# IP Multimedia Subsystem : Principles and Architecture

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## 1 Introduction

Many successful services are available today on the Internet, including e-mail, web browsing, chat, and audio and video downloading/streaming. Internet telephony and Multimedia Communications Services, some of the latest to be launched, are already being proposed by Microsoft MSN, AOL and Skype.
As telephony is simply another Internet application, any company, even if it is not an access provider, can provide a telephony service. The above actors are already active in this market, but are all proposing proprietary Internet telephony solutions.
In this context, the operators which telephony service was their core business, are facing the following alternatives :

1. Reposition their business towards value-added IP services including telephony, becoming global service providers. In this case, they will have to rapidly push IMS before proprietary solutions become largely adopted. IMS is the only standardized solution in the telecommunications world.
2. Abandon the market of value added services including telephony and reduce their business to that of a commodity access provider or IP packet transporter. The difficulties will be to maintain revenues in a context where the access and transport will become a commodity business under strong price pressure and of little interest to users.

IMS – IP Multimedia Subsystem standardized by the telecommunications world is a new architecture based on new concepts, new technologies, new partners and ecosystem. IMS provides real-time multimedia sessions (voice session, video session , conference session, etc) and non real-time multimedia sessions (Push to talk, Presence, instant messaging) over an all-IP network. IMS targets convergence of services supplied indifferently by different types of networks : fixed, mobile, Internet. IMS is also called Multimedia NGN (Next Generation Network).
IMS deployment is a strategic decision, not a network technology decision. It can be taken either by a traditional service provider in the context of repositioning its business on IP services or by any entity that would decide to start an activity in IP services even without owning an access or transport network.

Acquisition of the basics of IMS architecture and standards, in particular specification of specific protocols and interfaces such as SIP, Diameter, COPS, and the knowledge of the vendors solutions already available are essential for any stakeholder – network or service provider, telecommunications vendor, or customer that wants to be an actor in the emerging business of value added IP services.

This white paper presents the IMS Network and Service Architectures with the underlying concepts, involved entities and their functionalities.

# 2 IMS Architecture

The IMS (IP Multimedia Subsystem) vision is to integrate mobile/fixed voice communications and Internet technologies, bringing the power and wealth of internet services to mobile and fixed users. It allows the creation and deployment of IP-based multimedia services in the 3G networks.
IMS can enable IP interoperability for real-time services between fixed and mobile networks and so holds the promise of seamless converged voice/data services. Services transparency and integration are key features for accelerating end-user adoption.

Two aspects of IMS are of fundamental importance to deliver these features :
• IP-based transport for both real-time and non-real-time services
• Introduction of a multimedia call model based on SIP (Session initiation Protocol).

The IMS will provide:

- A multi-service multi-protocol, multi-access, IP based network - secure, reliable and trusted
  - Multi-services: Any type of service may be delivered by a common QoS enabled core network,
  - Multi-access: diverse access networks (WiFi, WiMAX, UMTS, CDMA2000, xDSL, Cable, etc.) can interface with IMS

IMS is Not one network, but different networks that interoperate seamlessly thanks to roaming agreements between any type of IMS service provider.

IMS is « An enabler » for Service Providers to offer :

- Real-time and non real-time, communication services between peers, or in a client-server configuration.
- Mobility of services and mobility of users (Nomadicity)
- Multiple sessions and services simultaneously over the same connection. One can get his communications services anywhere, on any terminal.

## 2.1 Layers of the IMS Architecture

The IMS architecture as defined by the 3GPP standards is an all-packet core network that creates an access-agnostic environment to deliver a wide range of multimedia services that a user can access using any device or network connection. Leveraging the SIP protocol, IMS supports IP-to-IP sessions over any wireline connection (e.g., DSL, cable) or wireless network protocol (e.g., Wi-Fi, GSM or CDMA). The IMS infrastructure allows a carrier to interwork between the TDM and IP networks to provide a seamless service experience.

