (SLA)* with the home network. SPD notifies the home network of the initial user's access (includes, for example, the CSCF signaling transport address; see Step 6 in Section 15.3.1).

# Cont.

- **Address Handling (AH)** analyzes and translates (and may modify) addresses (see Step 5 in Section 15.3.3). It supports address portability and alias address mapping (for example, mapping between E.164 number and transport address). It may perform temporary address handling for inter-network routing.

# Cont.

- A CSCF can be interrogating, proxy, or serving.
- The *interrogating CSCF* (I-CSCF) determines how to route mobile terminated calls to the destination UEs. That is, I-CSCF is the contact point for the home network of the destination UE, which may be used to hide the configuration, capacity, and topology of the home network from the outside world.
- When a UE attaches to the network and performs PDP context activation, a *proxy CSCF* (P-CSCF) is assigned to the UE.

# Cont.

- The P-CSCF contains limited CSCF functions (that is, address translation) to forward the request to the I-CSCF at the home network.
  - Authorization for bearer resources in a network is performed by a P-CSCF within that network (see Step 7 in Section 15.3.3).
- By exercising the application-level registration described in Section 15.3.1, *a serving CSCF* (S-CSCF) is assigned to serve the UE.
  - Through the Gm interface, this S-CSCF supports the signaling interactions with the UE for call setup and supplementary services control (for example, service request and authentication).



# Cont.

- The S-CSCF provides SPD and AH functionalities to the UE. Details of proxy, interrogating, and serving CSCFs will be elaborated in Section 15.3.

## 15.2.2 Home Subscriber Server

- *Home Subscriber Server (HSS)* keeps a master list of features and services (*user profile* information; for example, user identities, subscribed services, numbering, and addressing information) associated with a user, and maintains the location of the user.
- The HSS provides the HLR functionality required by the PS and CS domains, and the IM functionality required by the IMS to support the network entities (for example, SGSN, GGSN, MSC server, and CSCF) actually handling calls. In other words, the HSS serves as terminations of the following functionalities:

# Cont.

- **MAP Termination.** The HSS enhances HLR to support the all-IP network. It stores mobility management information, and inter-system location information. Like the R99 HLR, the HSS communicates with the SGSN/GGSN in the PS domain and the GMSC server/MSC server in the CS domain through Gr/Gc and C/D, respectively. Unlike the R99 HLR, both interfaces for HSS are MAP transported over IP.

# Cont.

- **Addressing Protocol Termination.** The HSS provides logical-name to transport-address translation for answering Domain Name Server (DNS) queries (see Step 4 in Section 15.3.4).

# Cont.

- **Authentication and Authorization Protocol Termination.** The HSS may also generate, store, and manage security data and policies used in the IMS. CSCF-UE security parameters are sent from the HSS to the CSCF, which allows the CSCF and the UE to communicate in a trusted and secure way. The HSS stores the all-IP network service profiles

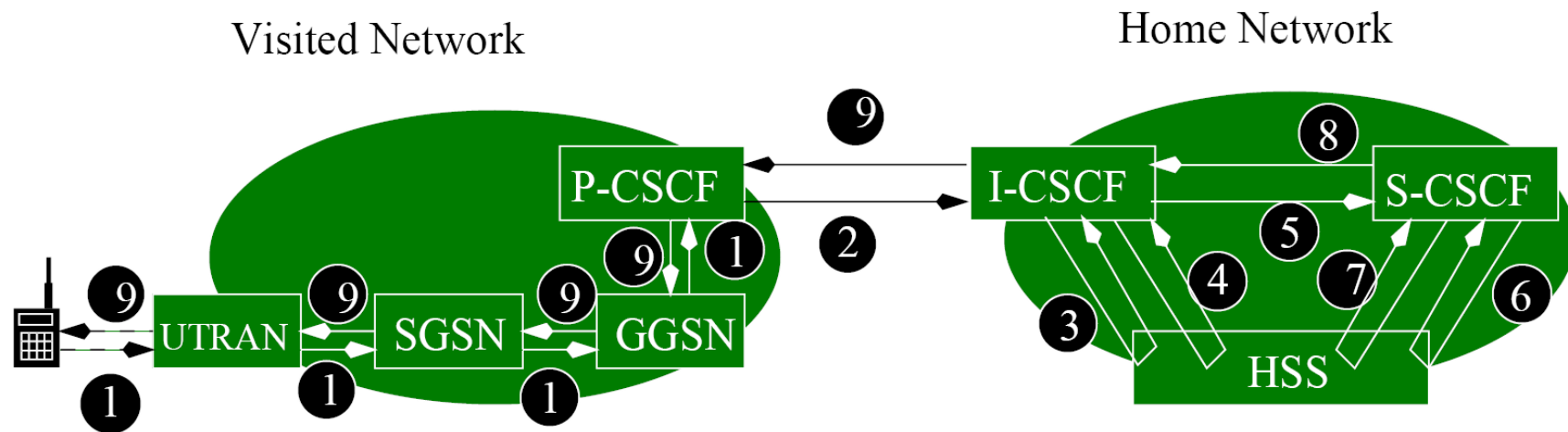
# Cont.

- and service mobility or S-CSCF-related information for the UEs. The HSS also provides the S-CSCF with the service parameters of UEs
  - (for example, supplementary service parameters, application server address, triggers, and so on; see Step 7 in Section 15.3.1). The HSS communicates with the CSCF using Cx that can be implemented based on the Diameter [3GP05a].

