# D B1.10p – Flexible multi-service edge router

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| *Abstract (for dissemination)* | A step forward to seamless networking in all-IP networks is the IP Multimedia Subsystem (IMS), originally standardized by 3GPP and later adopted by ETSI/TISPAN. To meet future demands in a highly competitive and dynamic environment, also new disruptive concepts beyond today's understanding of IMS have to be considered. This deliverable describes the evolution from the concept of the packet-to-packet gateway, developed during Phase I of MUSE (DB1.6) towards the Multi-Service Edge Router (MS-ER), thought as key element for an optimized IMS deployment. |

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# TABLE OF CONTENTS

# LIST OF FIGURES AND TABLES

# ABBREVIATIONS

| | |
|---|---|
| APS | Automatic Protection Switching |
| AS | Application Server |
| B2BUA | Back-to-Back User Agent |
| BGCF | Breakout Gateway Control Function |
| CPU | Central Processor Unit |
| CSCF | Call Session Control Function |
| DHCP | Dynamic Host Configuration Protocol |
| DNS | Domain Name Server |
| ETSI | European Telecommunications Standards Institute |
| FMC | Fixed-Mobile Convergence |
| GGSN | GPRS Gateway Support Node |
| GPRS | General Packet Radio Services |
| HSS | Home Subscriber Server |
| I-CSCF | Interrogating-CSCF |
| IETF | Internet Engineering Task Force |
| IMS | IP Multimedia Subsystem |
| IMX | IP Multimedia eXchange |
| InB | IMS in a Box |
| IP | Internet Protocol |
| MRF | Media Resource Function |
| NGN | Next Generation Networks |
| Pa2Pa | Packet-to-Packet |
| P-CSCF | Proxy-CSCF |
| PDP | Policy Decision Point |
| POTS | Plain Old Telephony System |
| PSTN | Public Switching Telephone Network |
| QoS | Quality of Service |
| RM | Resource Manager |
| RTCP | Real Time Control Protocol |
| RTP | Real Time Protocol |
| SBC | Session Border Controller |
| S-CSCF | Serving-CSCF |
| SDP | Session Description Protocol |
| SGW | Signalling Gateway |
| SIP | Session Initiation Protocol |
| TCP | Transport Control Protocol |
| TISPAN | Telecoms & Internet converged Services & Protocols for Advanced Networks |
| UA | User Agent |
| UAC | User Agent Client |
| UAS | User Agent Server |
| UCM | User Call Manager |
| UDP | User Datagram Protocol |
| VoIP | Voice over Internet Protocol |

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# EXECUTIVE SUMMARY

A step forward to seamless networking in all-IP networks is the IP Multimedia Subsystem (IMS), originally standardized by 3GPP and later adopted by ETSI/TISPAN. This common denominator means that IMS will become the core of operators' networks in a FMC scenario. In essence, IMS technology provides a SIP-based call control layer with open interfaces to the transport layer and the services layer above. IMS will enable Service Providers to offer new SIP based services, enabling ways to embed conversational services into numerous new applications for end users across multiple mobile and fixed access networks.
To meet future demands in a highly competitive and dynamic environment, also new disruptive concepts beyond today's understanding of IMS have to be considered. We have to face the trend to offer more terminal centric services and at the same time transform the call control focused infrastructure into a flexible service platform to provide a broad spectrum of new and existing services faster and more cost efficient. The user centric broadband vision manifests the perception that users are expecting personalized services at different terminals/devices, independent of the access network technology. In consequence also session mobility across intra- and inter-network domains, embracing fixed and mobile networks becomes a major objective for the network infrastructure.

This deliverable describes the evolution from the concept of the packet-to-packet gateway, developed during Phase I of MUSE (DB1.6) towards the Multi-Service Edge Router (MS-ER). The addition to the work performed in Phase I to reach the final goal of the MS-ER is further called in this document IP Multimedia Exchange (IMX).

IMX – IP Multimedia eXchange – is a further innovative evolution of the enhanced Session Border Controller concept as described in DB1.6. Several IMX nodes build an IMX domain which is a specific implementation of the 3GPP/IMS system. The target is an "optimized IMS", by implementing the standardized IMS functions in an innovative way by keeping the standardized external interfaces to other networks.

*Deliverable content:*
Chapter 1 gives a short overview of the main building blocks of IMS to give the reader a short overview of IMS terms used in this document.

Chapter 2 first gives an overview on the evolution path from the eSBC towards the IMX concept and describes the overall architecture of an IMX domain, meaning several IMX nodes build an IMX domain which is a specific implementation of the 3GPP/IMS system. In the context of the system description also resource management in an IMX domain as well as redundancy concepts are provided. Finally chapter 3 gives an outlook.

# 1 IMS COMPONENTS

## 1.1 Introduction

The IP Multimedia Subsystem (IMS) is a standardized Next Generation Networking (NGN) architecture for telecom operators that want to provide mobile and fixed multimedia services. It uses a Voice-over-IP (VoIP) implementation based on a 3GPP standardized implementation of SIP, and runs over the standard Internet Protocol (IP). Existing phone systems (both packet-switched and circuit-switched) are supported.

The aim of IMS is not only to provide new services but all the services that the Internet provides. In this way, IMS will give network operators and service providers the ability to control and charge for each service. In addition, users have to be able to execute all their services when roaming as well as from their home networks. To achieve these goals, IMS uses open standard IP based protocols, defined by the IETF. So, a multimedia session between two IMS users, between an IMS user and a user on the Internet, and between two users on the Internet is established using exactly the same protocol. Moreover, the interfaces for service developers are also based on IP protocols. This is why IMS truly merges the Internet with the cellular world; it uses cellular technologies to provide ubiquitous access and Internet technologies to provide appealing services. [wiki]

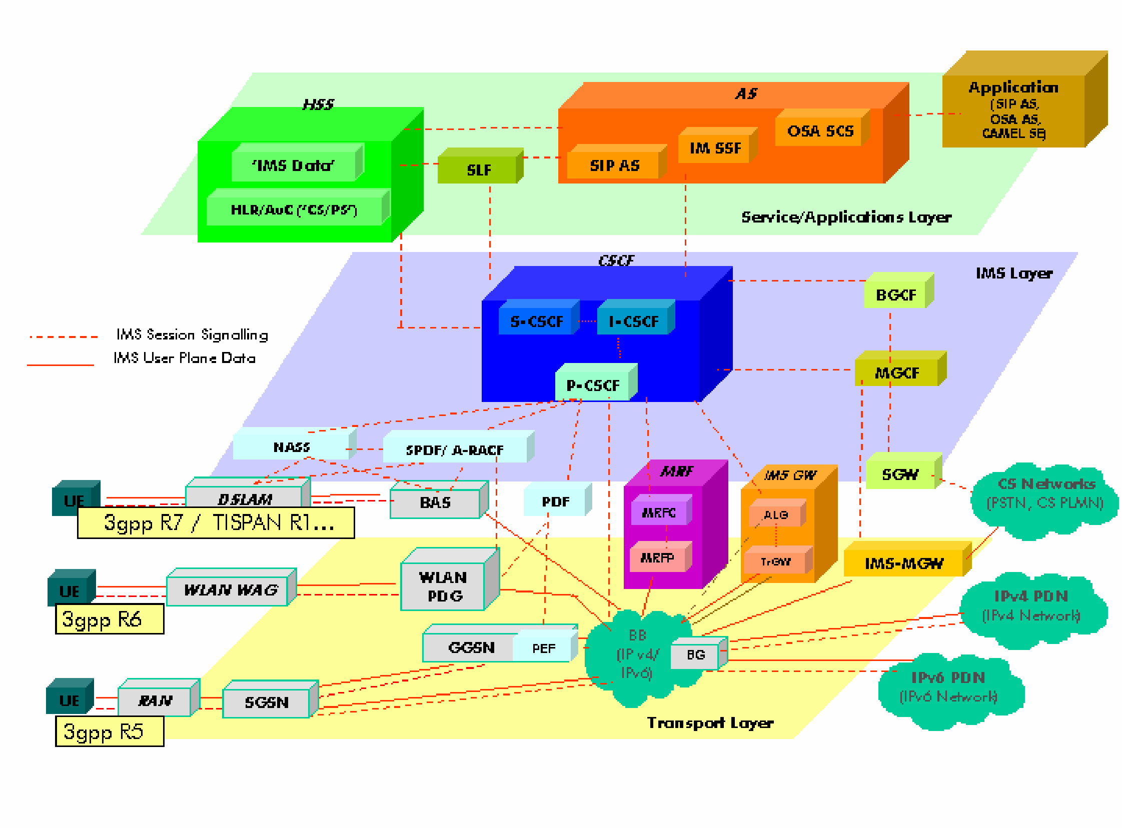



Figure 1: IP Multimedia Subsystem (IMS)

## 1.2 User Database (HSS and SLF)

The Home Subscriber Server (HSS) is the central repository for user-related information. Technically, the HSS is an evolution of the HLR (Home Location Register), which is a GSM node. The HSS contains all the user-related subscription data required to handle multimedia sessions. These data include, among other items, location information, security information (including both authentication and authorization information), user profile information (including the services that the user is subscribed to), and the S-CSCF (Serving-CSCF) allocated to the user.
A network may contain more than one HSS, in case the number of subscribers is too high to be handled by a single HSS. In any case, all the data related to a particular user is stored in a single HSS (of course in a redundant configuration to avoid a single point of failure).
Networks with a single HSS do not need a SLF (Subscriber Location Function). On the other hand, networks with more than one HSS do require a SLF.
The SLF is a simple database that maps users' addresses to HSSs. A node that queries the SLF, with the user's address as the input, obtains the HSS that contains all the information related to that user as the output. [camarillo]

## 1.3 Call/Session Control

The CSCF (Call Session Control Function), which is a SIP server, is an essential node in the IMS. The CSCF processes SIP signalling in the IMS. There are three types of CSCFs, depending on the functionality they provide.