**Access layer** : IMS is access independent. In case of mobile, it can be GPRS, EDGE (also called enhanced GPRS), UMTS or Wireless LAN. 3GPP UMTS R5 focuses on EDGE and UMTS accesses. 3GPP UMTS R6 adds WLAN. 3GPP2 assumes cdma2000 accesses. Fixed service providers will apply IMS to ADSL and cable network accesses.
**Transport layer** : It is an all-IP network that consists of IP routers (edge and core IP routers).
**Connectivity layer = Access Layer and Transport Layer**

**Session Control layer** : Comprises network control servers for managing calls or establishing sessions and modifications. The two main elements of this layer are the CSCF (call session control function) and the HSS (home subscriber server). Sometimes called the SIP server, the CSCF performs end-point registration and routing of the SIP signaling messages to the application server related to a particular service. In addition, the CSCF interworks with the access and transport layers to guarantee QoS for all services. The HSS database maintains each end user's service profile. Stored in a central location, this information could include location information, service triggers, etc.

**Application layer** : Utilizes application and content servers to provide various value-added services. At the heart of this layer are the AS (application server), MRFC (multimedia resource function controller), and the MRFP (multimedia resource function processor). The AS is responsible for the execution of service-specific logic, for example call flows and user interface interactions with subscribers, while the MRFP—more commonly known as the IP media server—provides adjunct media processing for the application layer. Through the media server, a service provider can deliver various non-telephony services (e.g., push-to-talk) as well as speech-enabled services, video services, and other more mainstream services such as conferencing, prepaid card and personalized ring-back tones.

Control and application layers are access and transport independent so that a user can access to his/her IMS services from any access.

The overall IMS architecture is described in figure 1.