## 15.3.1 Application-Level Registration

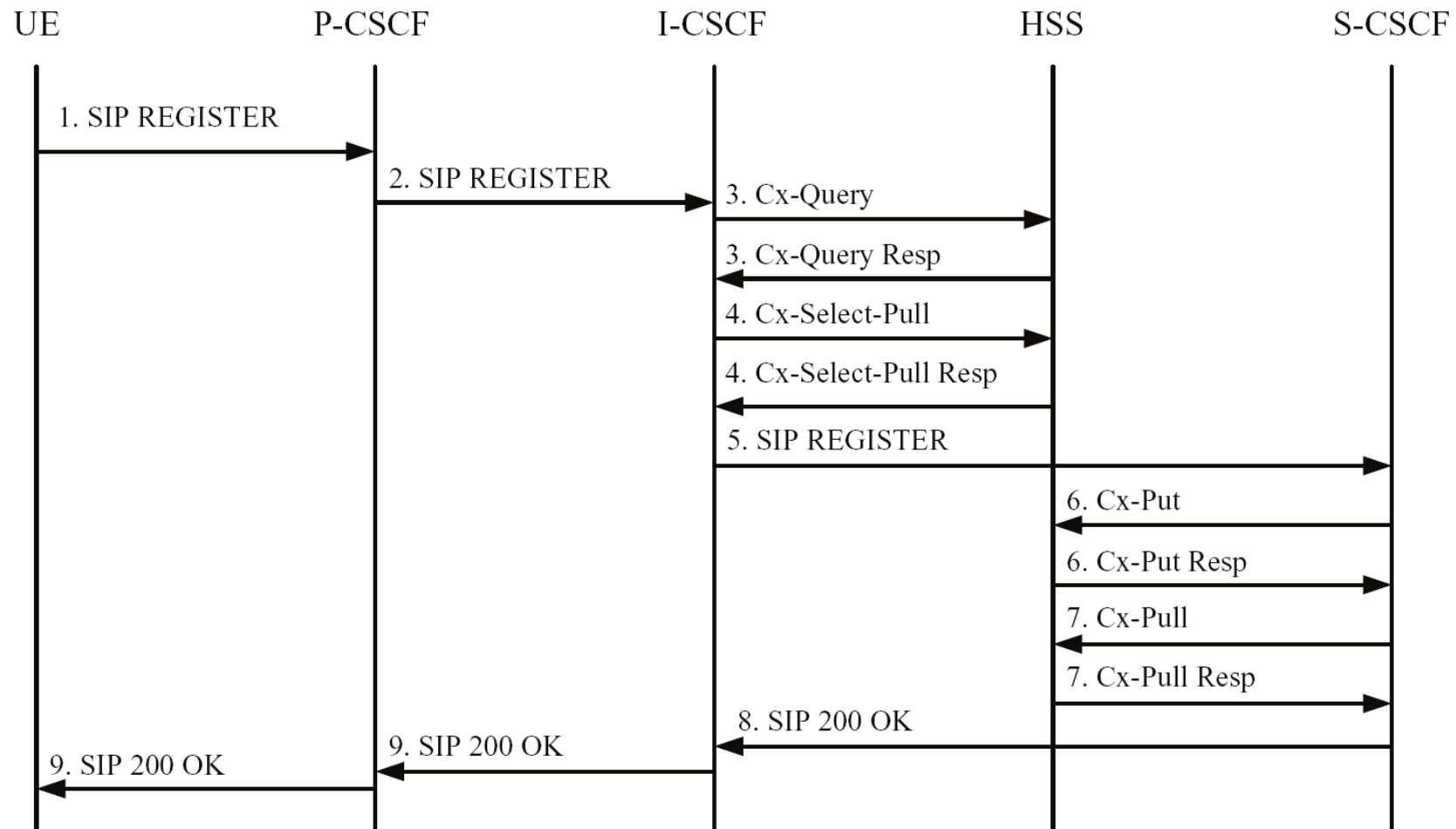
- **Step 1.** The UE sends the SIP REGISTER message to the P-CSCF through UTRAN, SGSN, and GGSN. The request includes the *home domain name* of the UE. In SIP, REGISTER is issued by a client (UE in our example) to the server (UMTS network) with an address at which the client can be reached for a SIP session.

# Fig. 15.4 Application Level Registration





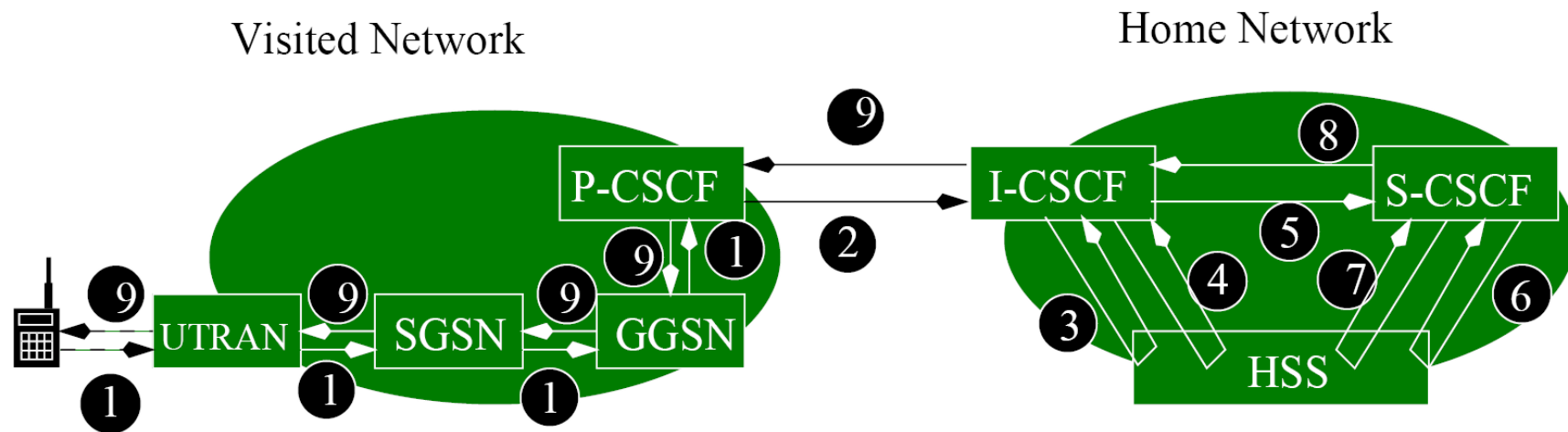
# Fig. 15.5 Message Flow for Application-Level Registration



- **Step 2.** Based on the home domain name, the P-CSCF performs address translation (through a DNS-based mechanism) to find the I-CSCF address. Then it proxies the REGISTER message to the I-CSCF at the home network. Note that there may be multiple I-CSCFs within an operator's network.

