Integration of sensor nodes with IMS

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To my parents, and brothers

Abstract

The number of users adopting cellular system technologies over the past years has been enormous. This rapid adoption is not comparable in any other technology. Additionally, this has meant that these users have (at least some of the time) the possibility of connectivity to others and to remote services (advanced data and voice services, such as video conferences, mobile TV, navigation, and location services). Increasingly there is no longer a clear boundary between the wide area cellular network and Internet services, as the wide area cellular network is evolving from circuit switched based technologies to an IP based system; hence these wide area cellular systems are simply becoming part of the Internet. This evolution has become a challenge for the telecommunication operators, who have been used to completely controlling their network services and billing. In an attempt to maintain this traditional role for telecommunication operators, telecommunication vendors have introduced the IP Multimedia Subsystem (IMS). A system designed to enable telecommunication operators to be able to bill the user for all of the different services accessed through the wide area cellular network. The goal of such a system is to prevent the telecommunication operators from becoming a "bit pipe" (i.e., simply providing "commodity priced" connectivity). Another relevant change that has direct impact upon this project is the role of mobile handsets as gateways between sensor networks and other networks (especially the wide area cellular networks or Internet). This has lead to integrated solutions, such as the smart house concept, mobile health monitoring, and others.

This thesis project is a collaboration between Ericsson Research and SUUNTO, in which we have implemented a system for monitoring a user’s heart rate via IMS. The system (has a special focus on sports activities, but it could easily be adapted for health care) is based on internetworking sensor networks, specifically a heart rate belt that transmits data wirelessly, with the IMS network through a mobile phone or a PC. The implemented service runs on top of the SIP Presence service. This project examines two alternatives. The first is a mobile scenario, in which a person is jogging outdoors, in this setting the sensor node communicates via the person’s mobile phone, through the IMS network to a monitoring application. The second scenario is more fixed; such as a gym environment, where the sensor node communicates with a personal computer which in turn publishes the data via IMS. Once the data has been published to the Presence and group management sever, an application server subscribed to the athlete’s Presence service will be notified. The people interested in viewing this data will be able to see it through any web-browser. It will even be possible to archive, and download the data for later use by other applications.

The system is not optimized yet for a truly real-time communication, as the Presence service does not offer this as other technologies (RTP, SRTP or XMPP) do. There is a big delay difference between the mobile and the fixed solution. We can say that the fixed solution is almost a real-time system for transmitting low frequency data as heart rate information. This project is a first approach to a final high performance system.

Sammanfattning

Antalet användare som har fått tillgång till mobiltelefon under de senaste åren har varit enorm. Detta snabbt antagande är inte jämförbar med någon annan teknik. Dessutom innebär också detta att dessa användare har (åtminstone ibland) möjligheten till anslutning till andra och till avlägsna tjänster (avancerad data-och taltjänster, t.ex. videokonferenser, mobil TV, navigation och lokaliseringstjänster). Idags läget finns det inte längre en tydlig gräns mellan cellulära nätet och Internettjänster. Efter cellulära nätets utveckling från kretskopplad teknik till ett IP-baserat system, så håller dom cellulära systemem på att bli en del av Internet. Denna utveckling har blivit en utmaning för telekommunikationsföretag, som har varit vana att helt kontrollera sina nättjänster och fakturering. I ett försök att bevara denna traditionella roll för telekommunikationsföretag, har telekom-leverantörer infört IP Multimedia Subsystem (IMS). Ett system som syftar på att kunna göra telekommunikationsföretagen kapabla till att debitera användaren för alla dem olika tjänsterna som han har tillgång till via deras cellulära nät. Målet med ett sådant system är att förhindra telekommunikationsföretagen från att bli en "bit pipe" (dvs bara ge prissatt konnektivitet). En annan betydelsefull förändring som har direkt inverkan på detta projekt är den roll som mobiltelefoner kan utföra som gateways mellan sensornätverk och cellulära nät eller Internet. Detta har påverkat flera integrerade lösningar, såsom smarta hus begrepp, mobil hälsoövervakning och andra.

Denna examensarbetes projekt är ett samarbete mellan Ericsson Research och Suunto, där vi har implementerat ett system för övervakning av en användares hjärtslag genom IMS. Systemet (har en särskild inriktning på sport, men det kan lätt anpassas för hälso-och sjukvård) är baserad på Internetworking sensornätverk, särskilt en hjärtfrekvens bälte som överför data trådlöst till en mobiltelefon eller en dator, som sedan skickar ut datan via IMS-nätverket. Tjänsten genomförs ovan på SIP Presence service. Projektet undersöker två alternativ. Den första är en mobil scenario; exempelvis där en person joggar utomhus, vid ett sådant tillfälle kommunicerar sensorn noden genom personens mobiltelefon, via IMS-nätverk med en övervaknings application. Det andra scenariot är mer statiskt och ger inte samma rörlighet, denna lösning passar bättre in på gym activiteter eller liknande. I denna implementering kommunicerar sensorn noden med en persondator som i sin tur publicerar uppgifterna via IMS. När uppgifterna har publicerats hos Presence and group management (PGM) servern. En applikations server som är uppskriven på att få friidrottarens närvaro tjänst kommer att meddelas. De människor som intresserade av att se denna data kommer att kunna göra det via någon webbläsare. Det kommer även att vara möjligt att arkivera och hämta datan för senare en användning men andra tillämpningar.

Systemet är inte optimerad ännu för en verkligt realtid, eftersom Presence service inte erbjuder detta ännu som andra tekniker (RTP, SRTP eller XMPP) gör. Det finns en stor fördröjning skillnad mellan den mobila och fasta lösningen. Vi kan säga att den fasta lösningen är nästan ett realtids-system för överföring av lågfrekventa uppgifter som hjärtslag information. Detta projekt är en första strategi för en slutlig högpresterande system.

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I would like to thanks *Professor Gerald Maguire* for all his great help and support. I want to give my thanks to the people at Ericsson, especially *Gonzalo Camarillo* who gave me the opportunity to work on this project, and for his continuous support at all levels. I would also like to thanks *Tomas Mecklin, Heidi-Maria Rissanen, Oscar Novo*, and *Miljenko Opsenica* for their help.

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Glossary

3G	Third generation
3GPP	Third Generation Partnership Project
3GPP2	Third Generation Partnership Project 2
AAA	Authentication, Authorization and Accounting
AKA	Authentication and Key Agreement Protocol
ANSI	American National Standards Institute
AS	Application Server
AUTN	Authentication Token
B2BUA	Back to Back User Agent
BICC	Bearer Independent Call Control
BGCF	Breakout Gateway Control Function
BSF	Bootstrapping Server Function
BSN	Body Sensor Networks
CAMEL	Customized Applications for Mobile network Enhanced Logic
CENS	Center of Embedded Networked Sensing
CK	Cipher Key
CN	Core Network
CODEC	Coder/Decoder
CSCF	Call Session Control Function
CVD	Cardio Vascular Diseases
ESP	Encapsulating Security Payload
GBA	Generic Bootstrapping Architecture
GGSN	Gateway GPRS Support Node
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
HFMS	Heart Failure Management System
HLR	Home Location Register
HRM	Heart rate Monitor
HSS	Home Subscriber Server
HTTP	Hypertext Transport Protocol
IBCF	Interconnection Border Control Function
I-CSCF	Interrogating-Call Session Control Function
IDE	Integrated Development Environment
IETF	Internet Engineering Task Force

IK	Integrity Key
IM	Instant Messaging
IMS	IP Multimedia Subsystem
IMSI	International Mobile Subscriber Identity
IM-SSF	IP Multimedia Service Switching Function
IMS-MGW	IP Multimedia Subsystem-Media Gateway
IPsec	IP Security
ISIM	IP Multimedia Subscriber Identity Module
ISUP	ISDN User Part
ISWC	International Symposium on Wearable Computers
LDAP	Lightweight Directory Access Protocol
MAA	Multimedia Authentication Answer
MAR	Multimedia Authentication Request
MEGACO	Media Gateway Control Protocol
MGCF	Media Gateway Control Function
MPA	Mobile Phone Application
MRF	Media Resource Function
MRFC	Media Resource Function Controller
MRFP	Multimedia Resource Function Processors
MSC	Mobile Switching Center
NAF	Network Application Function
NAI	Network Access Identifiers
OMA	Open Mobile Alliance
OSA-SCS	Open Service Access-Service Capability Server
PA	Presence Agent
PC	Personal Computer
P-CSCF	Proxy-Call Session Control Function
PDA	Personal Digital Assistant
PDF	Policy Decision Function
PGM	Presence and Group Management
PSTN	Public switched telephone network
PUA	Presence User Agent
QoS	Quality of Service
RAND	Random challenge
RLS	Resource List Server
RTCP	Real-Time Transport Control Protocol
RTP	Real-time Transport Protocol

SAA	Server Assignment Answer
SAR	Server Assignment Request
S-CSCF	Serving-Call Session Control Function
SDP	Session Description Protocol
SGSN	Serving GPRS Support Node
SGW	Signaling Gateway
SIM	Subscriber Identity Module
SLF	Subscriber Location Function
SMTP	Simple Mail Transport Protocol
SPP	Serial Port Profile
SPU	Signaling and Processing Unit
SQN	Sequence number
SRTP	Secure Real-time Transport Protocol
SSI	Simple Sensor Interface
UA	User agent
UAA	User Authentication Answer
UAC	User Agent Client
UAR	User Authentication Request
UART	Universal Asynchronous Receiver/Transmitter
UAS	User Agent Server
UE	User Equipment
UICC	Universal Integrated Circuit Card
URI	Uniform Resource Identifier
USIM	Universal Subscriber Identity Module
VLR	Visited Location Register
XCAP	XML Configuration Access Protocol
XRES	Expected Response

1 Introduction

The number of users of the cellular phone systems has increased very rapidly over the past years. Today almost every person has accesses to mobile telephony services. In most of the cases users have connectivity to others and to remote services (such as video conferencing, mobile TV, navigation, and location-based services). Increasingly there is no longer a clear boundary between the wide area cellular network and Internet services, as the wide area cellular network is evolving from circuit switched based technologies to an IP based system; hence these wide area cellular systems are simply becoming part of the Internet. This evolution has become a challenge for the telecommunication operators, who have been used to completely control their network services and billing. In an attempt to maintain this traditional role for telecommunication operators, telecommunication vendors have introduced the IP Multimedia Subsystem (IMS) (See chapter 2). A system designed for the telecommunication operators to be able to bill the users for the different services accessed through the wide area cellular network. The goal of such a system is to prevent the telecommunication operators from becoming just a “bit pipe”.

Another relevant evolution, related to mobile phone systems is the role of mobile handsets as gateways between sensor networks, and wide area cellular networks or Internet. This leads to for example: integrated solutions, such as the smart house concept, mobile health monitoring, and others. Body sensing and monitoring for health care has gathered the attention of both the research community [4; 5] and governmental authorities [6], the interaction between these body sensing networks and mobile phones is crucial for real-time monitoring of chronically ill patients, it offers the health care provider the possibility of up to date information, then based on this data they can provide feedback and guidance to the patient, in order to help the patient in their daily life.