### *1.3.1 P-CSCF*

A P-CSCF (*Proxy-CSCF*) is a SIP proxy that is the first point of contact for the IMS terminal. It can be located either in the visited network (in full IMS networks) or in the home network (when the visited network isn't IMS compliant yet). Some networks might use a Session Border Controller for this function. The terminal will discover its P-CSCF with either DHCP, or it's assigned in the PDP Context (in GPRS).
A P-CSCF:

- it's assigned to an IMS terminal during registration, and does not change for the duration of the registration.
- it sits on the path of all signalling messages, and can inspect every message
- it authenticates the user and establishes an IPsec (security) association with the IMS terminal. This prevents spoofing attacks and replay attacks and protects the privacy of the user. Other nodes trust the P-CSCF, and do not have to authenticate the user again.
- it can also compress and decompress SIP messages using SigComp, which reduces the round-trip over slow radio links.
- it may include a PDF (*Policy Decision Function*), which authorizes media plane resources e.g. quality of service (QoS). It's used for policy control, bandwidth management, etc ... The PDF can also be a separate function.
- it also generates charging records. [wiki]

### 1.3.2 I-CSCF

An I-CSCF (Interrogating-CSCF) is a SIP proxy located at the edge of an administrative domain. Its IP address is published in the DNS of the domain (using NAPTR and SRV type of DNS records), so that remote servers (e.g., a P-CSCF in a visited domain, or a S-CSCF in a foreign domain) can find it, and use it as an entry point for all SIP packets to this domain. The I-CSCF queries the HSS using the DIAMETER Cx and Dx interfaces to retrieve the user location, and then routes the SIP request to its assigned S-CSCF. Up to Release 6 it can also be used to hide the internal network from the outside world (encrypting part of the SIP message), in which case it's called a THIG (Topology Hiding Interface Gateway). From Release 7 onwards this function is removed from the I-CSCF and is now part of the IBCF (Interconnection Border Control Function). The IBCF is used as gateway to external networks, and provides NAT and Firewall functions (pinholing). [wiki]

### 1.3.3 S-CSCF

An S-CSCF (Serving-CSCF) is the central node of the signalling plane. It's a SIP server, but performs session control as well. It's always located in the home network. The S-CSCF uses DIAMETER Cx and Dx interfaces to the HSS to download and upload user profiles - it has no local storage of the user.

- it handles SIP registrations, which allows it to bind the user location (e.g. the IP address of the terminal) and the SIP address.
- it sits on the path of all signalling messages, and can inspect every message.
- it decides to which application server(s) the SIP message will be forwarded, in order to provide their services.
- it provides routing services, typically using ENUM lookups.
- it enforces the policy of the network operator. [wiki]

## 1.4 Application Servers

Application servers (AS) host and execute services, and interface with the S-CSCF using SIP. This allows third party providers an easy integration and deployment of their value added services to the IMS infrastructure. Examples of services are:

- Caller ID related services (CLIP, CLIR, ...)
- Call waiting, Call holding, Push to talk
- Call forwarding, Call transfer
- Call blocking services, Malicious Caller Identification
- Lawful interception
- Announcement services
- Conference call services
- Voicemail, Text-to-speech, Speech-to-text
- Location based services
- SMS, MMS
- Presence information, Instant messaging
- Voice Call Continuity Function (VCC Server)

Depending on the actual service, the AS can operate in SIP proxy mode, SIP UA (user agent) mode or SIP B2BUA (back-to-back user agent) mode. An AS can be located in the home network or in an external third-party network. If located in the home network, it can query the HSS with the DIAMETER Sh interface (for SIP-AS and OSA-SCS) or the MAP interface (for IM-SSF).

- SIP AS : native IMS application server
- OSA-SCS : an Open Service Access - Service Capability Server interfaces with OSA Application Servers using Parlay
- IM-SSF : an IP Multimedia Service Switching Function interfaces with CAMEL Application Servers using CAP [wiki]

## 1.5 Media Servers (MRF)

An MRF (Media Resource Function) provides a source of media in the home network. It's used for:

- Playing of announcements (audio/video)
- Multimedia conferencing (e.g. mixing of audio streams)
- Text-to-speech conversion (TTS) and speech recognition.
- Realtime transcoding of multimedia data (i.e. conversion between different codecs)

Each MRF is further divided into:

- An MRFC (Media Resource Function Controller) is a signalling plane node that acts as a SIP User Agent to the S-CSCF, and which controls the MRFP with a H.248 interface
- An MRFP (Media Resource Function Processor) is a media plane node that implements all media-related functions. [wiki]

## 1.6 BGCF

A BGCF (Breakout Gateway Control Function) is a SIP server that includes routing functionality based on telephone numbers. It's only used when calling from the IMS to a phone in a circuit switched network, such as the PSTN or the PLMN. [wiki]

## 1.7 PSTN/CS Gateway

A PSTN/CS gateway interfaces with PSTN circuit switched (CS) networks. For signalling, CS networks use ISUP (or BICC) over MTP, while IMS uses SIP over IP. For media, CS networks use PCM, while IMS uses RTP.

- An SGW (Signalling Gateway) interfaces with the signalling plane of the CS. It transforms lower layer protocols as SCTP (which is an IP protocol) into MTP (which is a SS7 protocol), to pass ISUP from the MGCF to the CS network.
- An MGCF (Media Gateway Controller Function) does call control protocol conversion between SIP and ISUP, and interfaces with the SGW over SCTP. It also controls the resources in an MGW with a H.248 interface.
- An MGW (Media Gateway) interfaces with the media plane of the CS network, by converting between RTP and PCM. It can also transcode when the codecs don't match (e.g. IMS might use AMR, PSTN might use G.711). [wiki]

# 2 IMX BASED SYSTEM ARCHITECTURE

## 2.1 Introduction to IP Multimedia eXchange – IMX

IMS/TISPAN is the most consequent solution towards a converged all-IP network. Currently the originally mobile-centric IMS architecture is challenged by the enhanced security and inter-working requirements of fixed-network operators. With the transition from NGN and VoIP overlays to IMS, the integrity requirements remain valid, because the same functionality is required at the network borders. In consequence, IMS is boosting the SBC (Session Border Controller) market − not necessarily for stand-alone SBC products, more likely integrated with other IMS edge functions.

Within the ETSI TISPAN architecture the IMS P-CSCF (Proxy Call Session Control Function) is located at the border between the access network and core network. The implementation of the P-CSCF is very similar to the SIP proxy part of a stand-alone SBC. It is therefore the first natural step to integrate the full P-CSCF functionality and on its coat-tails the policy decision function (PDF) into the SBC and enhance it to a unique IMS-compliant network edge node: the Enhanced SBC.

Although counteracting a clear separation of access technology and access-independent IMS core, operators ask for an integrated IP Border Gateway node. Motivation is the consolidation of the various edge functions (as depicted in Figure 2) into a single product, by incorporation of one or multiple access border functions like the GPRS Gateway Support Node (GGSN), WiMAX access controller (WAC) or the Broadband Remote Access Server (BRAS) functionality.

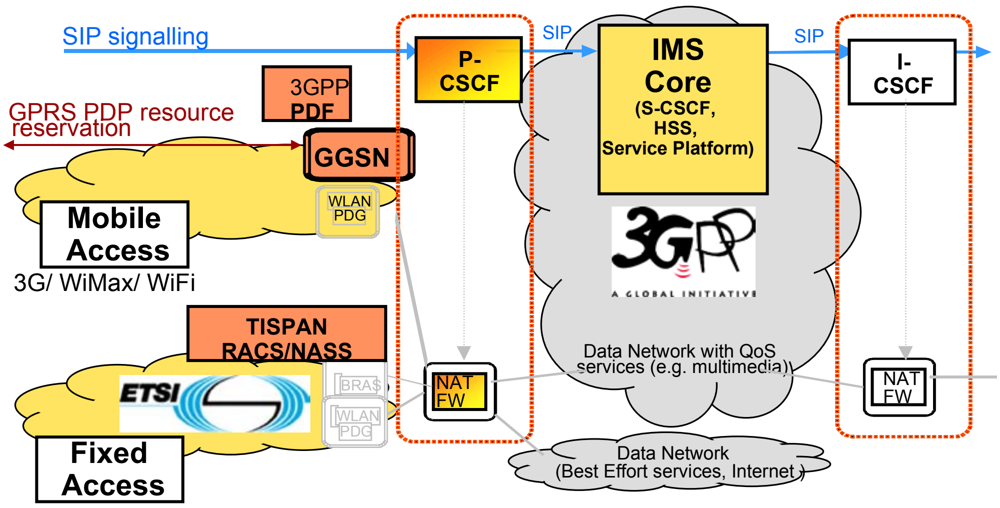



Figure 2: Integration of IMS/TISPAN standardized border elements as an evolution of the SBC.

## 2.2 The next step in IMS architecture: IMS in a Box

Above, it was shown that the integration of P-CSCF and SBC functions into a single IMS edge node, covering all functions mandatory at the IMS border, is an obvious and advantageous next evolution step. A further reasonable integration step may upgrade this network element towards a fully integrated IMS node, called IMS in a Box (InB). As indicated in Figure 3, InB implements all the mandatory enhanced SBC features, extended with additional I-, S-CSCF signalling functions and basic application server (AS) capabilities and Media Resource Functions (MRF). Thus, the InB becomes the major call control, AS and media node within IMS which allows simplifying the IMS scenarios significantly as the IMS network consists mainly of a cluster of distributed and homogeneous InB nodes and a number of special application servers – see Figure 4.
The InB concept represents also a change from the client server telco model towards a peer-to-peer style network of meshed co-equal nodes.