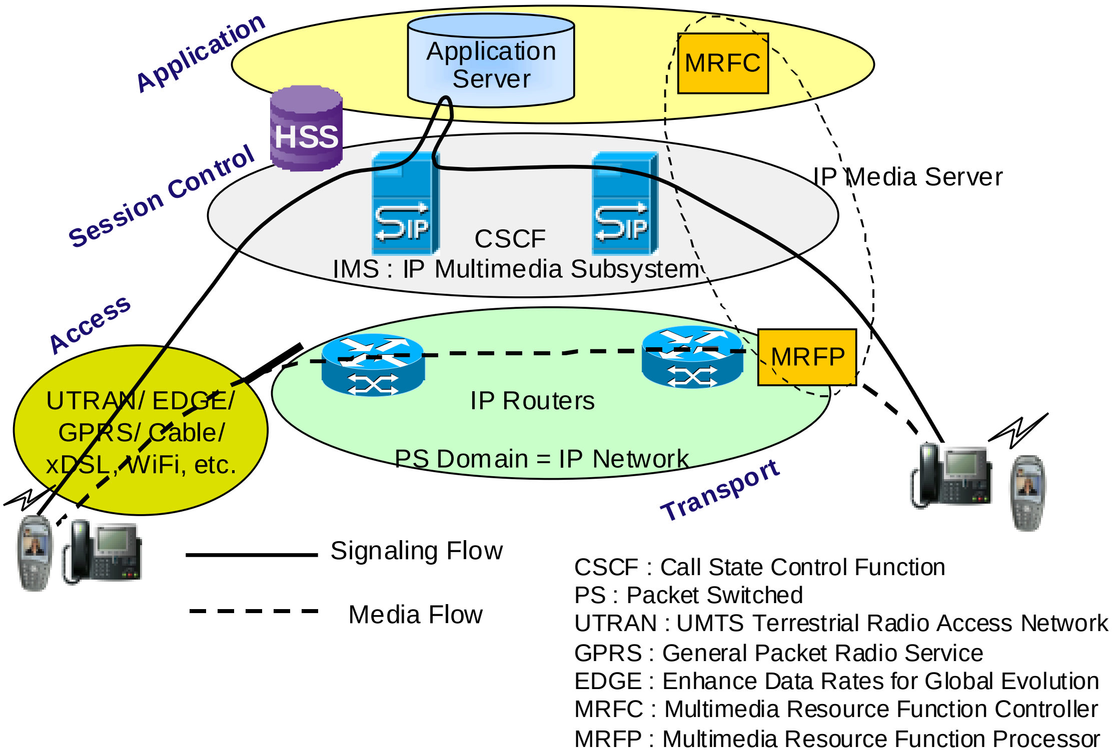


Figure 1 : IMS Network and Service Architectures

## 2.2 Underlying Concepts of the IMS Architecture

A set of requirements has been introduced for the design of IMS :

- **IP connectivity**

A fundamental requirement is that a client has to have IP connectivity to access IMS services. In addition, it is required that IPv6 is used.

- **Access Independence**

The IMS is designed to be access-independent so that IMS Services can be provided over any IP connectivity networks (e.g., GPRS, WLAN, broadband access xDSL, etc). Release 5 IMS specifications contain some GPRS-specific features. In Release 6 (e.g., GPRS) access-specific issues are separated from the core IMS description.

- **Ensures quality of service from IP Multimedia Services**

Via the IMS, the terminal negotiates its capabilities and expresses its QoS requirements during a Session Initiation Protocol (SIP) session set-up or session modification procedure. The terminal is able to negotiate such parameters as: Media type, Media type bit rate, packet size, packet transport frequency, bandwidth, etc. After negotiating the parameters at the application level, the terminals reserve suitable resources from the access network. When end-to-end QoS is created, the terminals encode and packetize individual media types with an appropriate protocol (e.g., RTP) and send these media packets to the access and transport network by using a transport layer protocol (e.g., TCP or UDP) over IP.

- **IP Policy control for ensuring correct usage of media resources**

IP policy control means the capability to authorize and control the usage of bearer traffic intended for IMS media, based on the signaling parameters at the IMS session. This requires interaction between the IP connectivity access network and the IMS.

- **Secure communication**

The IMS provides at least a similar level of security as the corresponding GPRS and GSM networks. The IMS ensures that users are authenticated before they can start using services, and users are able to request privacy when engaged in a session.

- **Charging arrangements**

The IMS architecture allows different charging capabilities to be used, particularly, off-line (postpaid) and on-line (prepaid) charging.

- **Support of roaming**

The roaming feature makes it possible to use services even though the user is not geographically located in the service area of the home network.

- **Interworking with other networks**

To be a new, successful communication network technology and architecture, the IMS has to be able to connect to as many users as possible. Therefore, the IMS supports communication with PSTN, ISDN, mobile and Internet users. Additionally, it will be possible to support sessions with Internet applications that have been developed outside the 3GPP community.

- **Service control**

IMS provides all the network with all the information about the services the user has subscribed to, so that standardized mechanisms are used to enable the network invoking the user's services.

- **Service development**

IMS provides service capabilities for multimedia service development. Presence, Conferencing, instant messaging, push-to-talk are examples of service capabilities.

## 2.3 IMS and SIP

SIP is an application-layer protocol defined by IETF (RFC 3261) that can establish, modify, and terminate multimedia sessions (conferences) over the Internet. A multimedia session is a set of senders and receivers and the data streams owing from the senders to the receivers. For example, a session may be a telephony call between two parties or a conference call among more than two parties. SIP can also be used to invite a participant to an ongoing session such as a conference. SIP messages could contain session descriptions such that participants can negotiate with media types and other parameters of the session. SIP provides its own mechanisms for reliable transmission and can run over several different transport protocols such as TCP, UDP, and SCTP (Stream Control Transmission Protocol). SIP is also compatible with both IPv4 and IPv6. SIP provides the following key capabilities for managing multimedia communications:

- Determine destination user 's current location.
- Determine whether a user is willing to participate in a session.
- Determine the capabilities of a user 's terminal.
- Set up a session.