This thesis work project is a joint project between Ericsson Research (Lars Magnus Finland) and SUUNTO. It explores the field of body sensing and monitoring (in a sports activity context, but it could easily be adapted for health care). The objective is to sense a person’s heart rate through a sensor chest belt that computes and transmits data wirelessly to a mobile phone or a PC, where the data is processed and forwarded to a Presence and group management (PGM) sever allocated in the IMS network, using the SIP Presence service publish mechanism. The PGM in turn notifies an application server of each update. This application server can be accessed from any web-browser, and the data can be viewed in a graphical form or downloaded from the server to be used with other applications. Details of these technologies will be presented in Chapter 2.

Two alternatives are examined. The first one is a mobile scenario, in which a person is doing an outdoor sports activity that requires mobility, in this situation the sensor node communicates via the person’s mobile phone, through the IMS network to the monitoring application. The second scenario is meant to be used for indoor activities, in a scenario where the user will have reduced mobility in terms of distance; such as a gym environment, where the sensor node communicates wirelessly with a personal computer which in turn publishes the data via IMS. Once the data is available via IMS, this solution is the same as the previous solution. The software development related to this project has been done within the scope of Ericsson Research's HiFive [7] project, which is the first real IMS environment that is publicly available for developers. This thesis work project is meant to be a proof of concept *application* for the HiFive project.

When comparing this project with other products already existing in the market or with known prototypes, we believe that within the field of athlete monitoring this is one of the more advanced systems. However, there are systems for non-real-time monitoring that are far more sophisticated. One of its major features is that it exploits the SIP Presence service for data transfer which is standardized; this gives our service the potential to be easy integrated to other presence aware services or applications. This solution exploits the concept of community data sharing, making information available for other users. While sharing of data is interesting and has been proposed (and done) by others - such as Runner+ [8], the real-time communication of sensor data is very handy for closely monitoring an athlete. The systems developed for health care vary widely and are normally more advanced when it come to the sensor nodes. Additionally, they commonly use wearable sensors that are incorporated to the user's garment and often utilize multiple sensors in order to monitor several vital signs. Many of these systems lack mobility, but there a few that are very highly integrated and offers full mobility. A difference between these systems and ours is the chosen communication technology. A discussion of these other systems will be given in Chapter 3.

This thesis project report is divided into 6 chapters; Chapter 1 is the introductory chapter. Chapter 2 gives a background of the different technologies used for building the project's system. Chapter 3 shows the state of the art for body sensing and monitoring systems, analyzing the commercially available products for physical training, environmental sensing, and healthcare systems for patient monitoring. Chapter 4 describes the two implemented solutions (fixed and mobile) for this system, going through the components, design, functionalities, and methodology. In chapter 5 we make functionality and performance tests over the system, after which we analysis of the results. Chapter 6 is the final chapter in this thesis project report; here we go through the conclusions and possible future work.

2 Background

This chapter gives a brief description of the technologies which were considered for use in this thesis project. This chapter and the cited references are intended to provide sufficient background for those with some familiarity with Internetworking.

2.1 IP Multimedia Subsystem

IP Multimedia Subsystem (IMS) combines the mobility of wide area cellular networks and the functions of an IP network. It is based on a number of protocols, including SIP (see section 2.2.1), to provide voice services as well as data services to mobile devices in real time over third generation (3G) wide area cellular networks. IMS is a key element for the operators of cellular networks using the 3G architecture; this technology gives the operators a means through which they will be able to control and bill the subscriber for the services that the subscriber's have utilized in both the IMS network and the Internet. [9]

2.1.1 IMS Standardizations bodies

The Third Generation Partnership Project (3GPP) standardization effort encompasses a series of standards specifying the radio, core network, and service architecture. This effort is to support the evolution of the Global System for Mobile Communications (GSM) specifications. 3GPP has standardized its version of IMS.

The Third Generation Partnership Project 2 (3GPP2) is the standards body that develops the standards for third generation mobile telecommunications systems for the American National Standards Institute (ANSI) community. 3GGP2 has standardized its own version of IMS. [9]

3GGP and 3GGP2 both use Internet protocols. Traditionally these protocols have been standardized by the IETF. Consequently, both 3GGP and 3GGP2 collaborate with the IETF to develop protocols that fulfill their requirements. In addition, to these standardization bodies, the Open Mobile Alliance (OMA) [10] has played an important role in the development of IMS services. OMA focuses on the standardization of service enablers on top of the IMS, focusing on interoperability between mobile terminals, operators, and countries.

2.1.2 IMS service overview

The idea behind IMS is to provide a versatile set of services **without loosing control of the subscriber’s communication**, in order to be able to bill for each service, rather than only for the use of the communication medium. The hope of the telecommunication vendors and operators is that new services will be quickly deployed due to the flexible architecture of IMS.

Operators in some countries have already deployed IMS services, Telefónica SA started to implement IPTV over IMS in 2006 for their “Imagenio” IPTV service concept [11, 12]. By the end of 2007 Com Hem released the first commercial IMS-platform for the Swedish telecommunication market to support their VoIP services and next generation IP-telephony [13]. Note that Com Hem's service is used on their cable TV network. Other services that are being deployed using IMS are the following:

Telephony services IMS is expected to enhance current wireless **and** wired line telephony technologies. For this reason, IMS provides common telephony services such as call forwarding, call waiting, and call barring.

Presence Some applications will be *presence-specific* applications, such as a phonebook showing presence information for all contacts and *presence-enhanced* applications such as push-to-talk (which enables a user to interact with a logical group of users who are all available at the same time).

IMS messaging There are currently 3 forms of IMS messaging:

- Immediate messages or instant messages,
- Session-based messages, and
- Deferred delivery messages

Conferencing Conferencing is currently provided by many instant messaging applications. Conferencing has mainly focused on video/audio transmission and reception to emulate face to face conversations between two or more parties. IMS utilizes the so called “tightly coupled conference” approach; as defined in 3GPP’s technical specification TS24.147 [14]. In tightly coupled conferences each party has a connection to a central point (a conference bridge) that offers services such as media mixing and participant list notifications.

Push-to-talk Push-to-talk is a service similar to walkie-talkie, as users are able to initiate a voice transmission by simply pressing a button, and upon releasing the button it ends. Unlike regular voice services push-to-talk is half duplex, it simply means that a user transmits without having a return channel - it is up to the receiver to decide how many such transmissions that they listen to. A push-to-talk session can have more than two participants, but only one can speak a time the rest are only listeners. Push-to-talk can run on top of low bandwidth and high delay links, and it doesn't require deployment of new radio technologies. This service is already available in many telecommunications operators network over the world, an example is [15].

Content sharing Content sharing allows users to immediately send multimedia content to a certain contact. To make this kind of service more attractive, the services are normally implemented together with presence services, thus users are be able to see who is online and share video, audio, or image information with their *on-line* contacts.

Some of the services presented in this section are currently under development, while others services such as push-to-talk have been used for a period of time. What is important to understand is that these services seek to take full advantage of the mobile device's hardware, so that customers can communicate in a greater variety of ways. [16]

Note: *IMS is not essential to these services, since they can be implemented on top of SIP and the Internet without using IMS. The services are likely to first appear in the Internet, as there is a lower barrier to new service deployment in the Internet than in each vendor's IMS network. Additionally, the lack of interworking between IMS networks is likely to delay the wide spread adoption of services.*

2.1.3 IMS architecture

In this section, the IMS entities and their key functionalities will be introduced. The 3GPP standards do not describe how IMS entities interact; instead they define reference points between entities and they define the functionality supported by each entity. [17] All the functions and reference points to be mentioned in this section can be observed in figure 1.

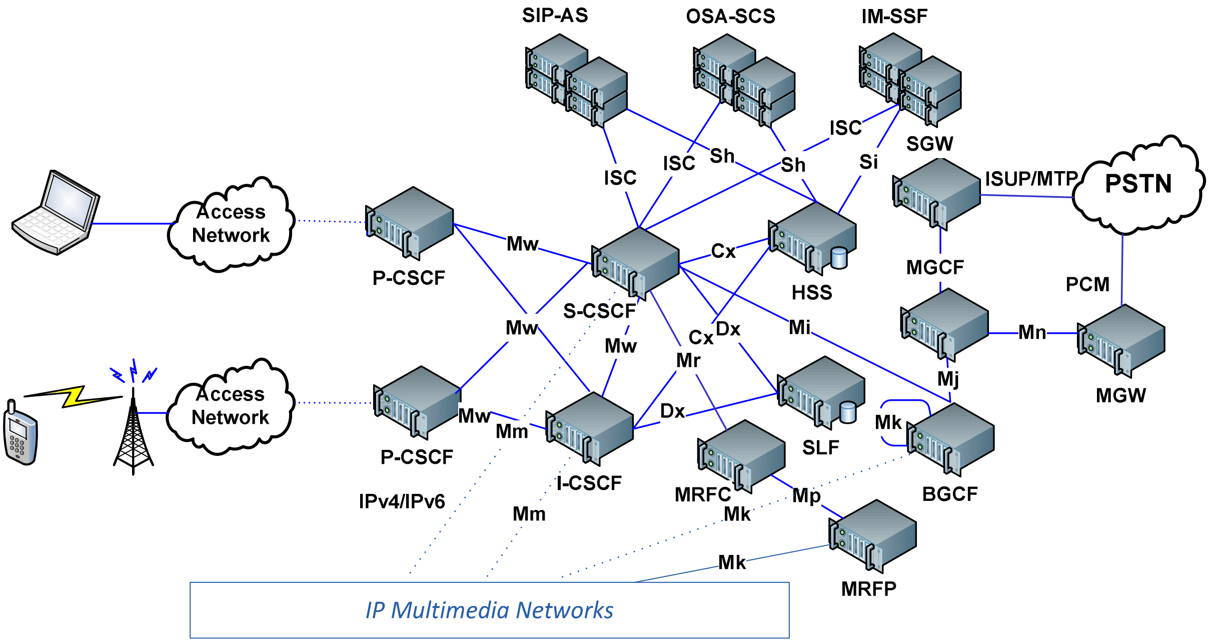


Figure 1: IMS architecture

Call Session Control Function (CSCF) is a SIP server and a *fundamental* entity in the IMS architecture. Most of the SIP signaling within the IMS is processed by a CSCF. The CSCF functionality is divided into three different clusters of functions: the P-CSCF, the I-CSCF, and the S-CSCF.

- The **Proxy-Call Session Control Function (P-CSCF)**, is the first point of contact for each user in the IMS architecture. The entire SIP signaling traffic to and from the user terminals goes via the P-CSCF. The P-CSCF acts as an inbound/outbound proxy server that has the ability to validate requests, process requests, and forward responses. The P-CSCF can also compress and decompress SIP messages (in cooperation with the terminal). P-CSCF implements security functions towards the IMS terminals based on IPsec, these features are further describe in section 2.5.

  The P-CSCF can be located either in the subscriber's home network or in a visited network. If the underlying packet network is based on General Packet Radio Service (GPRS), then the P-CSCF will always be located where the user's Gateway GPRS Support Node (GGSN) is located. The P-CSCF may contain a Policy Decision Function, either integrated with the P-CSCF or implemented as a standalone unit.