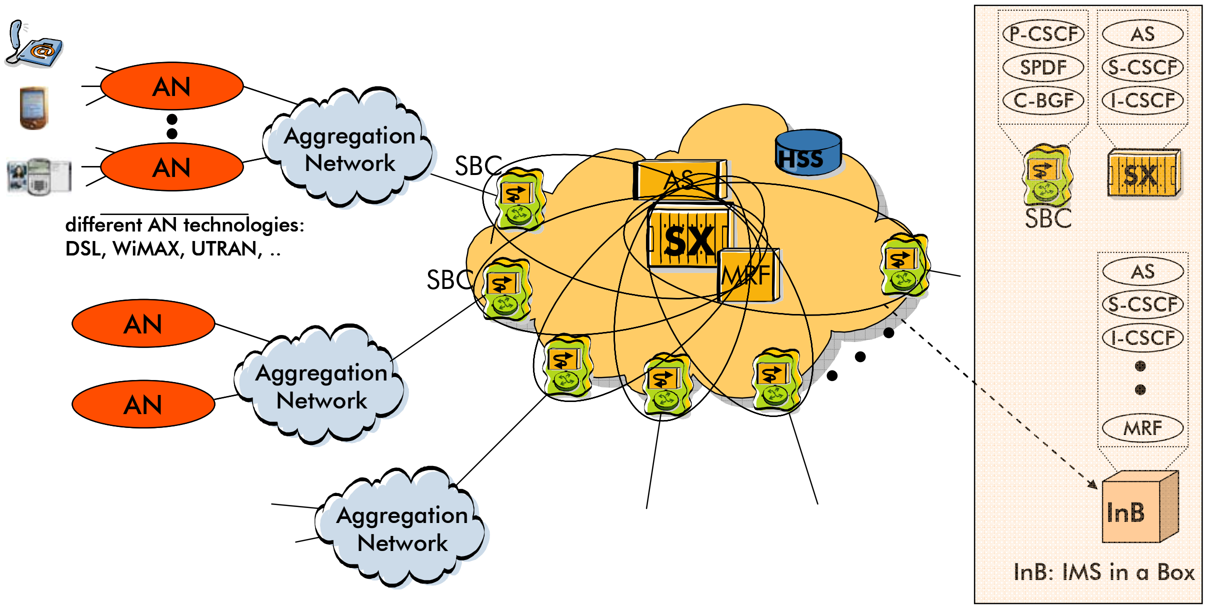



Figure 3: IMS in a Box

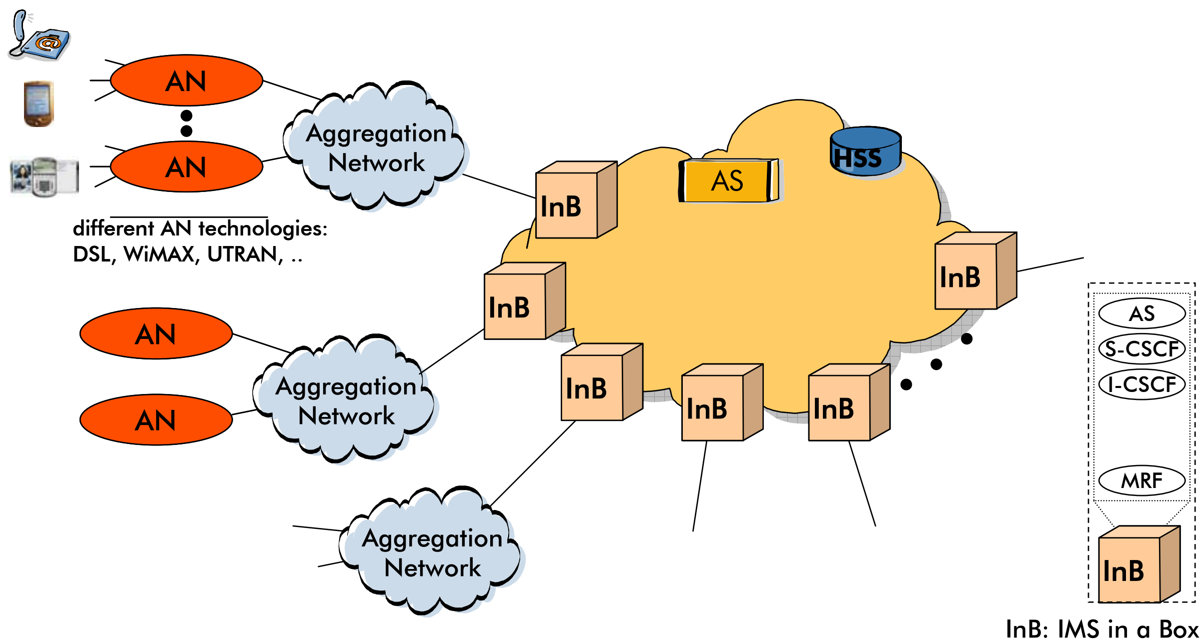



Figure 4: A cluster of distributed and homogeneous InB

The distribution of central functions (as control, application, media layer) into distributed InB nodes simplifies the IMS network architecture but increases hardware costs (installation of more processing and storage effort...) due to the reduced statistical gains. This drawback has been validated with a simulation tool for different scenarios. One simulation result for single domain scenario is shown in the following Figure 5. This scenario compares two architectures given in Figure 3 and Figure 4. The given total peak estimation values are normalized values and are proportional to the hardware to be spent. The maximum peak processing is the value required to ensure no-blocking behaviour of the complete system, normalized to 100% as reference value for a typical IMS system.

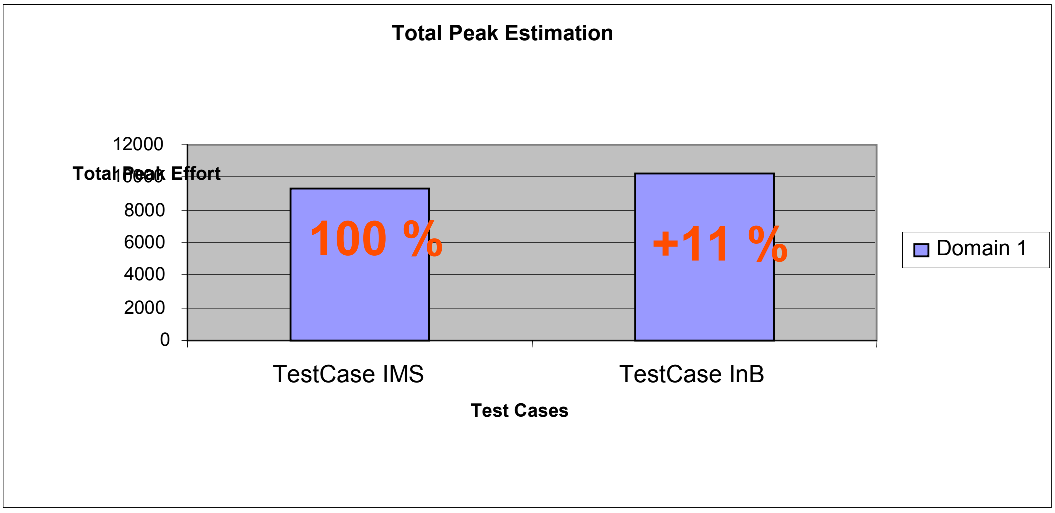



Figure 5: Simulation result comparing typical IMS architecture with InB architecture

## 2.3 Co-locating and grouping of IMS functions

To set up an end-to-end call in a typical IMS scenario a lot of CSC-Functions have to be traversed. Each of the CSC-Functions receives and forwards SIP messages and therefore it has to parse, un-marshal, process and to marshal the SIP messages. SIP messages are in a human readable text format and several studies ([IMS-Bell1], [IMS-Bell2], [Rosenberg]) show the high amount of processing resources required for parsing.
Figure 6 presents the result of a typical IMS scenario. This scenario takes into account multiple domains (10 domains). 20% of subscribers are located in a visited domain. The call setups are equally distributed between all subscribers. For this scenario an average number of CSCF hops are derived to 6.2.

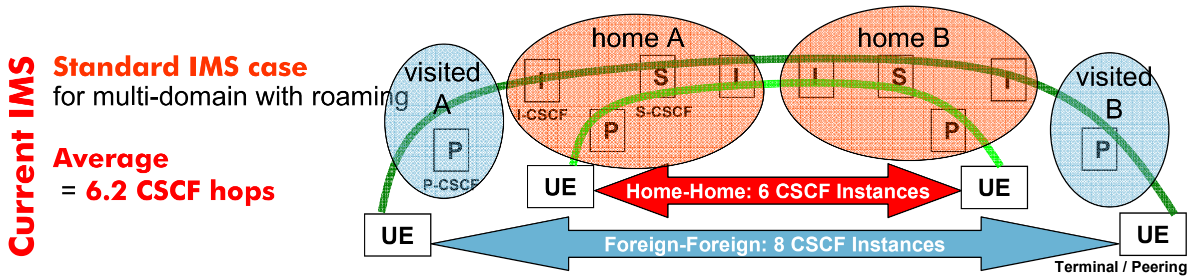



Figure 6: Average number of control function hops in an IMS system (10 domains; 20% roaming)

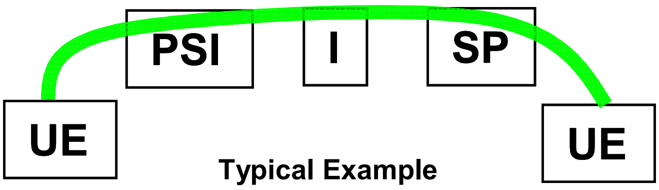
To evaluate the improvement potential, the above scenario was analyzed with the objective to identify the occurrence of multiple CSCFs tuples (co-located CSCFs) which are performed in a direct sequence at the same processing location. Figure 7 shows the occurrence results of co-located CSCFs. From this figure it can be deduced that the following co-located CSCFs can be advantageously combined: S-P-CSCF, P-S-I-CSCF, S-I-CSCF and P-S-CSCF. Combination of these functions (e.g. S-P-CSCF) can avoid parsing, string operation and marshalling processing effort. Figure 7 provides also the average number of CSCF hops if the proposed CSCF combinations are used. Compared to the above typical IMS solution, the CSCF combination achieves a reduction of about 43 %.
Concluding: It is worthwhile to combine the following CSCFs (S-P-CSCF, P-S-I-CSCF, S-I-CSCF and P-S-CSCF) within a common software module or process. Due to the frequent usage of these functions in a sequence on the same node (high occurrence of these co-located CSCFs) an integration of these functions in a common process avoids the process consuming standard SIP interface and a higher throughput can be achieved. The SIP message based interface can be replaced by a much more performent internal node interface.