- Manage a session. This includes modifying the parameters of a session, invoking service functions to provide services to a session, and terminating a session.

Like HTTP, SIP is a client-server protocol that uses a request and response transaction model. A SIP client is any network element that generates SIP requests and receives SIP responses. A SIP server is a network element that receives SIP requests in order to service them and sends back responses to these requests.

# 3 IMS Network Entities

## 3.1 IMS Terminal

It is an application on the user equipment that sends and receives SIP requests. It represents a software on a PC, on an IP phone or on a UMTS mobile station (UE, User Equipment).

## 3.2 Home Subscriber Server (HSS)

The Home Subscriber Server (HSS) is the main data storage for all subscriber and service-related data of the IMS. The main data stored in the HSS include user identities, registration information, access parameters and service-triggering information

## 3.3 Call State Control Function (CSCF)

In GSM, a user can roam on to visited networks provided that the visited network can access the home HLR and an agreement exists between the two operators. The same kind of roaming is supported for R5 multimedia services. In GSM roaming, call control always takes place in the visited network, the only connection to the home network being access to the HLR.

In IMS, there was a long and complicated discussion about whether IP multimedia call control for roamers should take place in the visited or home network. Those who said it should take place in the home network pushed the argument that the user would have signed for a range of services, and many of these would not be available or would work differently in a visited network. Those who favored visited network control were concerned about the long delays and signaling traffic created by having all services controlled from the home network that might be located on a different continent.

In the end, it was decided that IMS control would be controlled from the home network. This complication gives rise to three flavors of CSCF (Proxy CSCF, Interrogating, Serving CSCF). CSCF = Call Stateful Control Function.

A **P-CSCF** (Proxy CSCF) is a mobile's first contact point inside a local (or visited) IMS.

It acts as a SIP Proxy Server. In other words, the P-CSCF accepts SIP requests from the mobiles and then either serves these requests internally or forwards them to other servers.

The P-CSCF includes a Policy Control Function (PCF) that controls the policy regarding how bearers in the GGSN should be used.

The P-CSCF performs the following specific functions :

• Forward SIP REGISTER request from a mobile to the mobile 's home network.

• Forward other SIP messages from a mobile to a SIP server (e.g., the mobile's S-CSCF in the mobile's home network).

• Forward SIP messages from the network to a mobile.

• Perform necessary modifications to the SIP requests before forwarding them to other network entities.

• Maintain a security association with the mobile.

• Detect emergency session.

• Create CDRs.

An **I-CSCF** (Interrogating CSCF) is a contact point within an operator's network for all connections destined to a subscriber of that network operator. There may be multiple I-CSCFs within an operator's network. The functions performed by the I-CSCF are :

• To contact the HSS to obtain the name of the S-CSCF that is serving a user

• To assign an S-CSCF based on received capabilities from the HSS. An S-CSCF is assigned if there is no S-CSCF allocated.

• To forward SIP requests or responses to the S-CSCF

• To generate CDRs

• To provide a hiding functionality.

• The I-CSCF is an optional function that can be used to hide an operator network 's internal structure from an external network when an I-CSCF is used.

An **S-CSCF** (Serving CSCF) provides session control services for a user. It maintains session states for a registered user 's on-going sessions and performs the following main tasks :

• Registration : An S-CSCF can act as a SIP Registrar to accept users' SIP registration requests and make users 'registration and location information available to location servers such as the HSS (Home Subscriber Server).

• Session Control : An S-CSCF can perform SIP session control functions for a registered user. It relays SIP requests and responses between calling and called parties.

• Proxy Server : An S-CSCF may act as a SIP Proxy Server that relays SIP messages between users and other CSCFs or SIP servers.

• Interactions with Application Servers : An S-CSCF acts as the interface to application servers and other IP or legacy service platforms.

• Other functions : An S-CSCF performs a range of other functions not mentioned above. For example, it provides service-related event notifications to users and generates Call Detail Records (CDRs) needed for accounting and billing.