  The **Policy Decision Function (PDF)** is responsible for policy decisions based on session and media-related information obtained by the P-CSCF. It acts as a policy decision point for service-based local policy control. An example of its functions could be to enable the use of an authorized bearer for specific traffic (for example, in order to implement better than best effort service - of course this would entail higher charges).

- The **Interrogating-Call Session Control Function (I-CSCF)** is a SIP server that provides an entry point to an operator's IMS network. In an operator's network there may be multiple I-CSCFs. The I-CSCF address can be listed as an external address of an IMS network in DNS domain records for this IMS operator's domain. The I-CSCF is involved in the registration process as it assigns a S-CSCF to a user when performing SIP registration. The I-CSCF also takes part in session-related and session-unrelated flows**,** for example when obtaining the address of the S-CSCF from Home Subscriber Server (HSS) or when routing SIP requests received from another networks towards the responsible S-CSCF. The I-CSCF can be involved in charging for resource utilization by generating appropriate call data records.

Note: *If border control is applied, then the contact point for an operator's network may be different, this is explained below.*

- The **Serving-Call Session Control Function (S-CSCF)**, is the core of IMS; it provides the logic to invoke and manage the application servers as needed to deliver the requested services. This entity is located in the subscriber's home network, it interacts with the HSS in order to determine the subscriber's service eligibility by downloading the subscriber's user profile, it also provides session control and registration services for User Equipment (UE), i.e., terminals/handsets. It maintains a mapping between the user agent's location (IP address of the user terminal) and the user's SIP URI, for further details see [9].

The **Interconnection Border Control Function (IBCF)** may be applied between two IP Multimedia core network (CN) subsystems or between an IP Multimedia CN subsystem and other SIP based multimedia networks. If IBCF is implemented in an IMS network, it will acts as an entry point for this network (instead of the I-CSCF), and it will also be the exit point of this network. An IBCF can provide the following functions:

- Control of transport plane functions.
- Supports functions that allow establishing communication between IP Multimedia CN subsystems using different media CODECs based on the interworking agreement and session information.
- Network configuration hiding to restrict information from being passed outside of an operator's network, such as: number of S-CSCFs, capabilities of S-CSCFs, or capacity of the network.

- Screening of the SIP signalling information based on source/destination and operator policy (e.g. remove information that is of local significance to an operator).
- Generation of Call Data Records.
- Invocation of an interworking function in operations between different SIP profiles or different protocols (e.g., SIP and H.323) is necessary; in this case the interworking function acts as an entry point for the IMS network;

Note: *The IBCF and I-CSCF may be co-located as a single physical node. Network configuration hiding was not intended to be invoked in IMS roaming scenarios when the P-CSCF and IBCF are both located in the visited network. The interworking function is not specified within the latest release [18] of the specification.*

An **Application server (AS)** is a SIP entity that hosts and implements services. It will operate in different modes depending on the service. For example, it could operate as a SIP proxy, User agent (UA), or back-to-back user agent (B2BUA). An AS is built upon three different types of functions:

- **SIP AS** (the native AS) hosts and implements SIP based IMS services.
- **Open Service Access-Service Capability Server (OSA-SCS)** acts as an interface to the Open Service Access (OSA) framework. It provides secure access to IMS from visited networks.
- **IP Multimedia Service Switching Function (IM-SSF)**, with this AS an operator is able to offer access to services based on the Customized Applications for Mobile network Enhanced Logic (CAMEL) Service Environment. This is further described in [19].

An AS can reside in the home network or in a visited network. However, if the AS is located in a visited network, it will not have an interface to the subscriber's HSS.

The **Home Subscriber Server (HSS)** is a secure database. It stores the subscriber's user profile information, provides identity management, and user status (both presence and location(s)). This information is predominantly accessed by the S-CSCF for validation of the subscriber and to determine authorized service capabilities. The I-CSCF and the application servers also have access to the HSS database. The HSS is an evolution of the Home Location Register (HLR). If there are several HSSs in a domain, a Subscriber Location Function (SLF) is required. The SLF is simply a database that indicates in which HSS a subscriber's user profile is located. This is further described in [9].

Note: *The remaining IMS functions are not of relevance for this thesis project, but if the reader is interested, more detailed information can be found in [9].*

2.2 Protocols used in IMS

3GPP has adopted a number of different protocols, each with their specific usage and functionality for IMS. The most relevant protocols for this thesis work will be mentioned below.

2.2.1 Session Initiation Protocol (SIP)

The SIP protocol's latest specification is contained in the Internet Engineering Task Force (IETF) SIP Working Group's RFC 3261 [20]. SIP is a text-encoded protocol based on elements from the Hypertext Transport Protocol (HTTP) and the Simple Mail Transport Protocol (SMTP). SIP's main purpose is to manage sessions, specifically to establish, modify, and terminate multimedia sessions. An example of a session would be an Internet telephony call. SIP can also be used to invite participants to existing sessions, such as conferences. Media streams can be added or removed from an existing session; this media can be audio, video, text, etc. SIP transparently supports name mapping and redirection services, these features enable user mobility. Therefore users can maintain a single visible identifier regardless of their network location. A typical SIP system is based upon three main elements: SIP User Agents, SIP servers, and location servers. For detailed information the reader is encouraged to read the latest SIP RFC [20], as updated by RFC 3853[21] and RFC 4320 [22].

SIP Network elements

User Agents (UA) are the end components in a SIP network. They make SIP requests to establish media sessions; they may also send and receive media. A UA can be a SIP phone or SIP client software installed on a PC or other system. UAs generally contain both a client and a server part. The UA client (UAC) generates SIP requests, while the UA server (UAS) responses to received SIP requests.

SIP servers are SIP intermediaries that are located within a SIP network (i.e., the network of devices which understand SIP). These servers assist the UAs in session establishment and in other functions (such as routing of SIP requests and responses). SIP servers can be divided into Proxy servers, Redirect servers, and Registrar servers.

- **Proxy servers** receive SIP requests from UAs or other proxies and forwards or proxy the request to another destination. A proxy server can also authenticate and authorize users for services, implement provider call-routing policies, and assist users with features that will control the behavior of the proxy for subsequent sessions (for example, defining what is to be done with calls from a certain source, defining what is to be done with calls at different times or the day or on different days, etc.).

- **Redirect servers** send routing information back in response to a client's request, thereby redirecting further messages related to this request (for example, when a user's proxy has moved to a new location because the callee has changed SIP provider). When the originator of the request receives the redirect, it will send a new request to a different address, based on the Uniform Resource Identifier (URI) it has received from the redirect server.

- **Registrar servers** receive SIP registration requests from a UA and update the user's location information (by storing the new location at a location server), this information is used by the proxy servers when they wish to locate the user's current user agent(s).

SIP proxies, redirect, and registrar servers are purely logical SIP elements. They have no media capabilities and do not initiate requests - except on behalf of UAs. They can be implemented in one machine or replicated over many nodes (for increased reliability, availability, and capacity).

Location servers are not SIP entities, but they are an important part of a SIP network's architecture. A location server stores, and returns the location(s) of the user's user agent(s) when queried by a SIP server. The location server can make use of information from registrars or other databases. Most registrars upload location updates to a location server upon reception of new location information. The location server's database may store information about the user's user agent(s) such as their URIs, IP addresses, features, and other information. It may also contain routing information.

UAs do not interact directly with the location server, but rather do so via a registrar server. SIP servers use a non-SIP protocol to query, update, and retrieve records from the location servers (some servers uses the Lightweight Directory Access Protocol (LDAP) [23]).

SIP Request

The standard SIP implementation implements 6 different methods, but there are several extensions to the standard that have been implemented over the years, adding features enabling richer communication capabilities (e.g., Presence services and Instant messaging (IM)). SIP requests consist of headers and a message body. The standard SIP methods are shown in table 1.

Table 1: SIP Methods

Method	Description
INVITE	Session setup
ACK	Acknowledgment of final response to
BYE	Session termination
CANCEL	Pending session cancellation
REGISTER	Registration of a user’s URI
OPTIONS	Query of options and capabilities

INVITE This request is used to invite a user’s to participate in a session. The INVITE body contains a description of the session.

BYE This request is used to leave a session. When the session is only a two-party session, a BYE message will cause the session to end. In a multicast scenario, however, a BYE request from one of the participants simply indicates that a particular participant has left the session, but the session itself is not affected, unless this was the last participant - in which case the session should be terminated.

CANCEL This request terminates pending transactions. If a SIP server has received an INVITE, but has not returned a final response, then the CANCEL message will stop the server from processing the INVITE; but if the final response for the INVITE has already been returned, then the CANCEL request will have no effect on the transaction.

REGISTER The REGISTER request is used when a user wants to inform their SIP domain of the current location of one of this user's UAs. This is done by sending a REGISTER requests to a registrar server. The information that the registrar receives through the REGISTER request is stored in this SIP domain's location server(s), thus making the new information available for other SIP servers in this SIP domain. The registrar service offers flexibility, for instance a user can register a location until a certain time of the day, and after that the calls will be redirected to another of the currently registered locations.

OPTIONS This request is used to query a server about its capabilities. For example, what methods, encodings, and session description protocols it supports.

SIP Response

Many of the SIP response codes have been inspired by HTTP. The SIP response codes are divided into six classes, identified by the first digit of the code, as shown in table 2.

Table 2: Response codes

Class	Description
1xx	**Provisional or Informational** — Request is progressing but not yet complete.
2xx	**Success** — Request has been completed successfully.
3xx	**Redirection** — Request should be tried at another location.
4xx	**Client Error** — Request was not completed because of an error in the request, can be retried when corrected.
5xx	**Server Error** — Request was not completed because of an error in the recipient, can be retried at another location.
6xx	**Global Failure** — Request has failed and should not be retried again.

SIP session setup

Figure 2 illustrates a SIP session setup procedure. In this example a user called Bob registers his location through a REGISTER request (message 1) with the Registrar server, which updates its location server. The Registrar server acknowledges Bob's UA's registration (message 2).

When later Alice tries to call Bob (using SIP URI bob@example.com), her UA must first find the proxy server that can handle the request, this is done by querying a DNS server to find the in-coming SIP proxy for Bob's SIP domain, based upon the string to the right of the at-sign in Bob's SIP URI (message 3). An INVITE request (message 5) is forwarded to the proxy server who must decide where to forward the request; the proxy first queries (message 7) the location server to determine the callee’s current location(s). If the proxy server can at this stage directly forward the request, it will, otherwise it will query (message 9) a DNS to resolve the domain’s address, this may result in forwarding the request to another proxy server, that will repeat the process (not shown in the figure).

Once the address of Bob’s UA is determined, the INVITE request (message 11) is forwarded to the UA(s). The session is considered successfully established after a three way handshake is complete, steps from (message 11) to (message 15). In step (message 16) the data session is initiated directly between Alice's UA and Bob's UA (probably using RTP or SRTP – mentioned in sections 2.2.3 and 2.2.5).