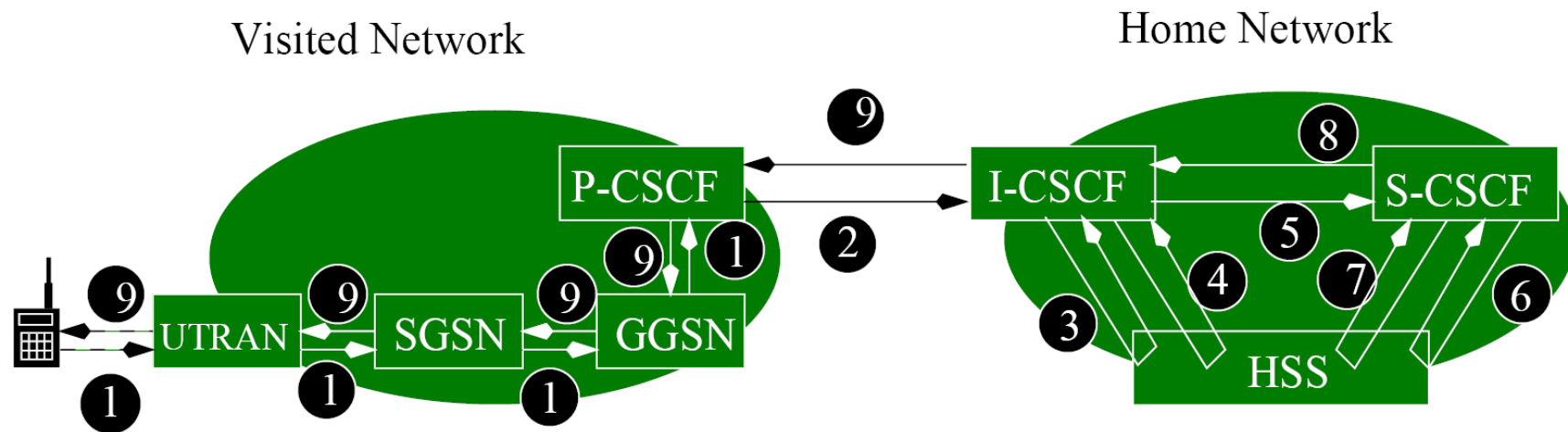
- **Step 3.** Based on the subscriber identity received from the P-CSCF and the home domain name, the I-CSCF determines the HSS address. Note that if there are two or more HSSs in the home network, the I-CSCF needs to query the *subscription location function* to find the HSS address.
  - The I-CSCF sends the Cx-Query message to the HSS. The HSS checks if the subscriber has been registered. Then it returns the Cx-Que Resp message to the I-CSCF. By the end of this step, the user has been authenticated.

# Fig. 15.4 Application Level Registration



- **Step 4.** The I-CSCF sends the Cx-Select-Pull message to the HSS to obtain the required S-CSCF capability information (supported service set and protocol version number). Based on the service network indication and subscriber identity provided by the I-CSCF, the location service of the HSS returns the information of the required S-CSCF capabilities through the Cx-Select-Pull-Resp message.
  - Based on the information provided by the HSS, the I-CSCF selects the name of an appropriate S-CSCF. This S-CSCF must be in the home network.

# Fig. 15.4 Application Level Registration

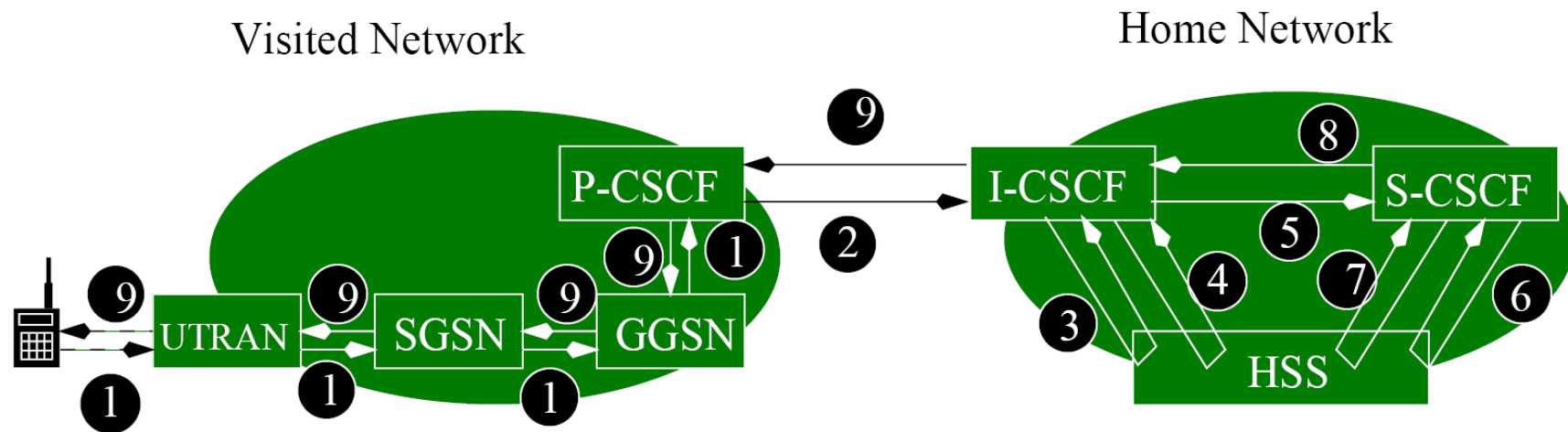


- **Step 5.** The I-CSCF sends the REGISTER request to the S-CSCF. The request includes the HSS name as a parameter.
- **Step 6.** Using Cx-Put, the S-CSCF sends its name and subscriber identity to the HSS, which will be used by the HSS to route mobile terminated calls to the S-CSCF. The HSS acknowledges with the Cx-Put Resp message.