Before being able to use the services of the IMS domain such as establish a multimedia session or receive a session request, a user should register to the network. Wherever the user is (home or visited network), this registration procedure involves a P-CSCF. All the signaling messages sent and received by the user terminal are forwarded by the P-CSCF. The terminal never knows the I-CSCF or S-CSCF addresses.

## 3.4 MGCF, IMS-MGW and T-SGW : Interworking with PSTN/GSM

The IMS networks need to interact with PSTN so that IMS users can establish services to PSTN users. The architecture for supporting PSTN and legacy mobile networks is shown in Figure 2. The interworking between IMS networks and PSTN/legacy networks occur at two levels: One is the user plane level and the other is the signaling plane level. In the user plane, interworking elements are required to convert IP based media streams on the IMS side to TDM based media streams on the PSTN side. The **IMS-Media Gateway** (IMS-MGW) element is responsible for this function. The IS-MGW elements are controlled by the **Media Gateway Control Function** (MGCF) through the Megaco protocol. On the signaling plane level, the SIP signaling needs to be converted to legacy signaling such as ISDN Signaling User Part (ISUP). The MGCF is responsible for converting SIP signaling to legacy signaling such as ISUP. The MGCF is responsible for transporting ISUP signaling messages to a Trunking Signaling Gateway (T-SGW) over IP transport bearer. The T-SGW transports these ISUP messages over the SS7 bearer to either the PSTN or the legacy wireless networks.

Please note that MGCF and T-SGW are logical functions. These functions may be implemented in one physical box.

Figure 2 represents a call initiated by the PSTN and to be delivered to an IMS terminal.

The PSTN switch reserves a voice circuit among those it shares with the IMS-MGW and sends an ISUP IAM message over SS7 to a T-SGW (Trunking Signaling Gateway). The T-SGW is responsible for signaling transport conversion. It forwards the ISUP IAM message to the MGCF entity over SIGTRAN (Signaling Transport over IP).
The MGCF creates a context in the IMS-MGW using the MEGACO/H.248 protocol. This context consists of an association between a TDM termination and an RTP termination. The TDM termination terminates the voice circuit the IMS-MGW shares with the PSTN switch. The RTP termination terminates the RTP channels between the IMS-MGW and the IMS terminal.
The MGCF entity originates a SIP INVITE method containing the SDP description returned by the IMS-MGW. This method is sends to the IMS subsystem that delivers it to the destination IMS terminal.