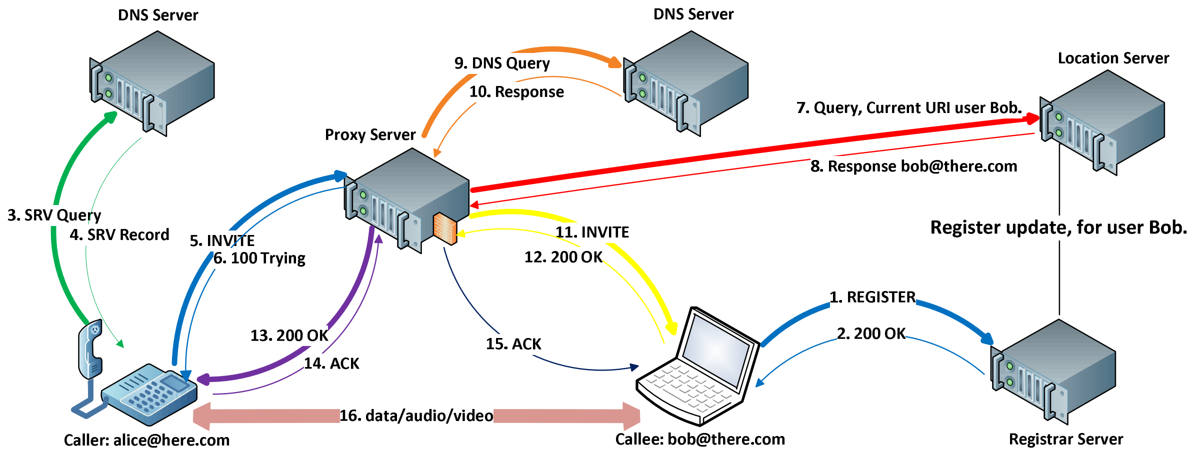


Figure 2: SIP session setup

Note: *Messages 7 and 8 are not SIP messages (they could be an LDAP query and response). Similarly the DNS queries and responses of messages 3, 4, 9, and 10 are not SIP messages.*

2.2.2 Session Description Protocol (SDP)

The SDP protocol was defined by the IETF in RFC 4566 [24]. SDP is purely a format for session description. A session description could include information such as the purpose of the session, the media and the codec's used in the session. SDP can use various transport protocols among them SIP. SDP is not intended to support negotiation of session content or media encoding. [24]

2.2.3 Real-time Transport Protocol (RTP)

IMS utilizes RTP for media sessions. This protocol was developed by the IETF and defined in RFC 3550 [25]. RTP was primarily designed to satisfy the needs of multi-participant multimedia conferencing, but today it is used for many different types of applications. RTP provides end-to-end delivery services for data with real-time characteristics, such as audio and video. RTP typically runs on top of UDP, no specific ports are defined for this purpose, but rather an even port and the next higher odd port are used (the later is used by the Real-time Transport Control Protocol (RTCP) to provide feedback on the RTP transported data). RTP does not provide any Quality of Service (QoS) guarantees at all. However, it does allow transmission imperfections such as packet loss or jitter to be detected with the help of the sequence numbers and time stamps in the RTP packets and the sender and receiver reports sent in RTCP. [25]

2.2.4 Real-time Transport Control Protocol (RTCP)

RTCP was defined by the IETF in RFC 3550 [24]. The primary function of this protocol is to provide information to monitor the quality of service for RTP flows. This information includes the number of bytes sent, packets sent, lost packets, jitter, and round trip delay. RTCP also transmits control packets to participants in a multimedia streaming session, so that the participants can learn who the other participants are. An application may use RTCP information to increase the quality of service perhaps by limiting flow, switching to a low compression coder-decoder (CODEC) instead of a high compression CODEC, turning off specific types of media (for example, turning off video), etc. For a description of this see [26].

There are several types of RTCP packets: Sender report packet, Receiver report packet, Source Description RTCP Packet, Goodbye RTCP Packet, and Application Specific RTCP packets as defined in RFC 3550 [25].

2.2.5 The Secure Real-time Transport Protocol (SRTP)

The secure real-time transport protocol (SRTP) was defined by the IETF in RFC 3711 [27]. SRTP is a profile of RTP. It can provide confidentiality, message authentication, and replay protection to the RTP traffic and to RTCP. For further details see [28].

2.2.6 Diameter

The 3GPP standards body has adopted Diameter as the primary signaling protocol for authentication, authorization, and accounting (AAA) in IMS. Diameter was developed and standardized by IETF as described in RFC 3588 [29]. Diameter is used by IMS's SIP servers (CSCFs) to perform authentication using information provided by the HSS and to determine if a client is authorized to access the services provided by the server.

2.3 User identification

In IMS the system's users and terminals need to be identified, as well as authenticated. Users have the option to have different identity profiles according to the service they wish to use. These identities are to two types: public and private.

2.3.1 Private User identities

A private user Identity is a globally unique identifier assigned by the subscriber's home network operator. Because private identities do not actually reveal the user's identity, but rather the user's subscription, they can be used for tasks such as administration, accounting, authorization, and registration. However, these private user identities are mainly used for authentication purposes. [16, 18]

Private user identities resemble email addresses, in the sense that they act as a Network Access Identifiers (NAI). [30] That is, a portion of the identity is a name given to the user and the other portion identifies the domain or network it belongs to. An example of a private user identity is *username@operatordomain*. This identity is permanently allocated by the home network to a user's subscription. The Private User Identity performs a similar function in the IMS as an International Mobile Subscriber Identifier (IMSI) does in GSM. This identity is valid as long as the user's subscription to the home network is applicable. [18]

2.3.2 Public User Identities

Public User Identities are the identities used by external entities to interact with the IMS network. These identities are public to the network and may be published in phone books, on business cards, etc. [16]. Public User Identities may take the form of a SIP URI (*sip:name.surname@domain*) or a TEL URI (*tel:+1234567*). These two forms are necessary for interworking between different networks such the Internet and GSM. [18] TEL URIs are needed when interworking with the PSTN. A Public User Identity plays a role in IMS similar to a Mobile Subscriber ISDN Number in GSM.

2.3.3 Linking Private and Public User Identities

Public and private user identities are related to each other. A user can have more than one public identity and use each of these identities for different services. In IMS, each public identity can establish a different treatment for incoming sessions. [16] Moreover, a user may use a certain identity for one service and merge the remaining identities for another type of service. IMS user profiles allow a user to have a set of identities for a service and each identity is treated differently within the service used. Figure 3 shows a graphical presentation of the relationship between public and private identities.

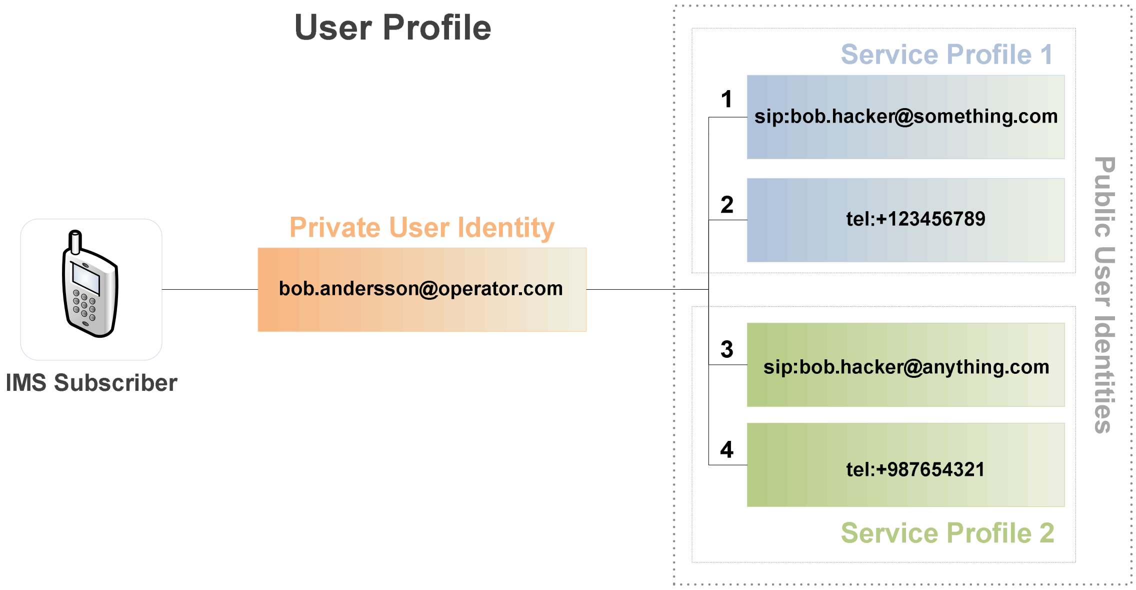


Figure 3: Public and Private Identities plus user

As shown in figure 3, a user has a private user identity and four different public identities linked to it. Public identities 1 and 2 are linked to profile 1 which provides a certain type of service. In the same way, public identities 3 and 4 are associated with profile 2 which provides another service. Moreover, the flexibility of public user identities allows the users to have a versatile combination of identities such as TEL URIs or SIP URIs. Notice, that a user profile is bound to the private user identity and also to a collection of public identities.

2.4 The SIM, USIM, and ISIM applications

A Universal Integrated Circuit Card (UICC) is a removable smart card, which is used to store subscription information, authentication keys, messages, and an electronic phonebook - among other things. A UICC can contain several logical modules, such as a Subscriber Identity Module (SIM), a Universal Subscriber Identity Module (USIM), and an IP Multimedia Subscriber Identity Module (ISIM). The UICC gives users the flexibility to easily move their user subscription from one terminal to another. [9]

2.4.1 SIM

Subscriber Identity Module (SIM) is a module that resides in the UICC, which provides storage for a set of parameters, such as user subscription information, user preference, authentication keys, and storage of messages, that are used for the operation of terminals in a GSM network.

2.4.2 USIM

A Universal Subscriber Identity Module (USIM) is a module that resides in the third generation UICCs used to access UMTS networks. There are terminals capable of operating with both SIM and USIM, i.e., to operate in GSM and UMTS networks. A USIM provides information similar in nature that provided by a SIM: user subscriber information, authentication information, payment methods, and message storage. More detailed information about the USIM can be found in [31].

2.4.3 ISIM

IP Multimedia Subscriber Identity Module (ISIM) is a third module that can be implemented in the UICC. The ISIM contains a set of parameters that are used for user identification, user authentication, and terminal configuration when operating over IMS. ISIM can coexist with both USIM and SIM. The most relevant parameters stored in the ISIM are the Private User Identity, Public User Identity, Home Network Domain URI, and a long term secret used for authentication purposes and for calculating integrity and cipher keys used between the terminal and the network. For further information refer to [32].

2.5 Secure Access

The user that accesses the IMS needs to be authenticated and authorized before being permitted to use any of the IMS services. A user that has been authorized will have their SIP traffic protected on the path from the terminal to the P-CSCF by using IP security (IPsec -- is a suite of protocols for securing IP communications). The protocols used in IMS will be described in the following subsections.

Authentication and authorization are established as a result of the REGISTER transaction. During the authentication process the user also authenticates the network to make sure that it is not a forged network, i.e., someone pretending to be a legitimate network. [9]

2.5.1 Authentication and authorization

IMS provides a set of security features such as data privacy/integrity and authentication. Authentication is an important part of IMS, and it is achieved by means of the Authentication and Key Agreement Protocol (AKA) [33], it is based on a one-time password generation mechanism for HTTP digest access authentication. As SIP's authentication framework closely follows the HTTP authentication framework defined in RFC 2617 [34], digest AKA is directly applicable to SIP.