## Grouping IMS CSC-Functions in IMX

**IMX Solution**

Most advantageous CSCF combinations:
SP-CSCF, PSI-CSCF, SI-CSCF, …

**Average CSCF hops: 3.5**
**Reduction: 43 %**




**About 57 % of the simulated cases require 3 CSCF hops**

### Simulation Result:

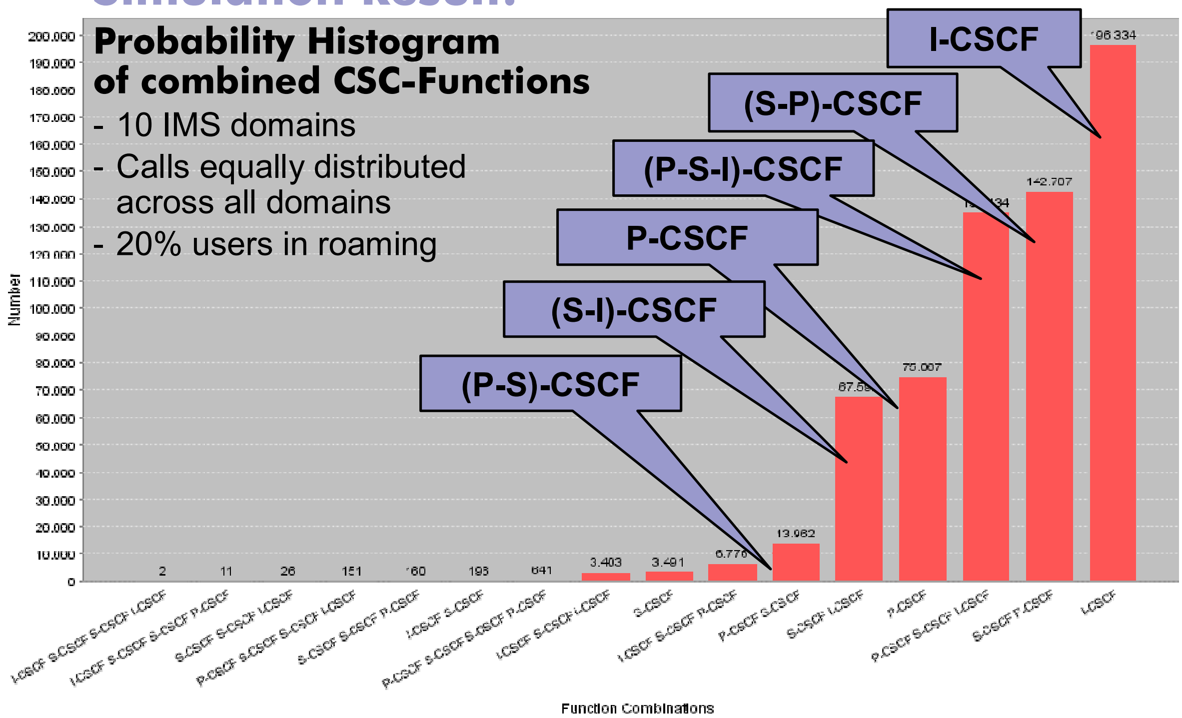



Figure 7: Average number of control function hops in an IMS system (10 domains; 20% roaming)

## 2.4 Concept evolution from InB domain to IMX domain

All InB nodes together are building a single domain. Control and signalling exchange between InBs of the same domain is performed with an inter InB interfaces optimized for most efficient (message delay and processing effort) communication exchange. With the introduction of an optimized non standard inter InB interface it is no longer an "IMS in a Box" (InB) concept but will now be called an IP Multimedia eXchange IMX concept (Figure 8). But the change of the inter control and signalling interface is not the only characterization of the IMX concept further amendments will be given in the following chapters.

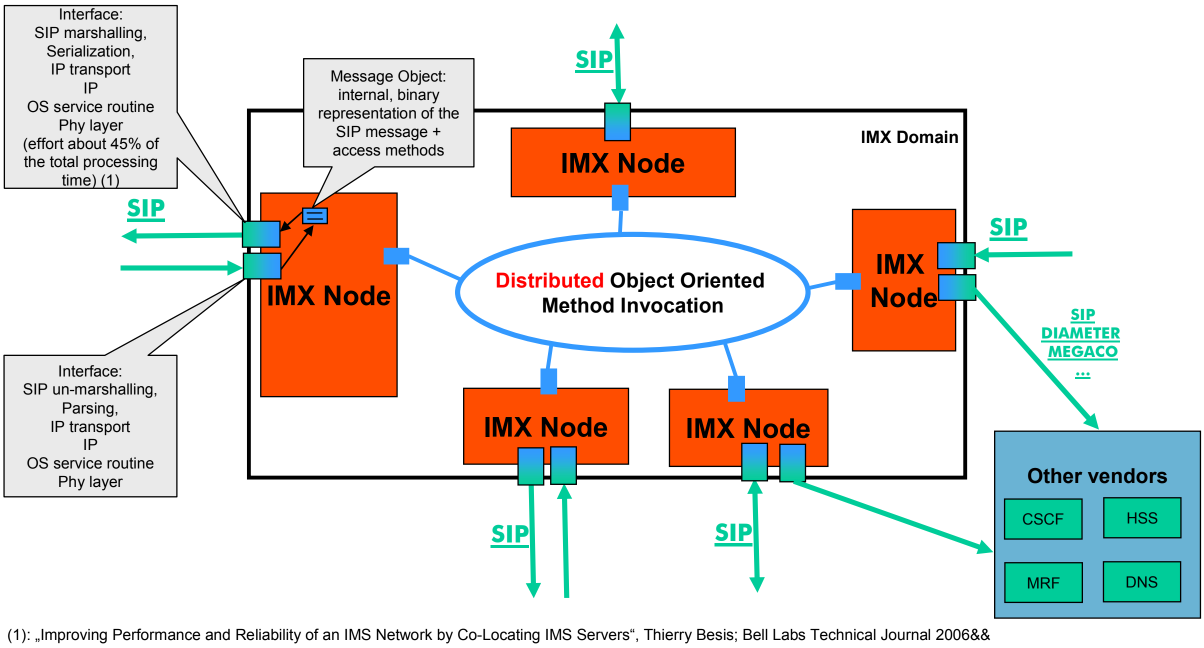



Figure 8: IP Multimedia eXchange

Although it is preferred to perform all the control and signalling within the IMX domain to achieve the maximum (processing effort) gain, the field deployments will require, in addition, standardized interfaces (SIP, Diameter, ..) for connecting network elements of other vendors to the IMX domain. This is indicated also in Figure 8, whereby any IMX node may/must have these interfaces.