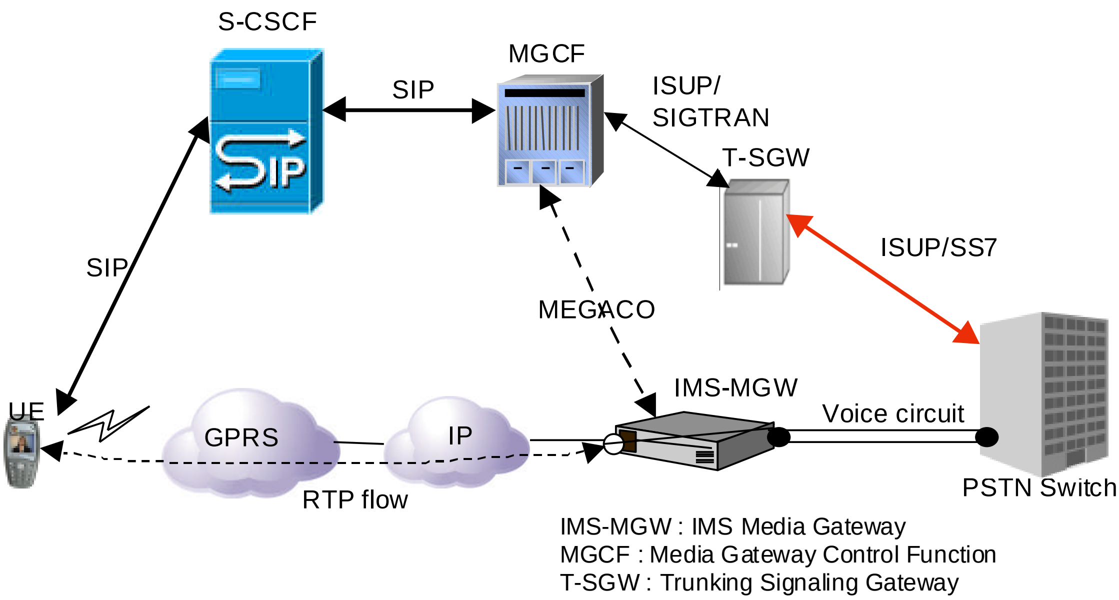


Figure 2 : Interworking between PSTN and IMS

# 4 Deployment of an IMS Architecture

From the above concepts, one can state that :

• IMS is access independent. GPRS/EDGE/UMTS users as well as fixed broadband users (xDSL, cable) can access to IMS.
• IMS provides the interface towards the circuit switched networks (e.g., PSTN, GSM).
• IMS provides a standardized interface (ISC, IMS Service Control) to access to services.

IMS can be deployed by :
• A mobile service provider to offer advanced services and multimedia services to its users GPRS/EDGE/UMTS.
• A fixed network operator (xDSL, cable)

• A virtual network operator that deploys IMS and relies on the access networks of third party operators.
These operators can deploy their own IMS services and open their service architecture to ASP that interface with their own application servers through the ISC interface.
Moreover, There are different approaches for the deployment of an IMS based-infrastructure for a service provider with mobile and fixed infrastructures.
• It may deploy **two independent IMS-based infrastructures** for fixed (e.g., xDSL) and mobile (e.g., EDGE or UMTS). The equipment of these two infrastructures may be from the same equipment vendor.
• It may deploy **a unique IMS-based infrastructure** from a vendor that is capable of supporting the two types of accesses.
• It may consider **a hybrid IMS-based infrastructure** with two IMS network infrastructures but sharing common application servers.

# 5 IMS Service Architecture

The IMS service architecture consists of Application Servers (AS), Multimedia Resource Functions (MRF) also called IP media servers, and S-CSCF equivalent to call servers (Figure 3).

The **AS** (Application Server) provides a service execution environment, application-specific logic (e.g., Push To Talk, Presence, Prepaid, Instant messaging), and all the signaling for one or more services. It may influence and impact the SIP session on behalf of the services. The AS corresponds to the SCF (Service Control Function) of the Intelligent Network.

The **MRF** (Multimedia Resource Function) is a network element whose sole purpose is the processing of media streams, also known as RTP streams for network-based services. Media stream processing includes such functions as playing announcements, collecting DTMF digits, audio recording and playback, bridging multiple streams (also known as conferencing), speech recognition, text-to-speech rendering, and video processing. In performing these functions, the MRF's role in the network is that of a slave device: it always operates under the direct control of an AS. The MRF corresponds to the SRF (Specialized Resource function) of the Intelligent Network.

The call server called **S-CSCF** (Serving - Call State Control Function) plays the role of a point from which services are invoked. It has the user profile that indicates the services the user has subscribed to, and the conditions under which services are invoked. The S-CSCF corresponds to the SSF (Service Switching function) of the Intelligent Network.