AKA is a challenge-response based mechanism that uses symmetric cryptography. AKA uses the IM Services Identity Module (ISIM), which resides in the UICC (as described in section 2.4.3). A 3G terminal must implement USIM or ISIM, to be granted access to the network, although today ISIM is preferred. Both USIM and ISIM offer greater flexibility and stronger security that the earlier SIM.

Integrity and confidentiality in IMS are achieved by using IPSec Encapsulating Security Payload (ESP). AKA session keys, Integrity Key (IK), and Cipher Key (CK), are used as the keys for the ESP security associations, [33]. Here the IK will be used as the authentication key and CK as the encryption key.

2.5.2 Authentication and authorization with ISIM

Mutual authentication between the user and the IMS network is performed based on a long term shared secret stored in the subscriber's ISIM and in an HSS that resides in the subscriber's home network. To achieve mutual authentication the ISIM and the HSS have to show each other that they know the secret. However, the ISIM and the HSS are not in direct communication, thus the S-CSCF assigned to the user takes the role of the authenticator. The S-CSCF uses the Diameter protocol to obtain authentication vectors from the HSS. The HSS creates an authentication vector using the shared secret key K (established beforehand between the ISIM and the HSS), and a sequence number SQN that is kept in synchronization with the ISIM. Each authentication vector is only used once. Several vectors are downloaded to avoid contacting the HSS multiple times within a short period. An authentication vector contains a network authentication token (AUTN), a random challenge (RAND), an expected response (XRES) to the challenge, a session IK, and a session CK. When the S-CSCF receives a REGISTER request from a non-registered user, the S-CSCF responds with a *401 Unauthorized* response which includes a *WWW-Authenticate* header field. This field contains an authentication request for the ISIM, a random challenge RAND, and the network authenticator token AUTN encoded in base64. When the terminal receives the *401 Unauthorized* response, it deduces the RAND and AUTN (since they are delivered as a message digest) by using the shared secret K and the sequence number SQN, after that the terminal computes its own AUTN and compares it to the AUTN received. If they match, then the network has been authenticated. The client computes an authentication response RES, using the shared secret K and the random challenge RAND, and computes the IK and CK. The authentication response RES, is delivered to the S-CSCF in a new REGISTER request. Once the S-CSCF receives the RES it compares it with the XRES in the authentication vector, if they are the same, then the S-CSCF considers the user to have been successfully authenticated, and the session keys, IK and CK, can be used for protecting further communications between the client and the server. Finally the S-CSCF returns a 200 OK response to the terminal. Figure 4 illustrates the authentication procedure.

For more specific information on the AKA mechanism and generation of the cryptographic parameters AUTN, RES, IK, and CK, see 3GPP's TS 33.102 [35].

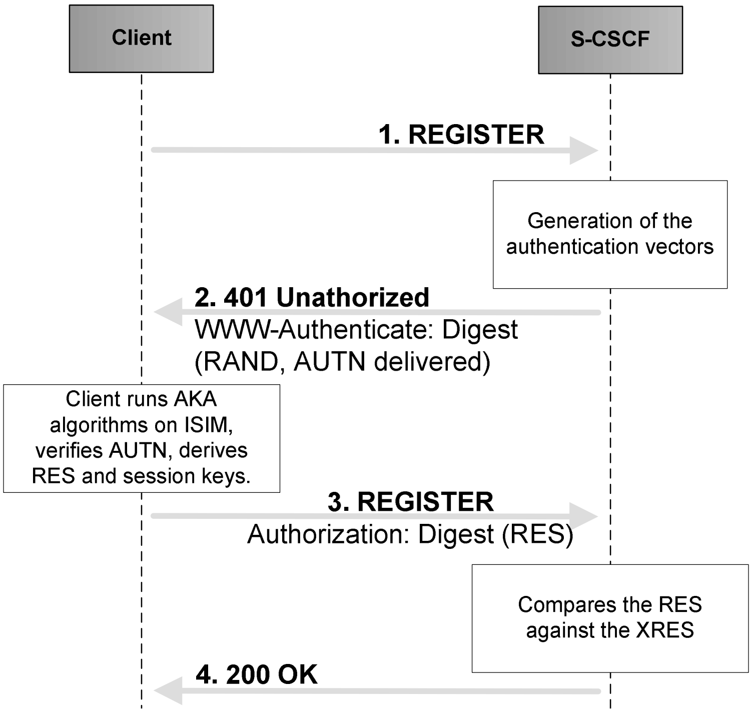

Client
S-CSCF
1. REGISTER
Generation of the authentication vectors
2. 401 Unathorized
WWW-Authenticate: Digest
(RAND, AUTN delivered)
Client runs AKA algorithms on ISIM, verifies AUTN, derives RES and session keys.
3. REGISTER
Authorization: Digest (RES)
Compares the RES against the XRES
4. 200 OK

Figure 4: authentication process.

2.5.3 The Generic Bootstrapping Architecture

As part of the Generic Authentication Architecture, the 3GGP defines the Generic Bootstrapping Architecture (GBA) in TS 33.220 [36]. This architecture is illustrated in figure 5.

The GBA consists of two main functional components, a Bootstrapping Server Function (BSF) and a Network Application Function (NAF). The BSF has a Diameter interface to the HSS to fetch the subscriber's authentication vectors. The BSF and the UE performs mutual authentication based on AKA, and agree on the session keys that are afterwards applied between UE and a NAF. The BSF restricts the applicability of the keys to specific a NAF. After the bootstrapping has been completed, the UE and a NAF can utilize an application specific protocol where the authentication of messages will be based on the session keys generated during the mutual authentication between the UE and BSF.

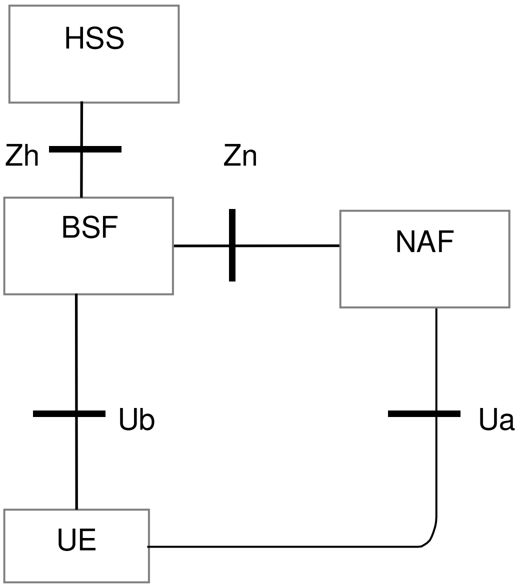


Figure 5: Generic Bootstrapping Architecture

2.6 IMS Registration

Once a IMS terminal has connectivity to an IP access network, it acquires or constructs an IP address, and discovers the network address of the P-CSCF. At this point the terminal can begin registration with the IMS. During this procedure the user is authenticated and authorized to access the IMS network.

This registration is performed using a SIP REGISTER request. This procedure is heavily overloaded in the IMS, in order to fulfill the 3GPP requirement of a minimum number of round trips; the procedure is completed after two round trips. [9]

2.6.1 Registering with an ISIM

To perform the registration process an IMS terminal must be equipped with an UICC, which must include an ISIM application, a USIM application, or both. In the registration procedure described below, registration based on ISIM will be described.

The registration procedure consists of the following steps:

i. The user agent binds a Public User Identity to a contact address (this *Contact* header field value contains the URI at which the User Agent would like to receive requests).

ii. The home network authenticates the user.

iii. The user authenticates the home network.

iv. The SIP registration and usage of IMS resources are authorized by the home network.

v. If the P-CSCF is located in a visited network, before authorizing use of the P-CSCF, the home network verifies the roaming agreements between the home and visited network.

vi. The user is informed by the home network about other possible identities that the home operator has allocated exclusively to that user.

vii. A security scheme for signaling is negotiated between the terminal and the P-CSCF.

viii. The IMS terminal and the P-CSCF establish security associations to protect the integrity of the SIP messages sent between them.

ix. The compression algorithm for the SIP messages are exchanged by IMS terminal and the P-CSCF.

In order to perform the steps described above, the IMS terminal obtains from the ISIM the Private User Identity, the Public User Identity (which is to be used at this time), and the home network UR, then it creates a SIP REGISTER request and attaches four parameters to it:

i. The registration URI, which is a SIP URI that identifies the home network domain. This will be used to emit the SIP register request.

ii. A Public User Identity, which is a SIP URI that represents the user identity which is being registered.

iii. The Private User Identity; used for authentication purposes.

iv. The Contact Address, this is a SIP URI, that includes the IP address of the terminal or its hostname.

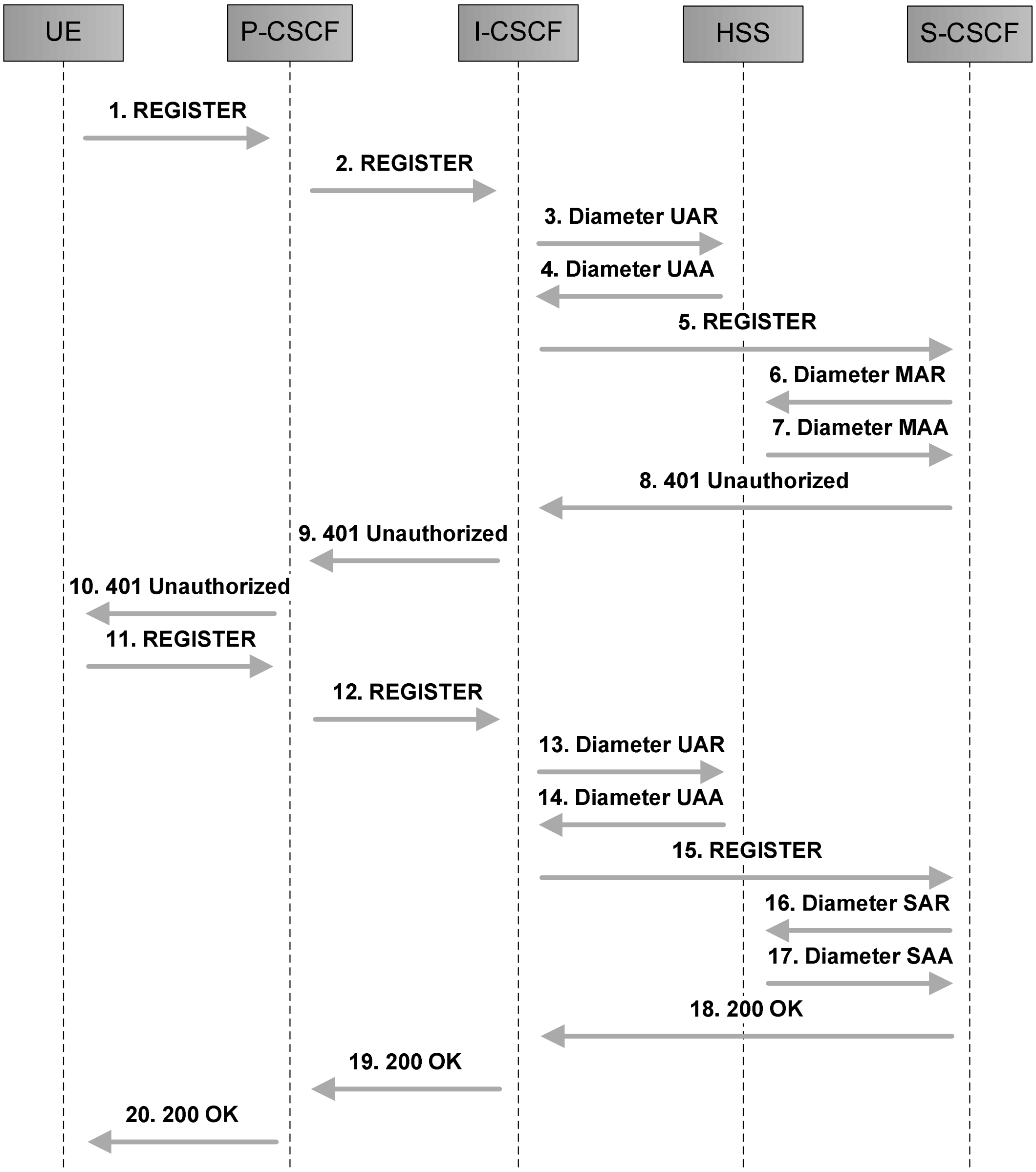


Figure 6: IMS Registration flow.