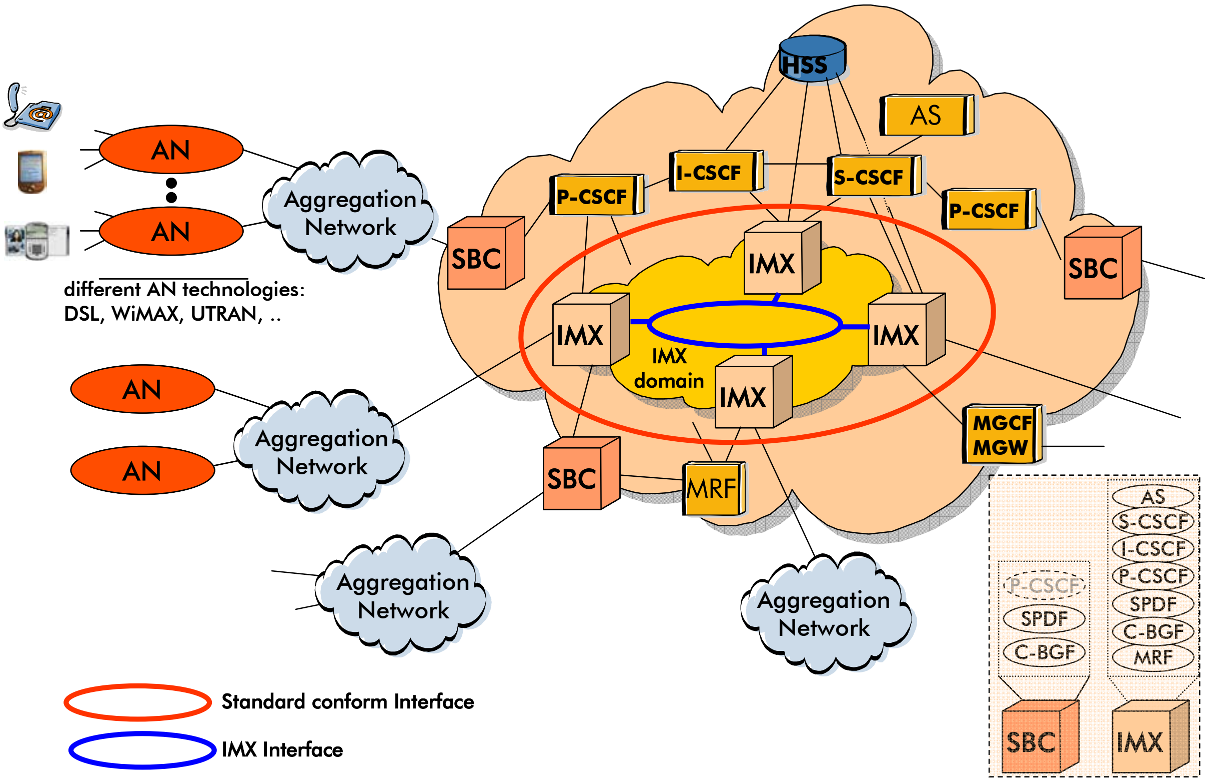



Figure 9: Single Provider multi vendor IMS scenario

Figure 9 illustrates an example of a single IMS Service Provider scenario whereby the equipment is delivered from different vendors. In the diagram it is supposed that aggregation networks are connected to either an SBC or an IMX node which both provides SBC functions and some of the SBC's may also be equipped with P-CSCF functions. Depending on the HSS entries some of the subscribers are served by (stand-alone) S-CSCF or S-CSCFs located on the IMX domain. Similar variants exist for the other functions as Application Server and Media server. The IMX cloud appears to the other equipment as a single equipment with multiple interfaces and multiple CSC-, AS- or Media- and SBC functions. To enable the interworking between different vendor equipment the IMX nodes have to provide standardized interfaces.
But for exploitation of the whole advantage of the IMX solution subscriber sessions (including application services and media resource functions) have to be purely served by the IMX domain equipment. But as soon as other vendor's equipment has to be involved, the IMX must use the standardized interface and looses a part of its advantages. The blue oval within the IMX domain cloud symbolizes the inter IMX node interface which is based on a binary pre-parsed and object oriented interface. The red oval symbolizes the multiple IMS standardized interfaces.

### 2.4.1 IMX internal Interface

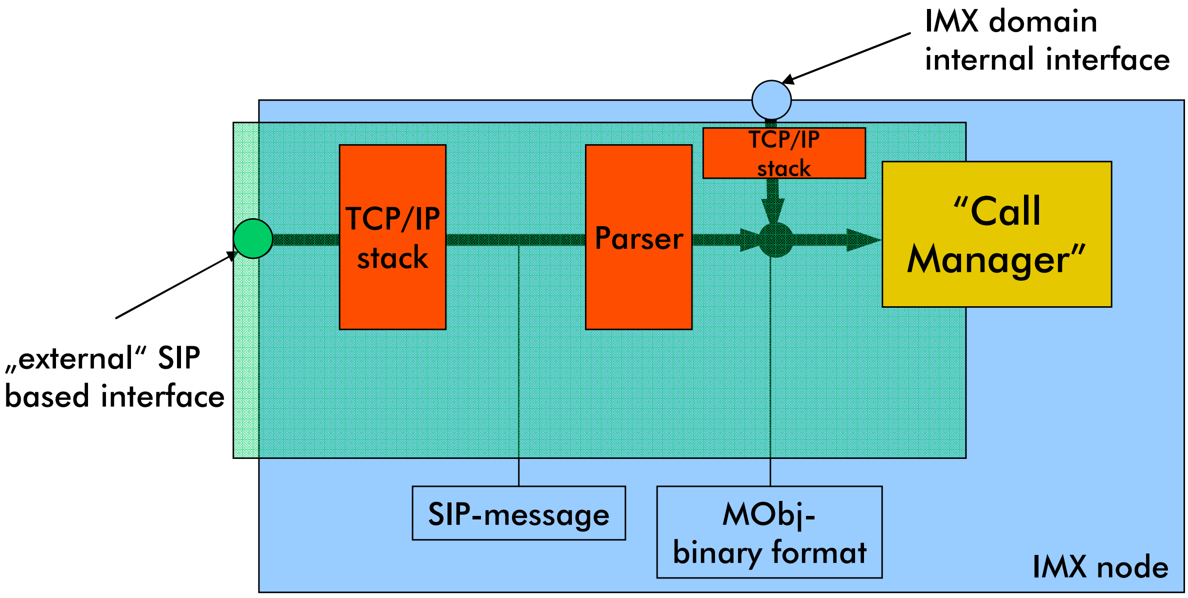



Figure 10: External and internal IMX interfaces

Figure 10 illustrates that the SIP messages arriving at the external SIP based IMX node interface are first parsed and are then transferred in an internal binary Message Object format – IMX domain internal interface. All further IMX domain internal call management functions are fully compliant to this IMX domain internal interface and no further parsing or conversion is required. The same interface is used for efficient message exchange between IMX nodes.
Figure 11 summarizes investigations on processing efforts on different layers. It can be shown that parsing and serialization can occupy about 25 % of the whole message processing effort. Furthermore, grouping of (e.g. CSCF) functions as described above (in chapter 2.3) omits the traversal of the IP/UDP/TCP stack which reduces the processing effort by further 20%.

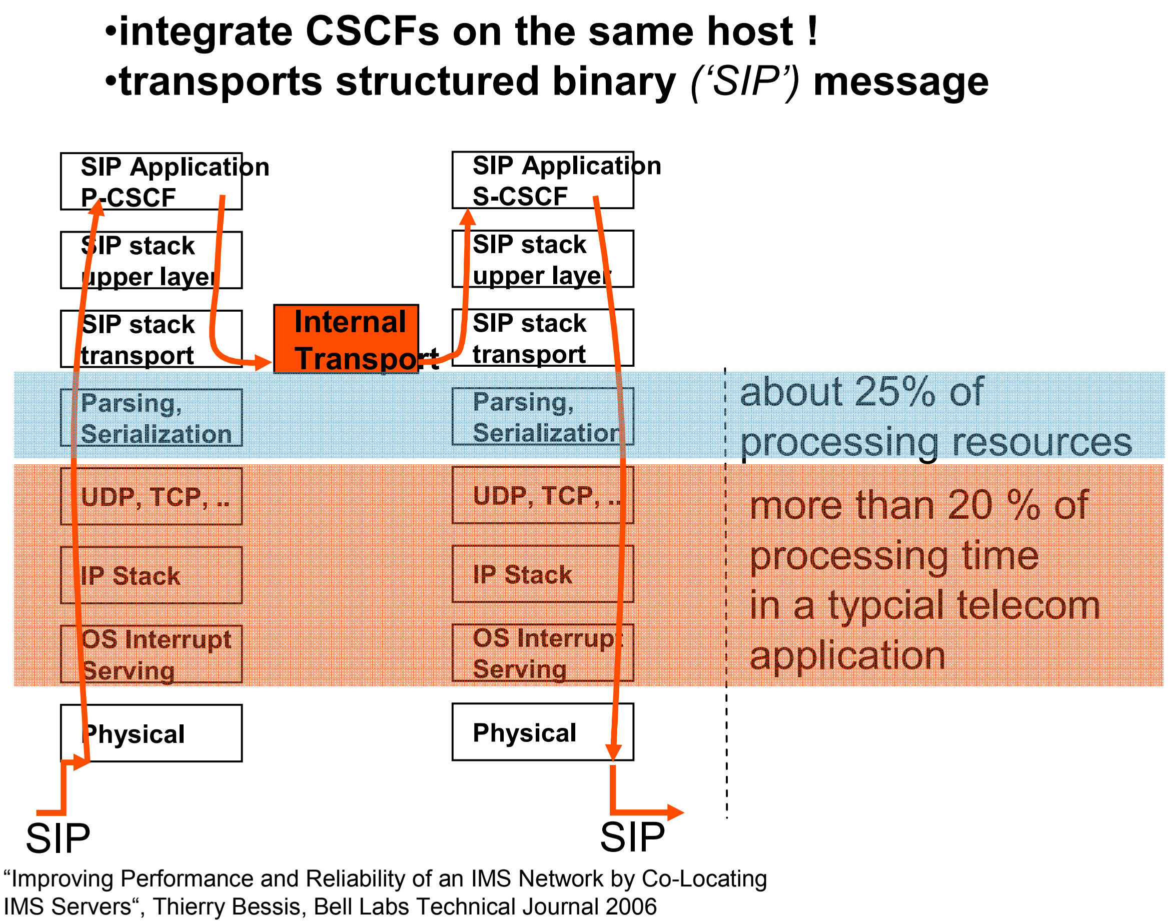



Figure 11: Optimized interface

### *2.4.2 Validations of improved message interface and co-located IMS functions*

With the simulation runs which have been performed, determine a network wide computational effort for different scenarios. These simulations compare a typical IMS architecture with the above described IMX architecture. The simulation results (Figure 12 and Figure 13) show that already with the above described improvements a gain of 29 – 31% can be achieved depending on the applied use cases.