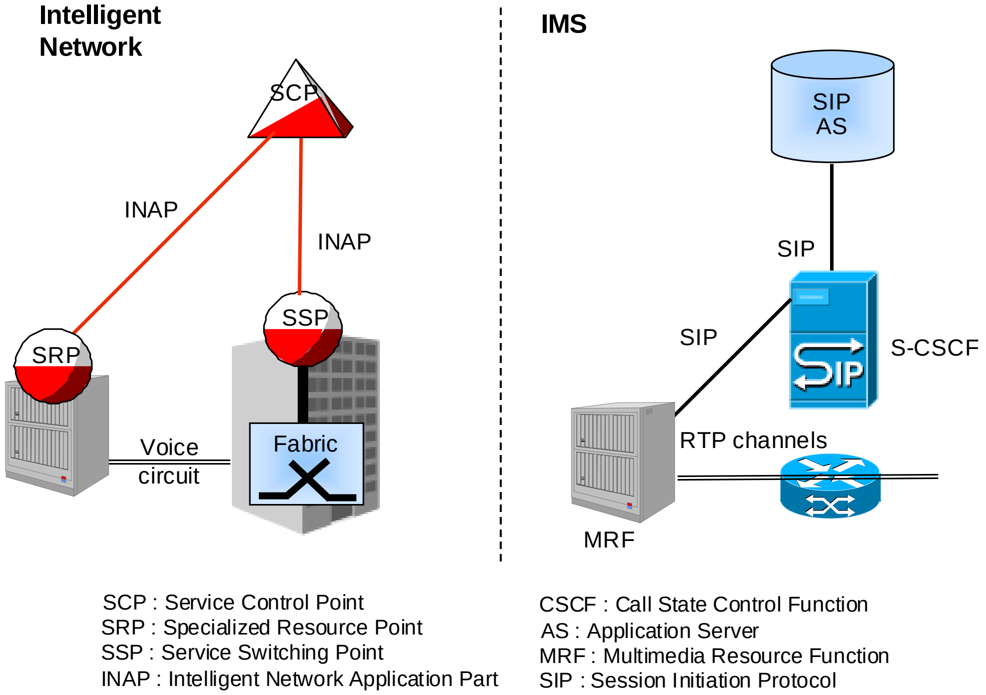


Figure 3 : Intelligent Network versus IMS Service Architecture

## 5.1 Entities of the IMS Service Architecture

The IMS services architecture allows deployment of new services by operators and third party service providers. This provides subscribes a wide choice of services. The S-CSCF is the anchor point for delivering new services since it manages the SIP sessions. However, services can be developed and deployed in a distributed architecture. Multiple service platforms may be used to deploy wide variety of services. The IMS defines three different ways of delivering services :

• **Native SIP Services**: In the last few years, a wide variety of technologies have been developed by various organizations for developing SIP services. They include SIP servlets, Call Processing Language (CPL) script, SIP Common Gateway Interface (CGI) and Java APIs for Integrated Networks (JAIN). One or more **SIP Application Servers** may be used to deploy services using these technologies. It is intended to allow the SIP Application Server to influence and impact the SIP session on behalf of the services. Service Control Interaction Manager (SCIM) is a specialized type of SIP Application Server, that performs the role of interaction management between other application servers.

• **Legacy IN services:** While new and innovative services are required, the legacy telephony services cannot be ignored provided by CAMEL. The **IMS Service Switching Point** (IMS-SSP) is a particular type of application server the purpose of which is to host the CAMEL network features (i.e. trigger detection points, CAMEL Service Switching Finite State Machine, etc) and to interface to CSE (CAMEL Service Environment). The IM SSP and the CAP interface support legacy services only.

• **Third party services:** UMTS has defined Open Services Access (OSA)7 to allow 3 rd party service providers to offer services through UMTS network. The OSA offers a secure API for third party service providers to access UMTS networks. Therefore, subscribers are not restricted to the services offered by the operators. **OSA Service Capability Server** (OSA SCS) interfaces to the OSA framework Application Server and provides a standardized way for third party secure access to the IM subsystem. The OSA reference architecture defines an OSA Application Server as an entity that provides the service logic execution environment for client applications using the OSA API. This definition of Application Server differs from the definition of Application Server in the context of service provisioning for the IM subsystem, i.e. the entity communicating to the S-CSCF via the ISC interface.

In addition the Application Servers can also interact with the **Multimedia Resource Function controller** (MRFC) via the S-CSCF in order to control Multimedia Resource Function processing (MRFP). MRF = MRFC+MRFP.