Figure 6 shows the interaction between the functions present in the registration process. With this figure as reference; the steps involved in IMS registration are described below.

Message 1: The UE sends a REGISTER request, if the UE is in a visited network, then the P-CSCF is not located in the home network and the visited network's P-CSCF contacts the user's home I-CSCF's (which is the entrance point to the home network) through its SIP URI. The IP address of this I-CSCF will be determined with the help of a DNS query as specified in RFC 3263 [37].

Message 2: The P-CSCF inserts a *P-Visited-Network-ID* in the REGISTER request that identifies the network where it is located. Using this header field, the home network will check if there is an applicable roaming agreement between the networks. The P-CSCF also inserts its own SIP URI in the *Path* header field, as a request to the home network, indicating it should forward SIP requests for this URI through this P-CSCF. Finally the P-CSCF will forward the SIP REGISTER request to the I-CSCF in the home network.

Message 3: To get authorization and discover if there is already an S-CSCF allocated to the subscriber, the I-CSCF sends a Diameter User-Authentication-Request (UAR) to the HSS, containing a Public User Identity, the Private User Identity, and the visited network identifiers (all this information was contained in the REGISTER request).

Message 4: If the HSS authorizes the user to roam to the visited network, then it sends a confirmation in a Diameter User-Authentication-Answer (UAA), which includes the SIP URI of the previously allocated S-CSCF, if there was one. Otherwise, it returns a set of S-CSCF capabilities to the I-CSCF, according to these capabilities the I-CSCF will chose a S-CSCF that suits the user's needs.

Message 5: The I-CSCF routes the SIP REGISTER request to the selected S-CSCF.

Message 6: The S-CSCF receives the REGISTER request and starts to authenticate the user. It communicates with the HSS, downloads authentication data, and at the same time the S-CSCF saves its own URI in the HSS. This URI may be used in the future, if the HSS is queried for the same user, it will then return routing information pointing to this S-CSCF. For this purpose the S-CSCF creates a Diameter Multimedia-Auth-Request (MAR) message and sends it to the HSS.

Message 7: Once the HSS stores the S-CSCF URI along with this subscriber's data it responds with a Diameter Multimedia-Auth-Answer (MAA) message.

Message 8-10: The S-CSCF creates a SIP 401 (Unauthorized) response and sends it to the IMS terminal. This response includes a challenge/credential (as described in section 2.5.2) in the *WWW-Authenticate* header field that the IMS terminal should respond to.

Message 11-12: The IMS terminal sends a new SIP REGISTER request to the P-CSCF. The P-CSCF performs the same operations as for the first REGISTER request.

Message 13: The I-CSCF sends a new Diameter UAR message.

Message 14: The HSS responses with a UAA, including routing information, the SIP URI of the S-CSCF allocated to the user (as previously stored by the HSS when it received a Diameter MAR in message 6). Note that, it does not matter if the I-CSCF used for this second REGISTER request is the same I-CSCF as in the first REGISTER request, since the second REGISTER request will end up at the same S-CSCF.

Message 15: When the REGISTER request is received by the S-CSCF, the response includes the user's credentials, which are validated against the authentication vectors, provided earlier by the HSS in the Diameter MAA message (message 7).

Message 16-17: If the authentication was successful, then the S-CSCF sends a Diameter Server-Assignment-Request (SAR) message to the HSS, to download the subscriber's user profile, and to inform the HSS that the subscriber has been registered. At this point the S-CSCF has stored the contact URI of the user, present in the *Contact* header field, and the list of URIs included in the *Path* header field of the SIP REGISTER request, the S-CSCF will later route the SIP requests addressed to the user via this URI list. The HSS sends back the information through a Server-Assignment-Answer (SAA) command.

Message 18-20: Finally, the S-CSCF sends a 200 OK response to the REGISTER request, which indicates success; it includes a *P-Associated-URI* header field that holds a list of URIs assigned to the user, a Service-Route header field that includes a list of SIP servers URIs. Future SIP requests that the IMS terminal sends, will be routed via these SIP servers, in addition to the P-CSCF. The registration procedure is now completed.

The IMS terminal will be registered with the IMS for the duration indicated in the *expire* parameter of the SIP 200 OK message's *Contact* header field. [9]

2.7 Real-time technologies: SIP, RTP and XMPP

The best technologies and protocols for creating real-time Internet applications are still being sorted out. In today's market there are a wide range of proprietary technologies (e.g., VoIP providers, IM services, gaming communities, etc.) as well as products built on a mix of standardized protocols. Even though proprietary solutions can be very successful, over time the market and regulation pressures have tended to push towards standard-based solutions, since large enterprises, service providers, and governments do not want to be locked in to proprietary technologies.

As previously mentioned **SIP** enables network endpoints to negotiate and manage (call-setup and call-management functionalities) data streams but does not handle the data itself. SIP's negotiation results in a "handoff" to a data streaming protocol such as RTP for multimedia, SIP it has been widely adopted as the basis for voice and video services over the Internet. SIP is being extended to handle messaging and presence via SIP for Instant Messaging and Presence Leveraging Extensions (SIMPLE). However, because SIP was designed for session negotiation, the SIMPLE extensions that are under development are still not optimized for rapid exchange of advanced structured data.

RTP has rapidly supplanted older technologies such as the International Telecommunications Union's H.323 standard. RTP is optimized only for certain types of real-time transport, such as computationally intensive, loss-tolerant binary data streams, where quality of service is the not so important (e.g., a VoIP calls where packet drop is acceptable, since small amounts of data loss can be compensated by software and the human ear). Transporting structured data such as Simple Object Access Protocol (SOAP) requests or Really Simple Syndication (RSS) feeds over RTP, might cause that critical information gets lost.

XMPP is an XML streaming technology defined in RFC 3920 [38], which is optimized for sending relatively small chunks of structured data between network endpoints. XMPP excels at transporting XML data, from chat messages and RSS notifications, and SOAP payloads, as well as specialized data formats for custom applications.

2.7.1 Why SIMPLE?

As our project is being built over IMS we will use SIMPLE. IMS has the SIMPLE infrastructure already implemented. This will keep us from building additional server module applications (e.g. a multicast application able to forward RTP traffic to several users interested in viewing the heart rate information. XMPP on the other hand is not considered as one of the strategic protocols for IMS) for handling the distribution of the collected heart rate information. Using SIMPLE at this point results the most natural step to follow, although we should not forget that there are other ways to solve this problem. The *SIP Presence service* framework offered by SIMPLE can provide our system unique features for easy expansion and integration with other presence aware service and applications, to offer richer and greater user experience.

2.8 Overview of the Presence service

The presence service is built on top of the SIP event notification framework. It allows system users to be informed about the status of fellow subscribers, i.e., to know who is online or offline, who is idle or busy, their preferred communication means, and their terminal's capabilities. The presence framework defines several roles; the most important ones are shown in figure 7.

The entity that provides presence information is called presentity, short for "presence entity". A presentity can have several devices associated with it; these devices are represented by Presence User Agents (PUAs). The presentity interacts directly with these Presence Agents (PAs). A PA manages the state of different event subscription's, it also collects the information received from the PUA (through PUBLISH transactions) creating a model of the presentity's presence state, and it also acts as a notifier to those SIP entities who have subscribed for information about this presentity. The PA notifies (using a SIP NOTIFY transaction) all the subscribers to this presentity when a change has occurred in the presentity's presence state.

In figure 7 we can see two watchers. A watcher is an entity that requests presence information about a certain presentity, or for his own watcher information (providing feedback about the watchers subscribed to his presentity information) from a PA. Requesting presence information done by using a SUBSCRIBE request.

All SUBSCRIBE/NOTIFY transactions contain a SIP Event header field that (1) identifies the actual event, the subscription or notification as per RFC 3856 [39] and (2) defines the "presence" event package identified by the value *presence* in the "Event" header field of SUBSCRIBE and NOTIFY requests. The SIP PUBLISH method defined in RFC 3903 [40] is used to publish the event state within the framework for SIP-specific event notification, as defined RFC 3265 [41].