- **Step 7.** The S-CSCF obtains the subscriber data from the HSS through the Cx-Pull and Cx-Pull-Resp message exchange. The subscriber data is stored in the S-CSCF, and includes supplementary service parameters, the application server address, triggers, and so on.

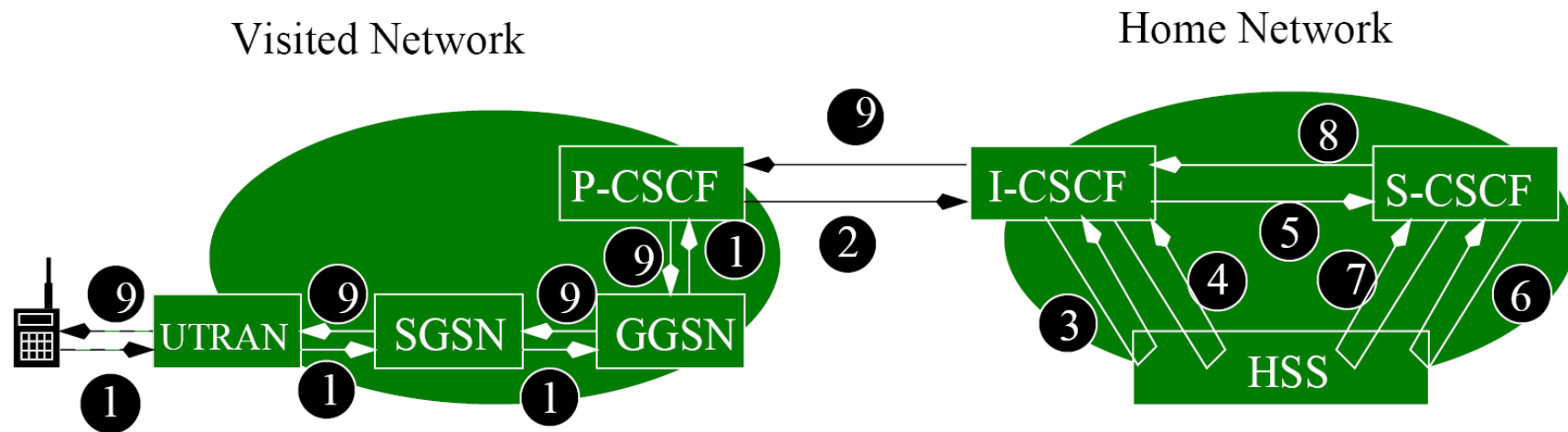


# Fig. 15.4 Application Level Registration



- **Step 8.** The S-CSCF determines if the home contact name is the S-CSCF name or the I-CSCF name. If the contact name is for the S-CSCF, then the P-CSCF can access the S-CSCF directly, and the internal configuration of the home network is known to the outside world. If the contact name is for the I-CSCF, then the P-CSCF can only access the S-CSCF indirectly through the I-CSCF. In this case, the home network configuration is hidden.
- The S-CSCF sends its address and the home contact name to the I-CSCF through the SIP 200 OK response message.

# Fig. 15.4 Application Level Registration

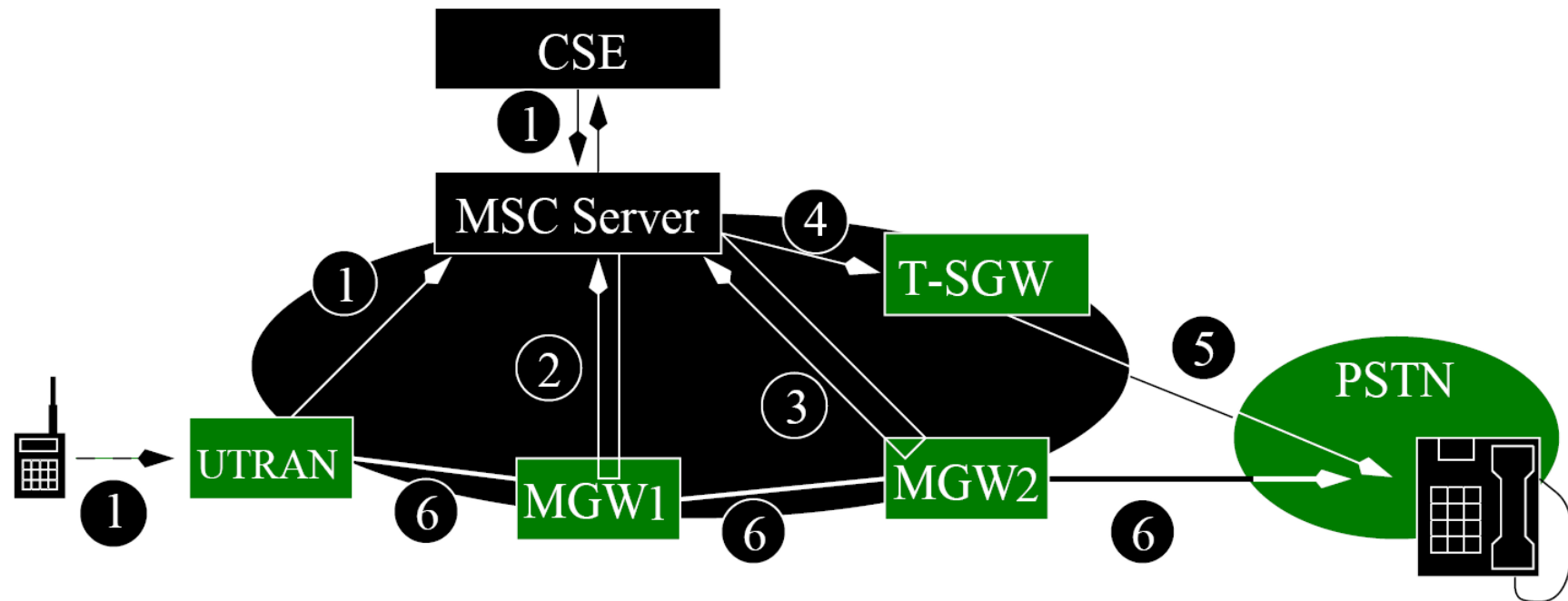


- **Step 9.** With the 200 OK message, the I-CSCF returns the home contact name (either the I-CSCF or the S-CSCF address) to the P-CSCF. The P-CSCF stores the home contact name, and forwards the 200 OK message to the UE, indicating that registration is successful.