All the Application Servers, (including the IM-SSF and the OSA SCS) behave as SIP application server on their interface towards the S-CSCF.

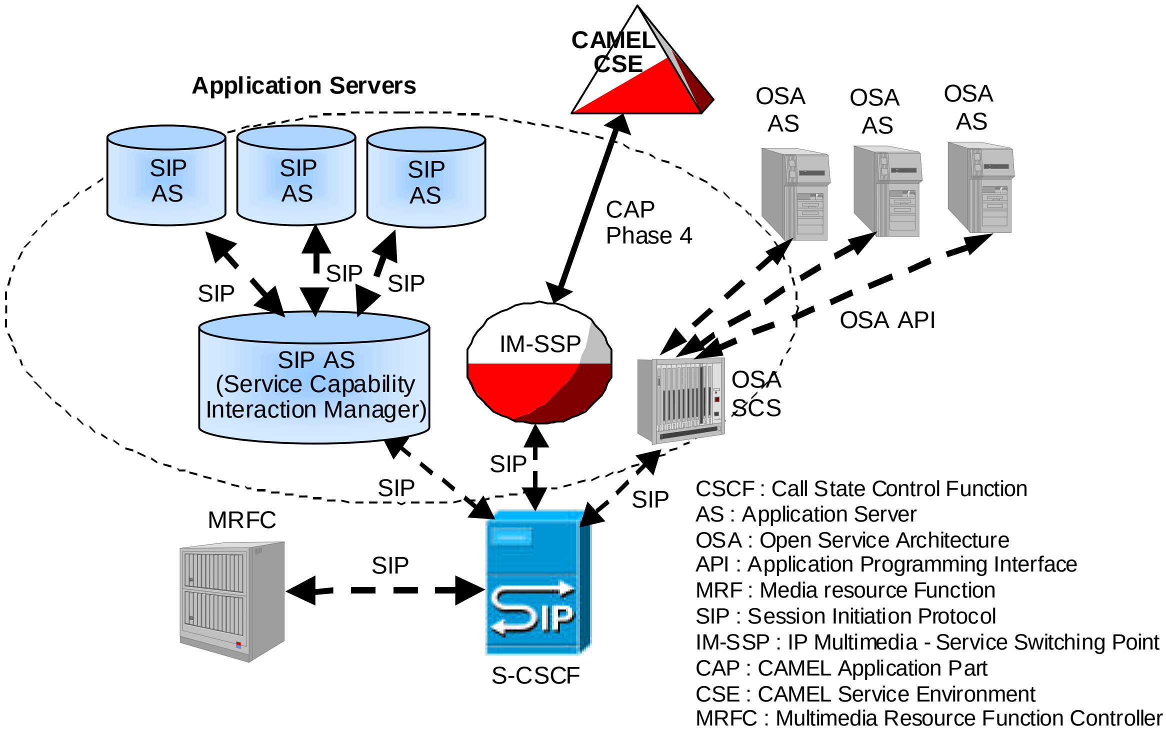


Figure 4 : IMS Service Architecture

# 6 Conclusion

IMS is the future architecture for IP multimedia telephony. It has been defined by operators that want to continue to deliver telephony services when their legacy networks are replaced by an IP network.
IMS is both a challenge and an opportunity as the foundation for the telephony, applications and services businesses over the coming decade.

Courses proposed by EFORT present the IMS network and service architectures but also the elements necessary to elaborate strategies of business development in value added IP services based on IMS.

- Development of new multimedia services handled by IMS and the principles of charging them.
- Migration scenarios towards an IMS architecture and in particular migration of services from IN to IMS

* Necessary investment in IMS

EFORT IMS course permanently integrate the ultimate state of new technologies presenting the concepts, architectures, vendors solutions, service offers and competition. is confronted with their practical application. They have already been taught in India, US, France, Sweden, Belgium, Chile. They provide the keys for developing and deploying IMS service and network architectures and for developing the business of value added IP services.