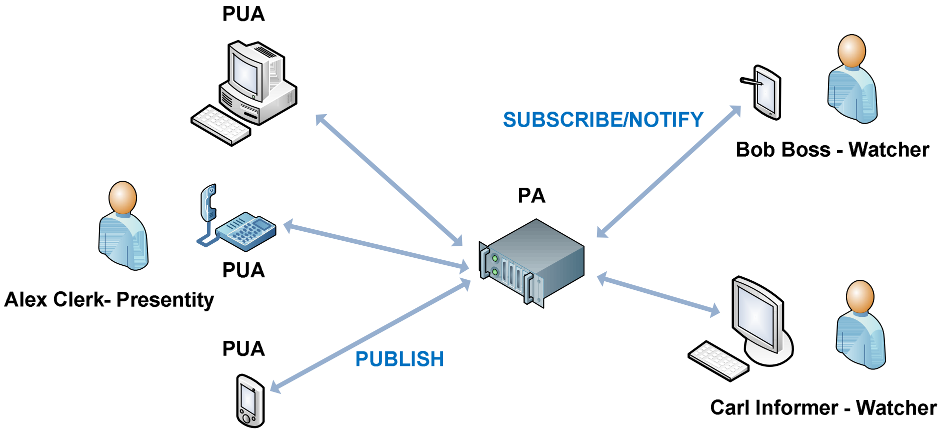


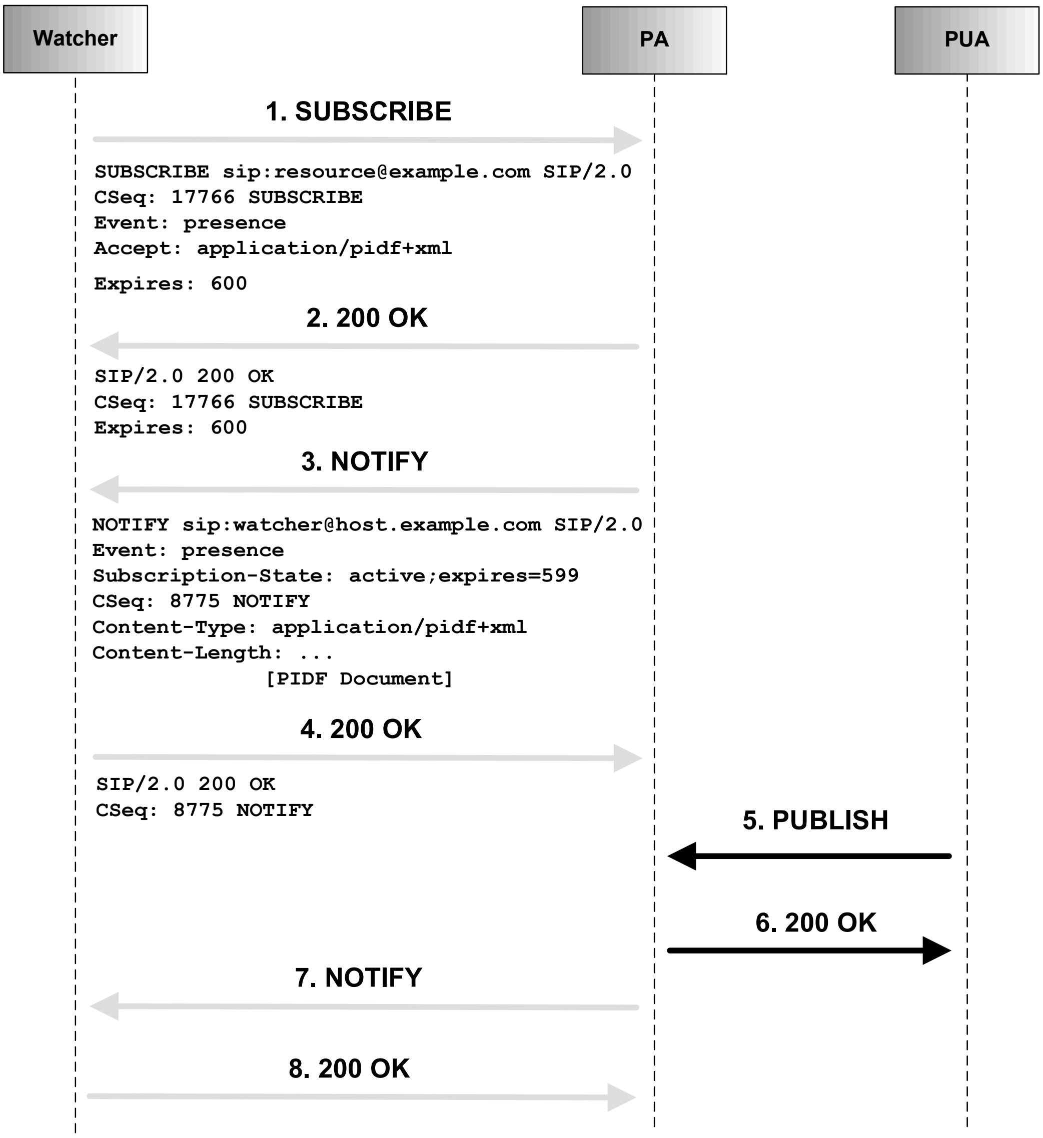
Figure 7: Presence network elements.

Note: *There is an additional entity called a Presence Sever (PS) which is not shown here. A PS is a functional entity, that acts either as a PA or as a proxy server for SUBSCRIBE requests. The PS is designed to increase the scalability of this event notification architecture, by acting as a proxy for one or more presentities.*

2.8.1 Presence Subscriptions and Notifications

A subscription can be a simple fetch operation to learn the *current* state of a presentity or a subscription which will last for a longer period of time (to enable asynchronous notification of a state change). To maintain a subscription the watcher needs to renew the subscription before it expires. The subscription state and the presentity's presence information is forwarded by the PA to the watcher(s) in the form of a NOTIFY request.

Figure 8 shows a SUBSCRIBE/NOTIFY flow with the most relevant header fields involved in the message exchange. The details of this message exchange will be explained in the following subsections.



```
SUBSCRIBE sip:resource@example.com SIP/2.0
CSeq: 17766 SUBSCRIBE
Event: presence
Accept: application/pidf+xml
Expires: 600
```

```
SIP/2.0 200 OK
CSeq: 17766 SUBSCRIBE
Expires: 600
```

```
NOTIFY sip:watcher@host.example.com SIP/2.0
Event: presence
Subscription-State: active;expires=599
CSeq: 8775 NOTIFY
Content-Type: application/pidf+xml
Content-Length: ...
                  [PIDF Document]
```

```
SIP/2.0 200 OK
CSeq: 8775 NOTIFY
```

Figure 8: Presence Subscriptions and Notifications.

2.8.2 SUBSCRIBE Initial Request

The watcher sends a SUBSCRIBE request with the “Event” header field set to *presence*, the desired duration for this subscription in the “Expires” header field, and the presentity’s URI-address.

When a PA receives a request, it authenticates the subscription before authorizing it. If the SUBSCRIBE request is accepted, the PA will respond with a 200 OK response followed by an immediate NOTIFY request, which specifies the subscription status, and the current presence information for the presentity, which is encoded as specified in the “Content-Type” header field.

2.8.3 SUBSCRIBE Refresh request

As noted above, when a watcher wishes to maintain an active subscription, it must refresh the subscription before the subscription expires. This is accomplished by sending a SUBSCRIBE refresh within the same dialog as the initial SUBSCRIBE with the “Event” header set to *presence*. If the request is accepted by the PA, then the subscription’s expiration timer is updated and set to the smaller of the time specified in the SUBSCRIBE request (if any) or the duration specified by the PA. The watcher is informed about the subscription state and new expiration time via an immediate NOTIFY.

2.8.4 SUBSCRIBE Poll request

A Subscribe Poll request is used by a watcher to learn the current presence information from a presentity as a one-time notification. Polling or fetching presence information from a presentity is done by issuing a SUBSCRIBE request with the “Expires” header field set to zero. The SUBSCRIBE request does **not** contain a body. If the operation is supported and authorized by the PA, then the watcher will receive a notification from the PA with the current presence information, a "Subscription-State" value of "terminated", and a "reason" parameter of "timeout". Any outstanding subscription of this watcher will be cancelled (due to the specification of a zero expires time).

2.8.5 Watcher-side subscription termination

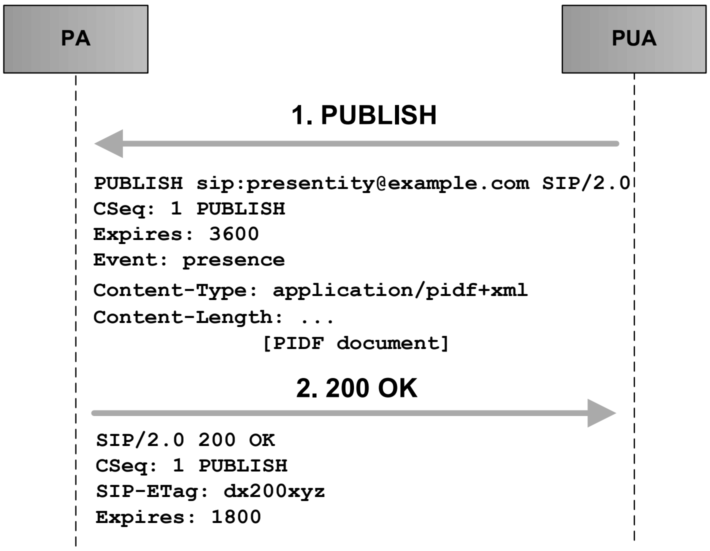
A subscription is immediately terminated by sending a SUBSCRIBE request with the “Expires” header field set to zero, this must be done within the same dialog as the initial SUBSCRIBE. This operation will terminate the subscription at the PA, thus ending notifications related to that subscription. A successful request will be followed by a notification containing the most recent presence information, with the “Expires” header field set to zero.

2.8.6 Server-side subscription termination

The PA can terminate a subscription at any time by sending a NOTIFY request. The “Subscription-state” header field is set to terminated and the reason parameter will indicate the cause. The NOTIFY request will contain the most current presence information, in addition to the reason for termination

2.9 Presence Publication

The purpose of a SIP PUBLISH method is to publish the event state used within the framework for a SIP-specific event notification. [41] Figure 9 shows an example of such a message flow with the most relevant header fields for this method. These fields will be explained in more detail in the following subsections.



```
PUBLISH sip:presentity@example.com SIP/2.0
CSeq: 1 PUBLISH
Expires: 3600
Event: presence
Content-Type: application/pidf+xml
Content-Length: ...
              [PIDF document]
```

```
SIP/2.0 200 OK
CSeq: 1 PUBLISH
SIP-ETag: dx200xyz
Expires: 1800
```

Figure 9: PUBLISH request.

2.9.1 PUBLISH Initial request

To create a new publication an initial PUBLISH request is emitted by the PUA. The message should contain an “Expires” header field set to the expiration time, and the presentity's presence information in the message body is in the format indicated by “Content-Type” header field. Every new successful PUBLISH request is assigned an identifier by the PA, in the form of an entity-tag specified in header field “SIP-Etag”. These entity-tags are unique for each PUA. This means that two instances of published presence information can have the same entity-tag value, as long as they are not published for the same user agent. If the publication is authorized and successful, the response message will have the “Expires” header field set, indicating the validity of the publication. The entity-tag for the new publication is also included in the response message.

2.9.2 PUBLISH Refresh request

The PUBLISH Refresh request operation enables a presentity, to refresh previously published presence information in the PA before it expires. This is done by sending a PUBLISH refresh request. The request must contain the entity-tag of the publication to be refreshed in the “SIP-If-Match” header field, and an expiration time in the “Expires” header field. A PUBLISH refresh only extends the expiration time of an existing publication, it does not affect the presence information in any other way; the request shall not contain a message body (therefore the header field “Content-Length” is always set to 0). In the response, the “Expires" header field indicates the actual duration for which the publication will remain active. If the Expires header field is left out, a default “Expiry” time will be used. No new entity-tag for the refreshed publication is created. A PUBLISH refresh for an invalid entity-tag will fail.

2.9.3 PUBLISH Modify request

This operation enables the presentity to modify existing presence information present in the PA. Modifying presence information means that the initial presence information is replaced by the new presence information in the PA. This is done to avoid creating completely new presence information. The request must specify the entity-tag of the publication to be modified in the “SIP-If-Match” header field. Optionally an expiration time may be included in the “Expires” header field. The request must also contain a body that includes the modified presence information. If the operation is successful, then the response will indicate the duration for which the publication will remain active, along with a newly created entity-tag for the modified publication. If the request did not contain an “Expires” header field, then the PA will chose one, according to prestablished criteria. A PUBLISH modify request for an invalid entity-tag will fail, this applies to all the PUBLISH requests.