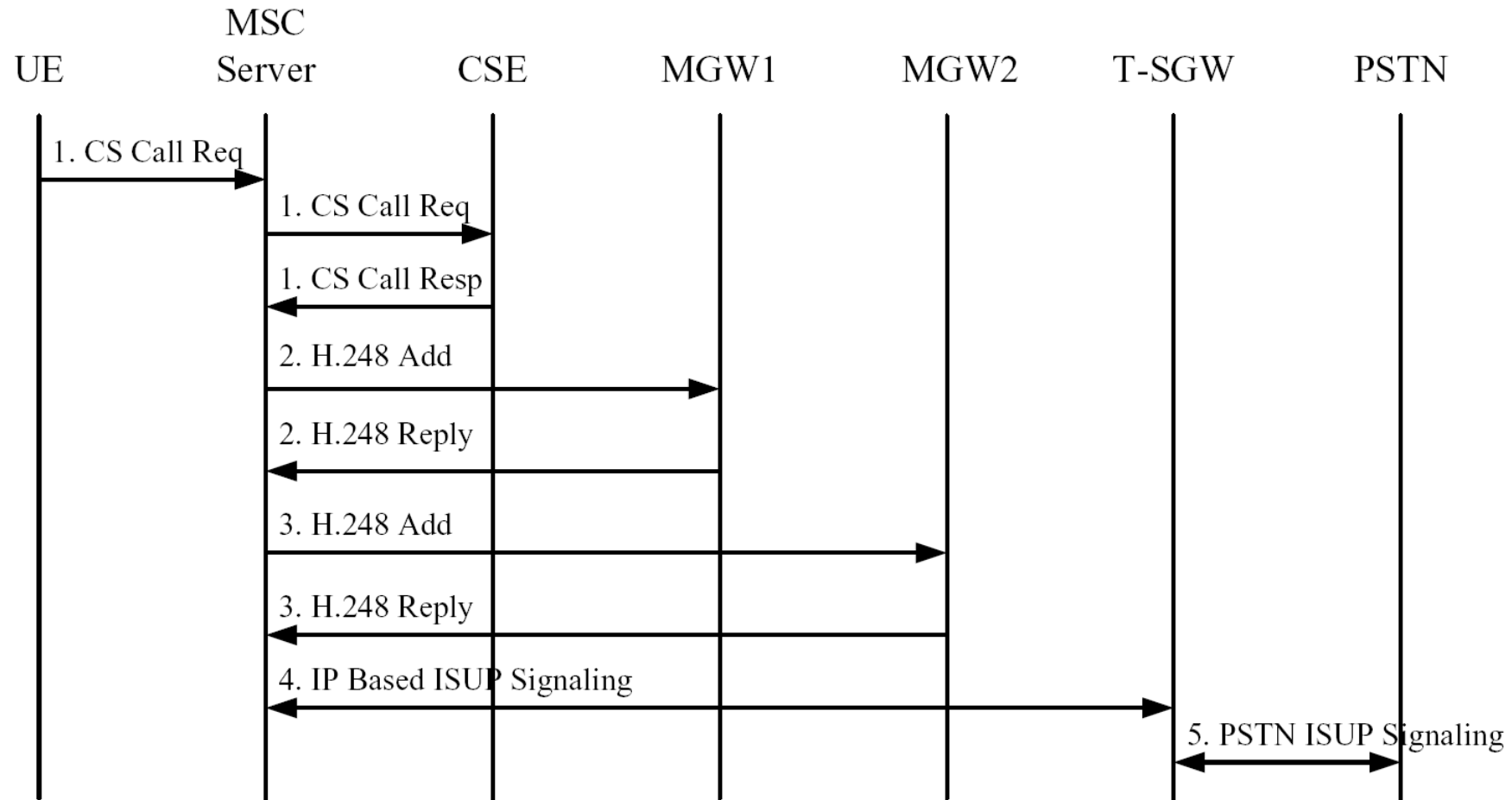
## 15.3.2 CS Mobile Call Origination

- CS mobile call origination is similar to that in UMTS R99. This procedure does not involve the CSCFs and the HSS. Before CS call origination, the UE has already attached to the UMTS CS domain, and has registered to the VLR of an MSC server. CS call origination is described in the following steps (see Figures 15.6 and 15.7):