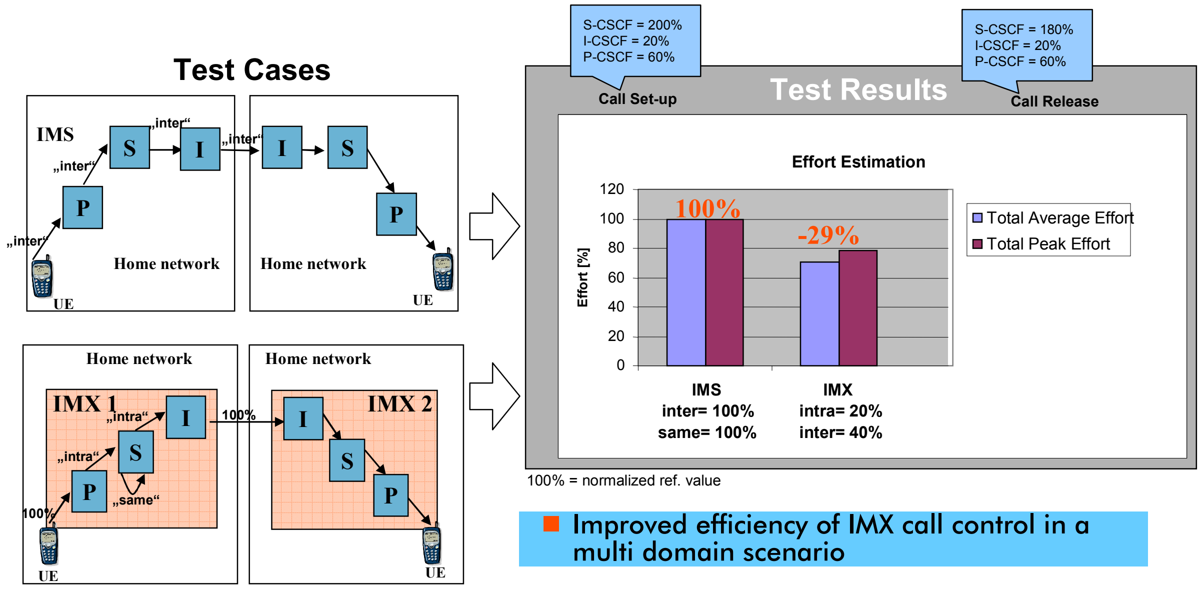



Figure 12: Call setup/release signalling effort applying an optimized IMX interface

Figure 12 and Figure 13 show on the left side the two compared architectures – test cases. On the right side – test results – the figures show the processing effort estimations for the compared architectures. Whereby, the IMS architecture is always used as reference architecture and its effort result value is normalized to 100%. The test results distinguish between the average and the peak processing effort to be spent to achieve a non- service blocking situation.

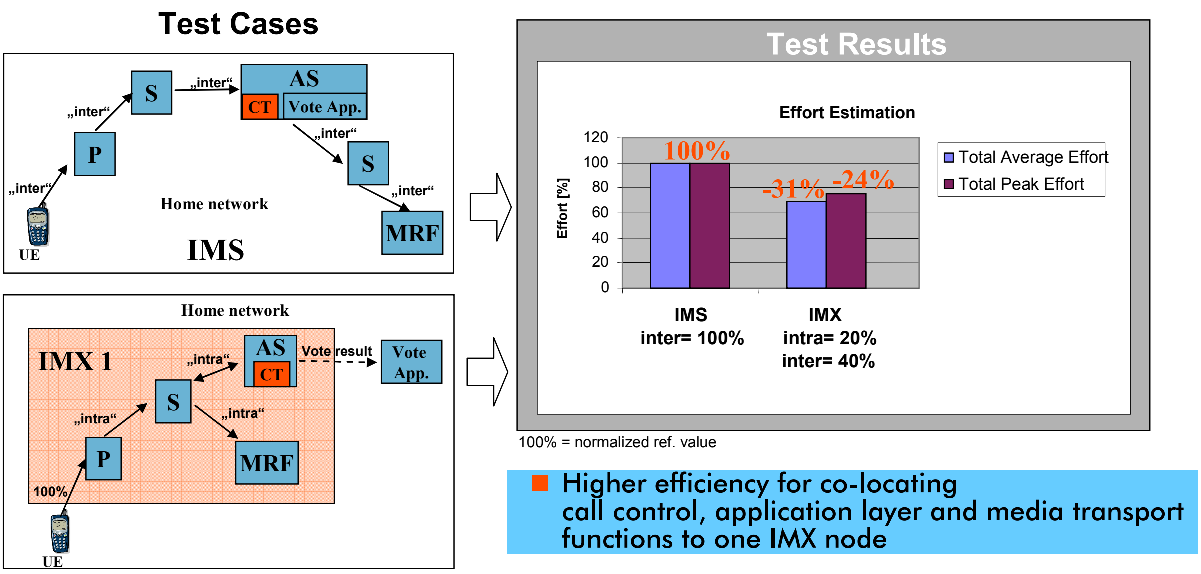



Figure 13: Effort estimation result from a test scenario using only televoting calls

In summary the described optimization steps are

- distributing the typical central functions (Softswitch, Application Server) into the IMX nodes located at the network edges
- improving the inter IMX node interface concerning processing effort

- grouping CSCF where rational

achieve for simple calls as well as for Application Server intensive service a processing effort advantage of about 30%.

### *2.4.3 Resource Manager*

#### *2.4.3.1 Resource Manager in an IMX domain*

Resource management in an IMX domain schedules the deployment of resources. The entities used in the IMX network are resources. Typically, a resource is a physical (hardware) network element limited in computation time, memory size and communication bandwidth (processing unit - blade). IMS functions are meant to be software modules that can be generally deployed on different classes of resources (see definition of resource box below).

IMS instances (CSCF or AS) consume computation time, memory and bandwidth of a resource. Instances have a minimum and maximum extent of resource usage, because the instance's actual utilized capacity might depend on its real-time configuration and may change over time.
As an IMX network has the characteristic of a very high dynamic network, i.e. self-adapting to constantly changing requirements, it needs a resource manager to schedule, locate and assign resources in the network.
In addition the IMX Resource Manager has to provide an efficient, failsafe and reliable redundancy concept for the resources in a network.

**Resource Definition:**

In an IMX context resource is the peripheral equipment, e.g. blade, for the runtime environment of an IMS function like CSCF or AS. A resource unit can be analyzed into three main hardware dimensions:

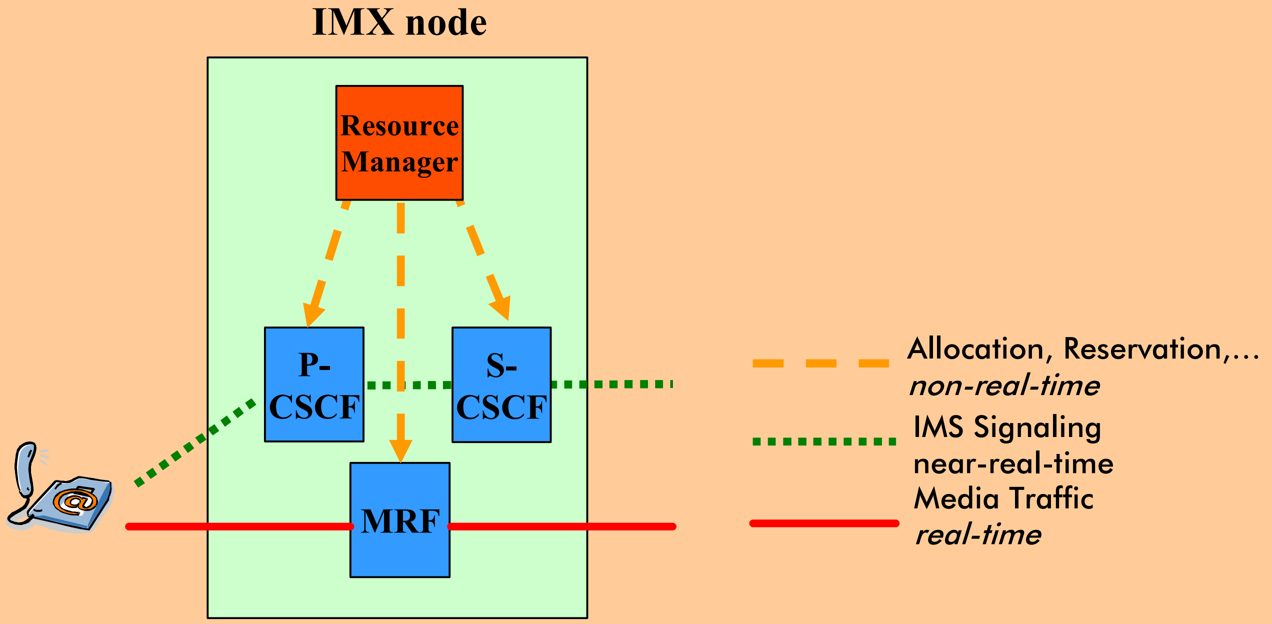
- CPU
- Memory
- Bandwidth

Depending on different requirements of an applied IMS function different classes of resources can be defined. There are three main resource classes in the IMX context:

- Media Resource (transcoding, IVR, …)
- Call Control Resource (P-,I-,S-CSCF,…)
- Application Server Resource (televoting, presence,…)

These three resource types differentiate in their necessary needed hardware. E.g. a media resource affords more hardware resources of all three kinds in contrast to an application server function which only needs a high computational speed and less memory and bandwidth.
As a resource provides the so called container (runtime environment) for an IMS function the resource has to guarantee hardware requirements which the different IMS functions need.

What is meant with real-time in an IMX environment?




In an IMS environment the requirement 'real-time execution' only applies to the processing of media streams, e.g. transcoding, by media resource functions. The red line in the figure above shows a media stream of an established call/session and thereby the IMS network cannot afford any delays.
The previous and on-going IMS signalling of an established call indicated by the dotted green line which traverses some IMS call control functions like CSCF or application server functions belongs to the near-real-time spectrum as a connection establishment requires a minimum of delay.