# Fig. 15.6 CS Call Origination



# Fig. 15.7 Message Flow for CS Call Origination

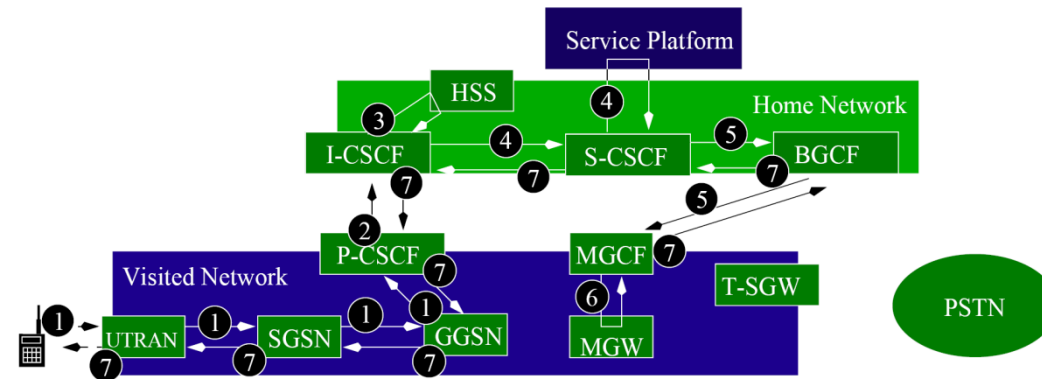


## 15.3.3 PS Mobile Call Origination

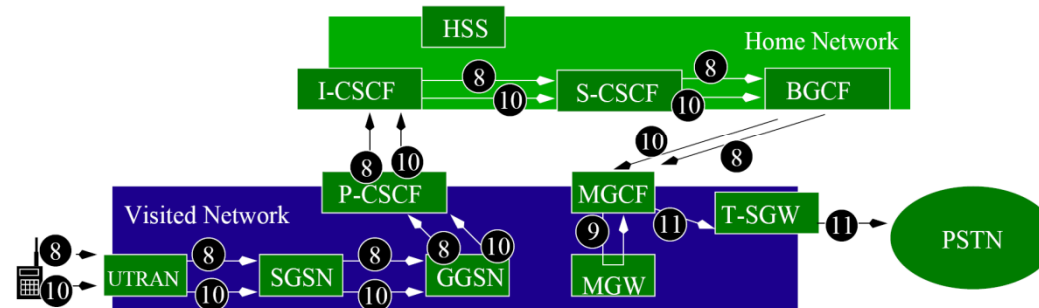
- Before PS call origination, the UE has already attached to the UMTS PS domain, and application-level registration is performed so that an S-CSCF is assigned to the UE (i.e., the user profile has been fetched from the HSS and stored in the S-CSCF). Assume that the UE is in a visited network.
- The PS mobile call origination to the PSTN is described as follows (see Figures 15.8 and 15.9):



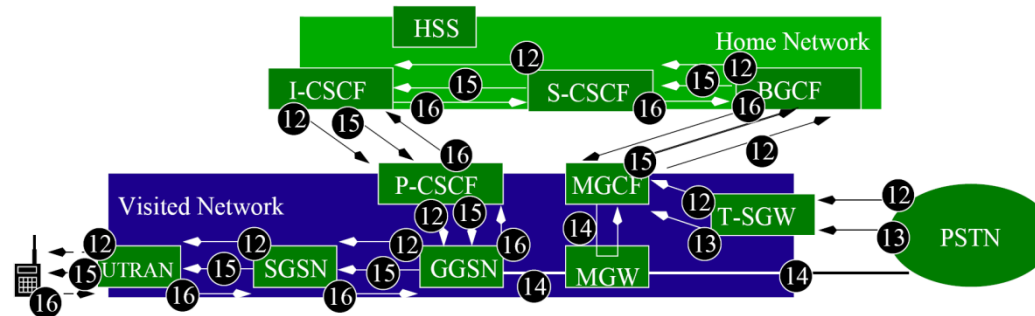
# Fig. 15.8 PS Call Origination



(a) Steps 1-7

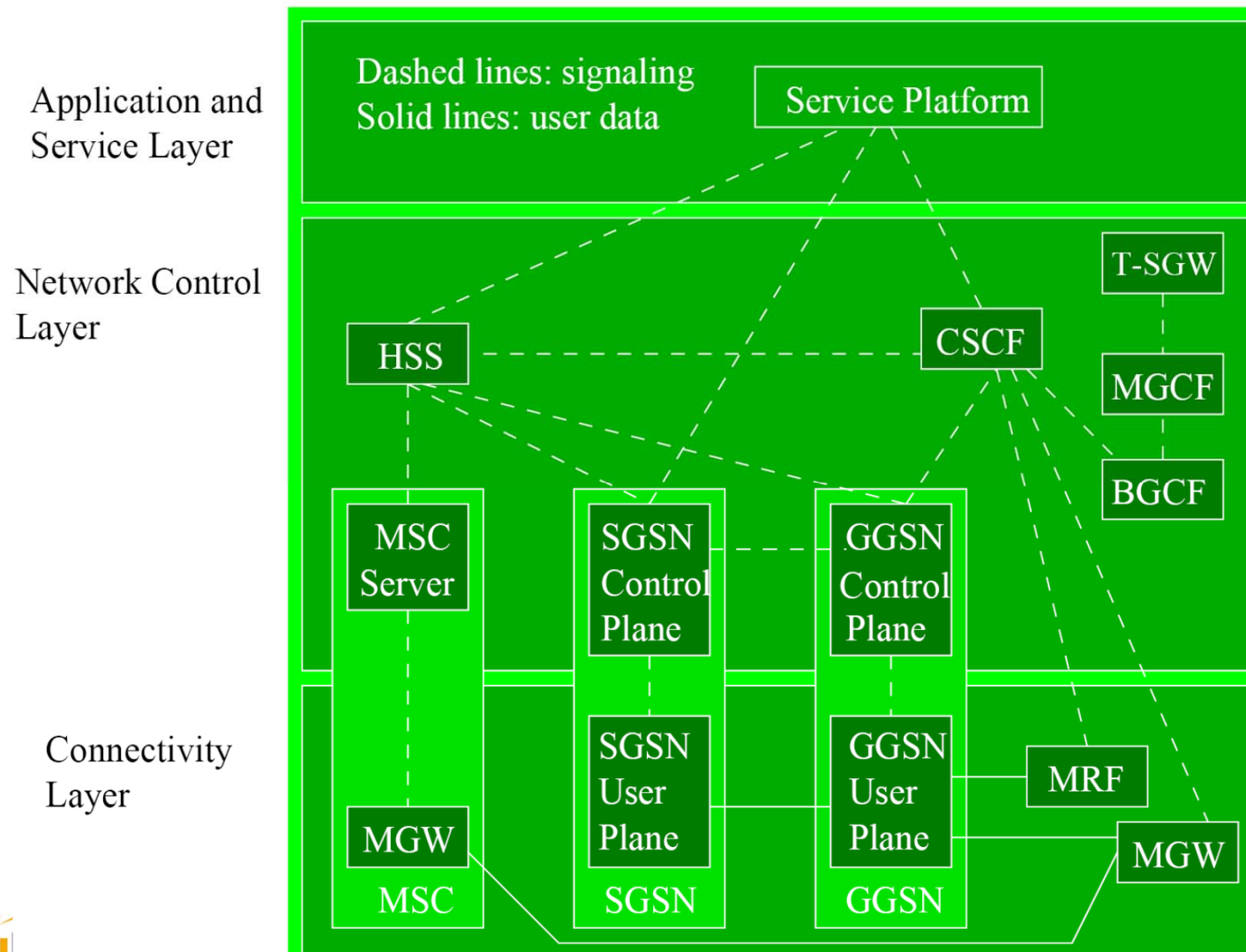


(b) Steps 8-11

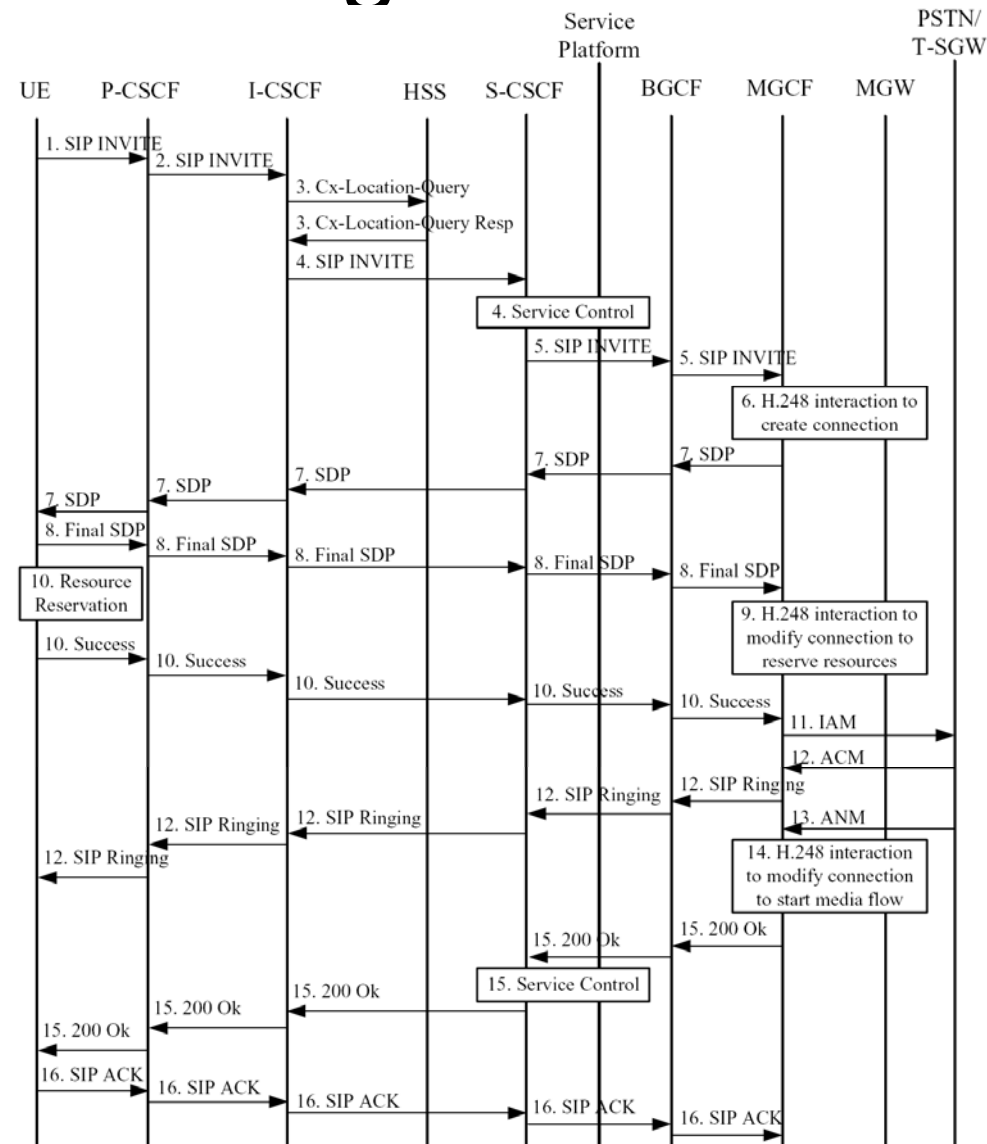


(c) Steps 12-16

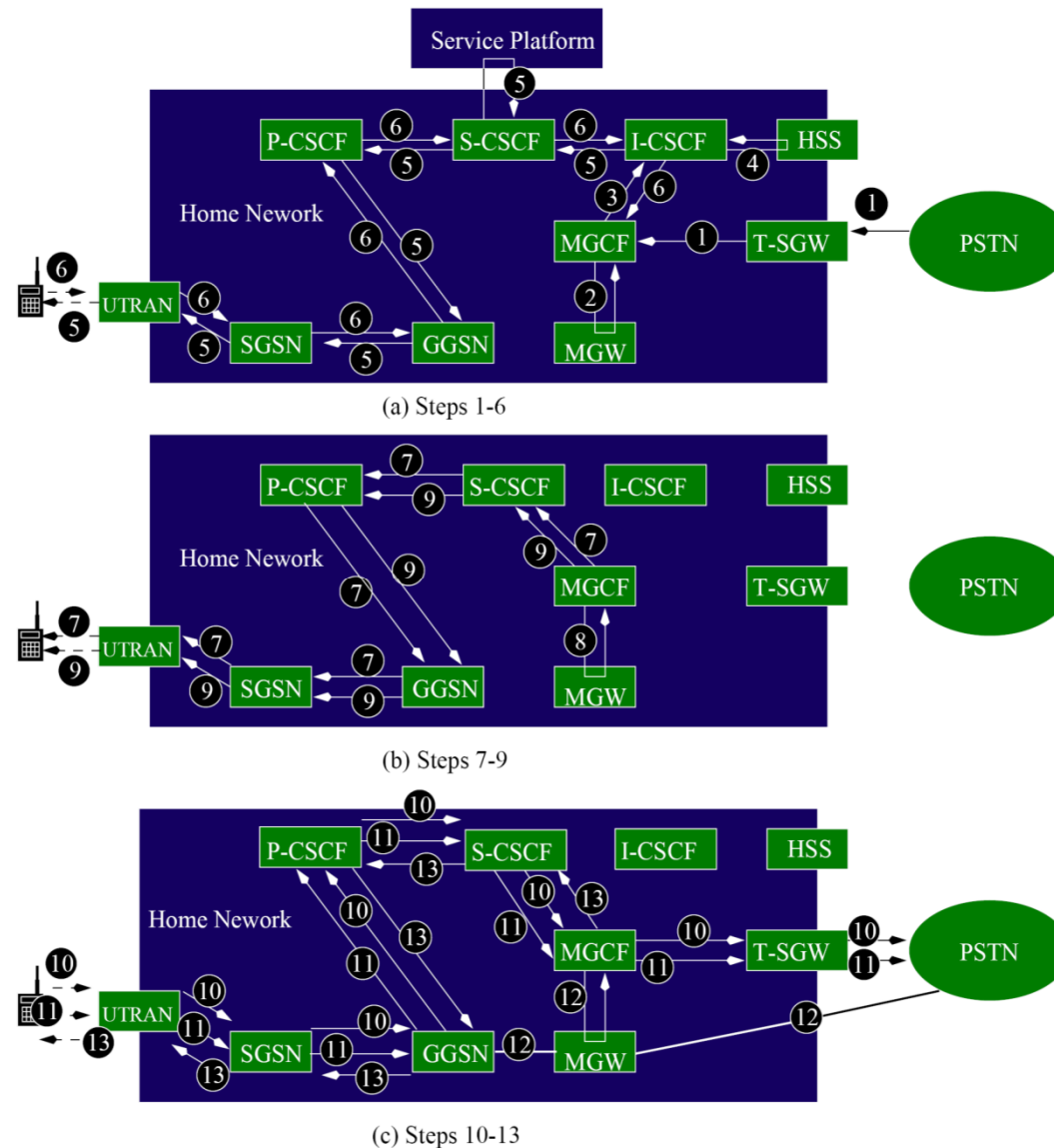
# Fig. 15.3 Horizontal Structure of UMTS all-IP Network