Allocating, reserving, balancing, shifting, calculating, etc. of IMS functions e.g. CSCF, AS, MRF is summarized in the term 'resource managing & organization' and illustrated by the orange dashed line. RM&O on local and between remote IMXs takes places previous and during a call or session and runs in background.
RM&O is done by the network function called "Resource Manager" and is a so called "pre-configuring" of the IMX network and its functions for a call or session.
Pre-configuring the network can be divided in two parts. First in the period "previous to a call" which means the RM expects a call or session and manages therefore the IMX network resources and second in the period where the IMX network proceeds an established call or session. Therefore the RM has to provide resources for scenarios like mobility or transcoding during the call or session.

For both periods RM&O runs in background and does not apply to the real-time requirement like a media function which is described above.
The next table shows what functions in an IMX network are time critical and which are not.
Note: The "time" requirement always belongs to the processing/execution of IMX functions like media, call control and M&O.

| requirement / IMS in a box function | resource management and organization | call control processing | media processing |
|---|---|---|---|
| non real-time | X | - | - |
| near real-time | - | X | - |
| real-time | - | - | X |

*2.4.3.2 Principle & Concept*

Introducing a Resource Manager in an IMX node and network requires some new premises in advance. In addition thereby the new selected – backup - CSCF can be located independent – on local or on remote IMX node - of the exchanged one. If a running CSCF function e.g. crashes a new one can continue to process immediately by the separation of logic and data.
Hereby the Resource Manager which is responsible to look for running, crashed, misbehaving, etc. resources can now dynamically exchange resource functions independent from their processing state at anytime by other resource functions These resources can also be exchange independent of their location.

Fast and efficient exchanging of resources becomes enabled first by the optimized interfaces between IMX nodes and second by the internal message representation initiated by the SIP parser. Both improvements were introduced and described in the previous chapter.
Due to these improvements there is nearly no effort difference if allocated or exchanged resources are located on local or on remote IMX nodes. Hence in prospect of IMX RM it does not depend where resources are located. But the preference where the RM allocates its resource is set to local, due to more efficient inter-communication (reduced number of messages).
It is advantageous to instantiate needed CSCF and other functions near to (or at) the IMX node where the user's terminal is connected to. Therefore a so called locality index of a resource indicates its location. By this locality index the load distribution procedure of the RM tries to distribute the load locally (IMX node) whenever necessary.

#### 2.4.3.3 Balancing Resource Scenario

The distribution of functions at the edges of the network (IMX nodes) and omitting central functions and servers has at first view the drawback that the multiplex gain is reduced. Under the requirement of non-blocking situation for all services, the system has to be designed in a way that each edge node must be capable to handle offered peak loads. Therefore hardware with enough processing effort has to be spent. The introduction of a (hierarchical) resource manager reduces the highest peak load at the IMX nodes by ensuring that the overflowed peak processing load could also be served by logical neighbour IMX nodes which do not experience the maximum peak load at the same time. Figure 14 shall illustrate the processing equalization process performed by the resource manager. With highest priority the resource management strategy allocates local resources and with a second priority tries to lean processing resources from other IMX nodes in the domain if the local resources are reaching a certain threshold. The design rule for the resource manager is not to find the optimum allocation of the resources across all IMX nodes but to reduce the peak loads at the IMX nodes with a restricted processing effort for the resource management algorithm. The strategy of the RM needs not to execute in real time to achieve an equalization of the allocated resources within the whole IMX domain. The consequence of this regulation process is that the IMX nodes are no more distributed stand-alone nodes but logical connected ones so that the resulting effect is similar to a single virtual IMX node.

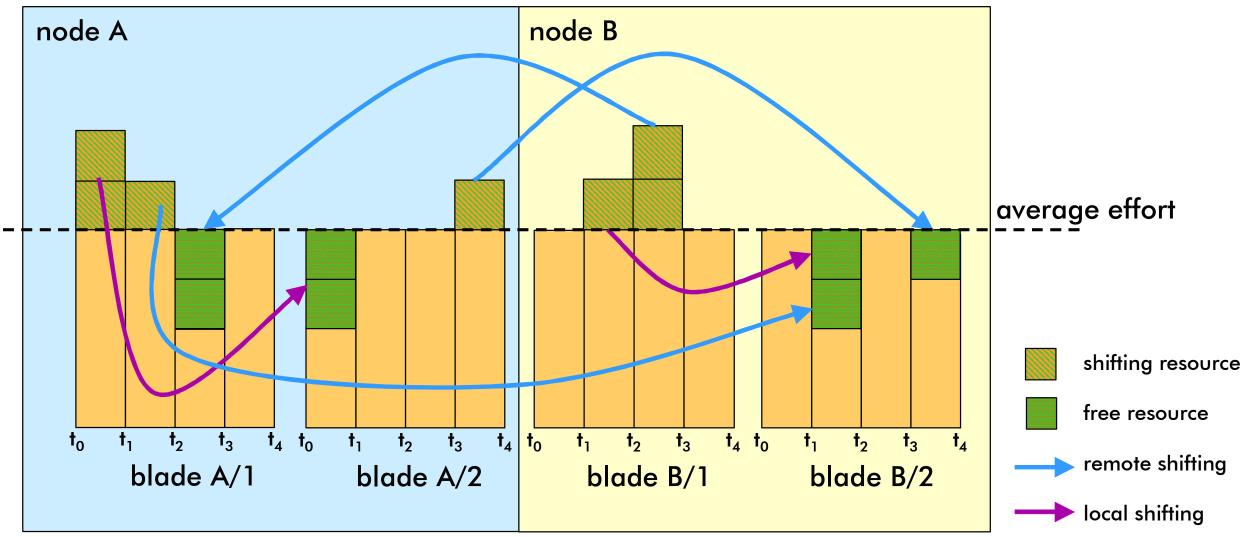



Figure 14: Resource management concept

Furthermore, the resource manager has control on different functions to be instantiated on the processing units and also on the amount of instantiations. Between the resource managers of the different IMX nodes a high level exchange protocol is introduced to request and allocate function instantiations.

### *2.4.4 Redundancy and APS*

Redundancy in an IMX environment can be divided in two separate topics which have two totally different redundancy concepts and targets:

- First the redundancy of single processing functions which are deployed, managed and dispatched by the IMX Resource Manager.
- Second the APS which handles a complete IMX node failure scenario. In this second IMX node redundancy concept only the failure of one single IMX node gets discussed as a second concurrent IMX node failure is improbable.

#### *2.4.4.1 Redundancy concept by the IMX Resource Manager*

By uncoupling the service execution logic functions (CSCF and AS) from the user specific call/session related data the IMX Resource Manager has the task to manage and optimize resources in an IMX domain. Hence it is easy to add the task of managing the redundancy of these single processing functions and call/session related data.
Therefore the IMX RM has to look for a free resource for a redundant copy of a call/session related data unit and a service logic unit on a local or a remote node. These redundant copies can be exchanged dynamically how it is described in the RM chapter. Thereby there is nearly no effort loss in IMX domain due to above described improvements of the internal message format and the internal interfaces. Hence single resource redundancy of service logic and call/session related data is solved inherent with the concept of the RM.
Lent resources from remote IMX nodes in a redundancy scenario get shifted back to the local node where the crashed resource was located.

#### *2.4.4.2 Active Protection System*

As mentioned before the APS just covers a single (complete) IMX node failure as more than one concurrent IMX node failure in an IMX domain is unlikely and has not to be discussed here.
The next figure shows how the node redundancy is solved by grouping clusters of IMX nodes. These clusters can be identified by closed curves using different colours and they indicate which IMX stands in for another failing IMX. The arrows indicate whereto an IMX node transfers its stable call states. Looking at one example in Figure 17, IMX nodes 1, 2 and 4 are building one cluster and it can be seen that IMX node 1 is protected by the nodes 2 and 4.

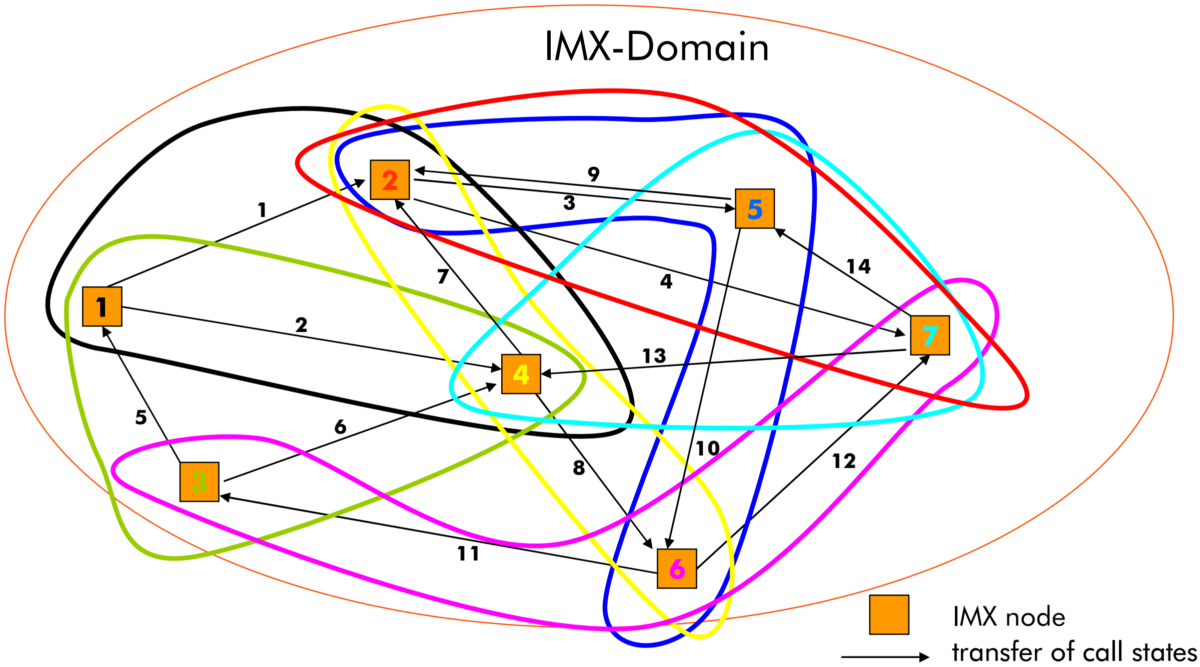



Figure 15: IMX redundancy clusters

The next figure (Figure 16) shows how each IMX node in the black framed cluster has an APS in front of itself and how the routing is solved via IP tunnels. If IMX node 1 goes offline or crashes, IMX node 2 or 4 plays via an additional tunnel with address IPx the backup for IMX node 1.