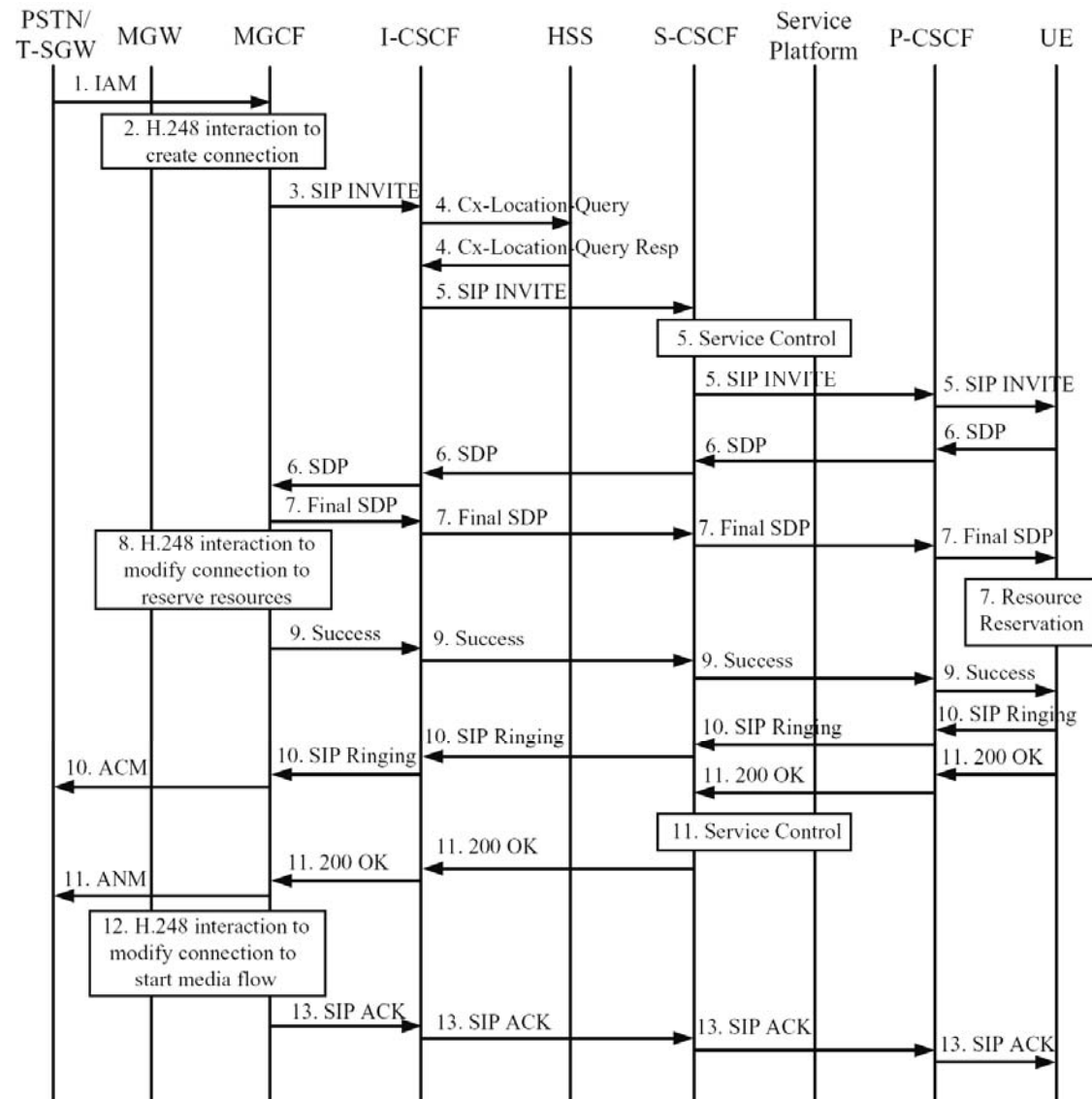
# Fig. 15.9 Message Flow for PS Call Origination



# Fig. 15.10 PS Call Termination



# Fig. 15.11 Message Flow for PS Call Termination



# Fig. 15.12 OSA Architecture