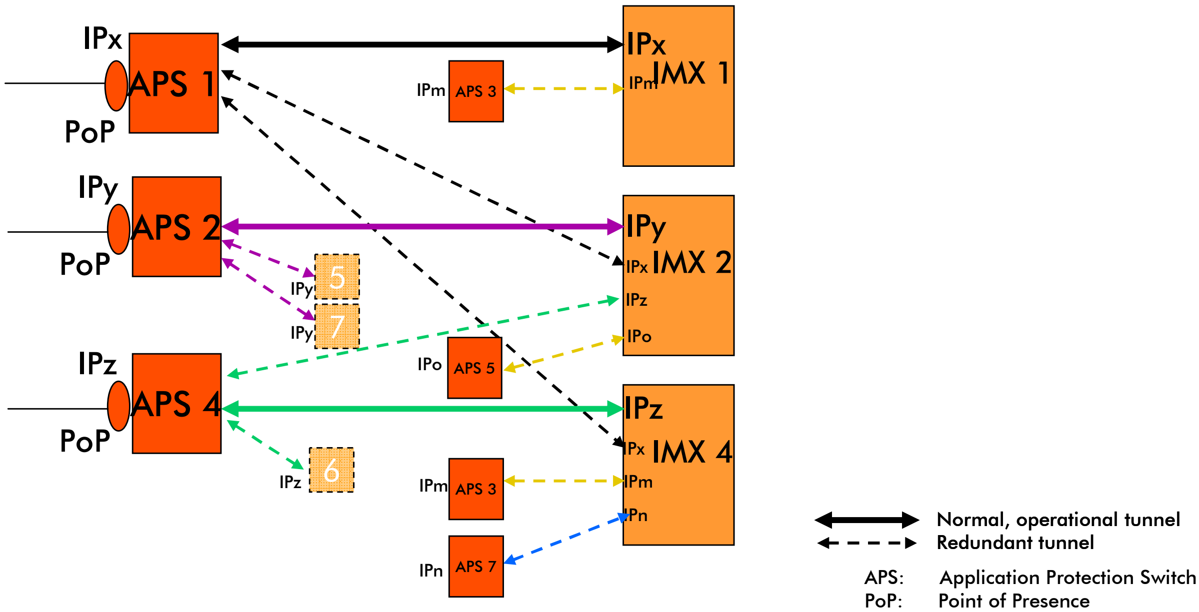



Figure 16: Example for an IMX redundancy cluster

The IMX domain protection system takes also as basis the separation of data and processing logic. Hence the protection concept has to look for a suitable backup for each of these units – data and logic, whereby a part of is done in the management system – defining the cluster and cluster sizes, calculation of the required resources for SLU and DSU. In the Figure 16 and Figure 17 the protection concept is illustrated within such an IMX redundancy cluster – exemplarily black-framed cluster with the nodes 1, 2 and 4. The arrows illustrate how the local call states get transferred to its redundant IMX node. For example IMX node 1 transfers its call states to node two and four.

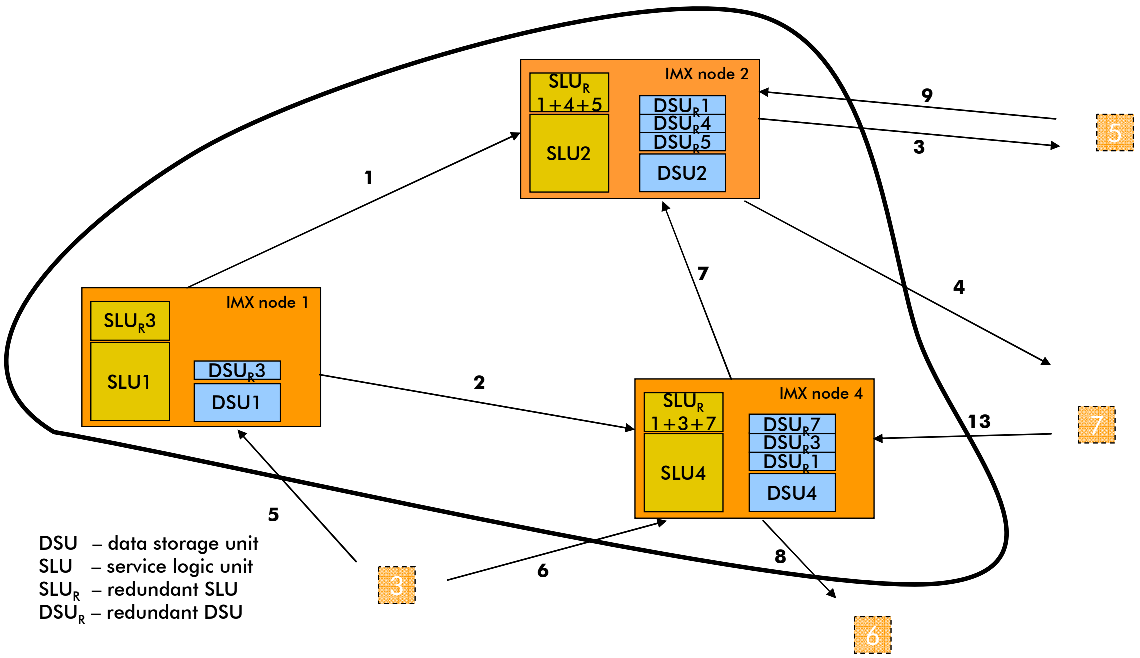



Figure 17: service logic and data unit redundancy

Exemplarily for the black framed cluster of Figure 15 IMX node four is one of the backup nodes for IMX node one. But IMX node 4 belongs also to other clusters (see Figure 15) and therefore builds the backup node for IMX node three and seven, too. As the processing logic (SLU) is not depending on any data (DSU), see chapter 2.4.3.2, it is adequate that node four just reserves once concurrently the SLU for node one, three and seven. This means that the same SLU resource block ($SLU_R$ 1+3+7) on node four stands in for SLU1, SLU3, and SLU7 (see green and turquoise framed cluster in Figure 15) independent of which IMX node fails. During the system planning for a deployment the expected peak processing performance for $SLU_R$ 1+3+7 is determined and added to the SLU4 performance value determining the total processing performance of the IMX node 4. The equalization effect of Resource Management (building one virtual IMX node out of the IMX nodes of the IMX domain) helps the calculated peak and average processing effort values being drawn nearer. With increasing cluster sizes whereby each IMX node has as is backup more than two other IMX nodes, the advantage for SLUs to be spent improves.

In contrast to the SLUs, each of the DSUs has to be fully backuped on one or several other IMX nodes. Hence this results in a one-to-one backup for DSUs and a less backup effort for SLUs.

A special case of the above described concept is the case where a single IMX node is designated as the backup IMX node. Then this backup node stores all the DSU information from all other IMX nodes and a single SLU (most performent of IMX nodes) has to be installed. Compared to the more general case described above an additional IMX node with processing units (SLU) has to be installed.
Recapitulating can be said regarding the whole IMX network that an IMX protection solution needs less backup resources as an active-active hot stand-by solution where the SLUs and DSUs get a one-to-one backup.

# 3 CONCLUSION

This deliverable presents the innovative concept of an optimized IMS, by implementing the standardized IMS functions in an innovative way by keeping the standardized external interfaces to other networks. An evolution from the concept of the packet-to-packet gateway developed during Phase I of MUSE (DB1.6) towards the Multi-Service Edge Router (MS-ER). The addition to the work performed in Phase I to reach the final goal of the MS-ER is called in this document IP Multimedia Exchange (IMX).

The main results out of this deliverable are:

- An evolution path from the eSBC (Phase 1) towards the IMX concept is described as well as the overall architecture of an IMX domain, meaning several IMX nodes build an IMX domain which is a specific implementation of the 3GPP/IMS system. In the context of the system description also resource management in an IMX domain as well as redundancy concepts are provided.
- An emulation and simulation tool has been designed for validating and verifying IMS like architectures and service scenarios. It provides means to configure easily the required network size and the amount of network domains. Application, call control and media layer functions can be arbitrarily grouped together building IMS network elements. For the proposed IMX concept the network elements are realized as a cluster solution, promising an overall optimized IMS deployment.
- The tool was used to evaluate standard IMS and the IMX (IP Multimedia eXchange) architectures applying various service scenarios. The evaluation results show a computational effort gain (based on parsing, call control, media processing and application logic) for the IMX architecture compared to the standard IMS architecture:
    - Depending on the network structure (single, multi domain, roaming) the effort reduction varies between 25% and 29%.
    - For the TeleVoting scenario in a single domain case the gain achieves 31%.
    - The IMX with co-located Application Server (AS) shows increasing gain (processing effort) with higher usage of supplementary services and AS functions.

The concepts described in DB1.10 will be transferred to MB1.10 to develop a prototype which will be integrated together with other network elements, developed in SPB, in an overall SPB demonstrator. The integrated lab trial results will be published in the document DB4.4.