2.9.4 PUBLISH Remove request

This operation enables a presentity to remove an existing publication from its PA *before* the expiration time. The PUBLISH remove request must contain the entity-tag of the publication to be removed in the “SIP-If-Match” header field, and **must** have the “Expires” header field set to zero. A PUBLISH remove request affects only the expiration time, and it shall not contain a body (hence the “Content-Length” is always zero). If the operation succeeds, the response message will have the “Expires” header field set to zero, as a confirmation that the publication has been terminated.

Note: *Removing presence information is effectively a refresh of the information with an infinitesimal expiration interval. Consequently, the presence information expires immediately after it has been refreshed.*

2.10 The Presence service in the IMS

The presence architecture for IMS was defined by the 3GPP in their technical specification TS 23.141 [42]. Figure 10 shows the principal elements involved. The ASs located in the home network can acts as PAs. The Resource List Server (RLS) is also implemented in ASs. An AS can be a watcher for presence information; this enables it to spread presence information to various services.

A PUA can be implemented using an AS. In this case, the PUA can obtain presence information from any potential source of information in the network, such as the HSS, the Mobile Switching Center/Visited Location Register (MSC/VLR) in circuit-switched networks, the Serving GPRS Support Node (SGSN) or the GGSN in GPRS networks, or the S-CSCF (due to IMS registration). This PUA can publish the acquired information directly to the PA.

Terminals in an IMS network can interact directly with an AS that is acting as a PA or RLS. This interface can be used to configure resource lists (such as presence lists) and change data, authorize watchers, etc. The protocol used is the XML Configuration Access Protocol (XCAP) as defined in RFC 4825 [43]. Further details are given in [9].

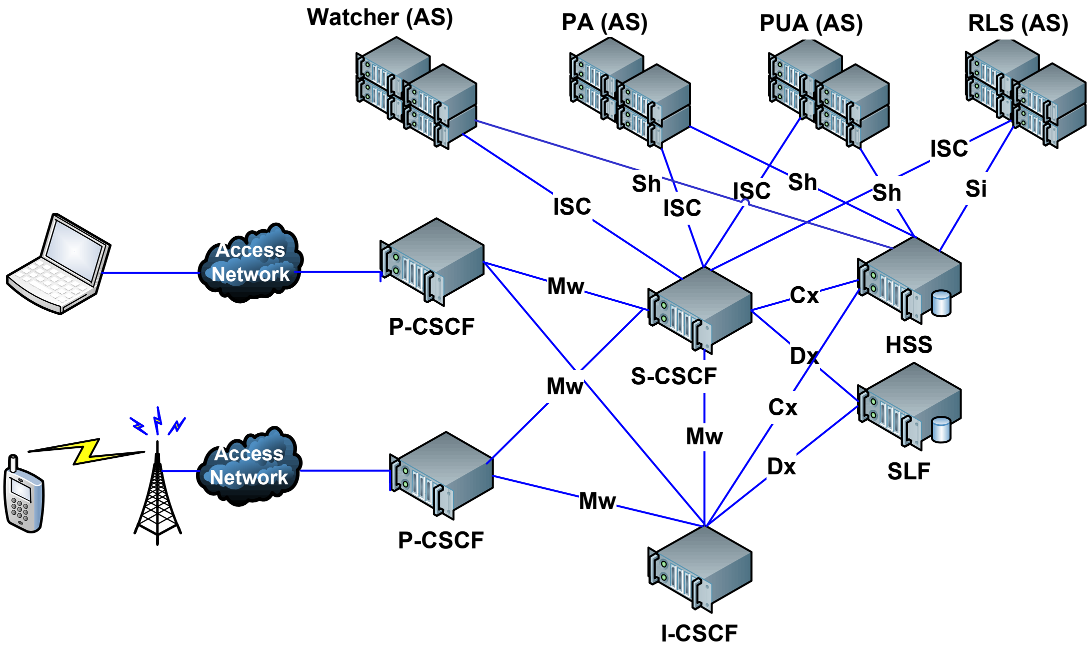


Figure 10: the Presence entities in IMS.

2.10.1 Watcher Subscription

A watcher within an IMS presence service can subscribe to individual presentity information or to complete presence lists. These presence lists are a list of SIP-URIs that map to specific presentities. These presence lists are stored in an RLS. Using a presence list is more efficient than subscribing to each presentity's presence information, as it reduces the number of messages exchanged between a watcher and PA. Thus only a single SUBSCRIBE request is sent to the watcher's presence list. The RLS acts on behalf of the watcher, performing all the subscription requests to the listed presentities.

2.10.2 Presence publication

When an IMS PUA sends a PUBLISH request intended for the presence service, the S-CSCF evaluates the request according to the initial filter criteria (which were downloaded by the S-CSCF in the PUA's registration process, as they are part of the subscriber's profile) for this presentity. If the request is permitted, then the request is forwarded to the AS acting as a PA, where the presentity's presence information is stored. If the PA authorizes publication of this presence information, then it will respond with a 200 OK.

2.10.3 The Presence and Group Management (PGM)

Ericsson has developed a concept for managing presence information and group data for IMS. This concept introduces a Presence and Group Management (PGM) server. This presence server can manage *group* resources. The PGM permits a PUA to effect the following operations: update presence information, subscribe to others' presence information, and subscribe to the list of buddies that watch the presentity's presence information. The PGM can allow or block others from watching the PUA's presentity's presence information. The PUA can retrieve the list of buddies who are allowed and blocked, and retrieve group lists. The PUA can add, remove, and modify buddies in a group. Modification or removals of groups are also possible.

2.11 Sensor network

The sensor node and the accessory equipment used in this project were provided by SUUNTO. The principal device is the chest belt model T6 [44] for heart rate monitoring. This is a wearable sensor with a processing unit that communicates with other equipment through ANT™ [45] radio technology (described further below). In addition to the chest belt, there is the "All-In-One" module, which is an experimental (is still under a development stage no official documentation is available) hardware that acts as gateway, between networks implementing ANT and Bluetooth networks running the Simple Sensor Interface (SSI) [46] protocol. The “All-In-One” modules enables communication between the heart rate monitor (HRM) and Bluetooth enabled devices. The chest belt comes with an ANT RF transceiver with a USB interface; this is a standard accessory for the T6 [44]. This ANT RF transceiver may be connected to any terminal that can act as a USB master [47], offering the possibility to interact with the HRM directly using ANT.

Figure 11 illustrates a possible sensor networking scenario, where a personal computer (PC) interacts with the HRM through an ANT USB adaptor. A mobile terminal communicates with the HRM by interacting with the All-In-One module. Such a module is needed as no currently available mobile phone handsets offer USB master support (specifically they lack the ability to power an attached USB device), so far only one *Internet tablet* have been found that in theory satisfies the required needs [48]. However, it might be possible to design a USB On-the-go device which could contain an ANT transceiver. Figure 12 illustrates the HRM, USB ANT transceiver, and the All-in-one module.

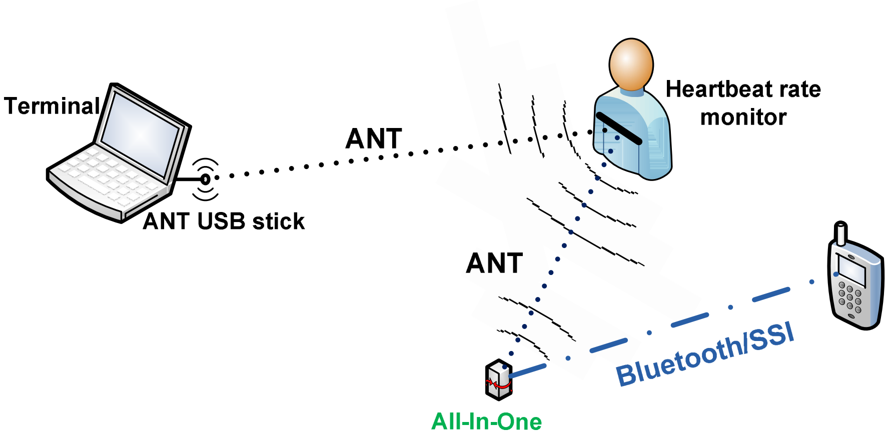


Figure 11: sensor network elements.

Note: *An alternative solution to having an ANT-to-Bluetooth converter is offered by a product that was announced earlier this year by Spectec Computer Company Ltd. They launched the SDA-320 miniSDIO ANT RF card that uses Nordic Semiconductor’s ANT specific nRF24AP1™ [49] 2.4 GHz ultra-low power transceiver, which allows a miniSDIO card slot-equipped Smartphone or PDA to communicate with ANT enabled sensors.* [50]

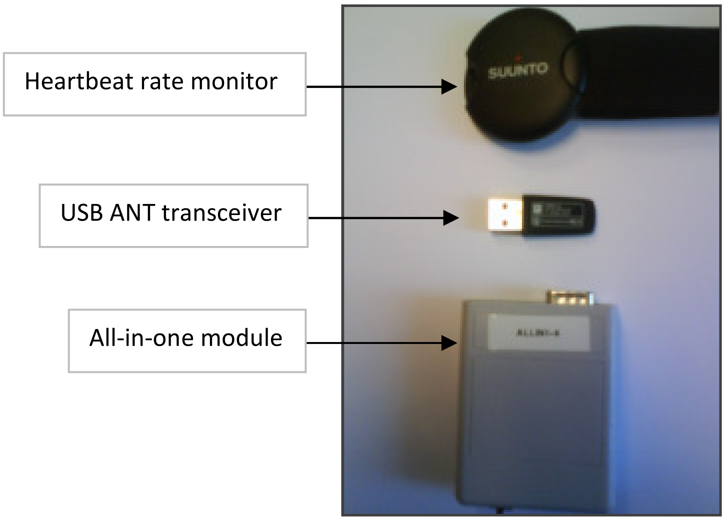


Figure 12: heart rate monitor, USB ANT transceiver, and All-in-one module.

Note: *There are several companies that offers similar products to the T6 heart rate monitor (e.g. Polar [51], Beurer [52], and Globalst [53]), in principal they are more or less the same, and their functionalities and usage are similar; basically a chest strap that has a sensor, a radio transmitter, and a computing unit that communicates with a wearable computer, that has more processing power and storage, it provides the user with different options and functionalities (e.g. display the elapsed session time, calorie burn, heartbeat rate, etc.).*

2.11.1 ANT

ANT is a low power, low duty cycle radio frequency technology that operates in the 2.4 GHz industrial, scientific and medical spectrum for wireless sensor networks. It is based on Time Division Multiple Access (TDMA). ANT was designed for easy implementation of point-to-point, star, tree, and meshes networks; among its features are design simplicity, efficiency, reliable data transmission, cross-talk immunity, ultra-low power consumption, and low system costs. Millions of ANT nodes have been deployed. ANT is well suited for low data rate sensor network topologies. [45]

ANT's protocol stack is extremely compact, allowing a low-cost 4-bit or 8-bit microcontroller to establish and maintain complex wireless networks, reducing system costs. Data transfers can be done in a deterministic or *ad hoc* fashion. The use of burst mode allows a more efficient transfer of large amounts of stored data to and from a PC or other computing device (e.g. when transferring data files from a wearable computer to a personal computer). ANT provides the physical, network, and transport OSI layers. In addition, ANT incorporates a network key [54] that provides a foundation for user-defined low-level security implementations. Figure 13 illustrates the protocol layers implemented by ANT.

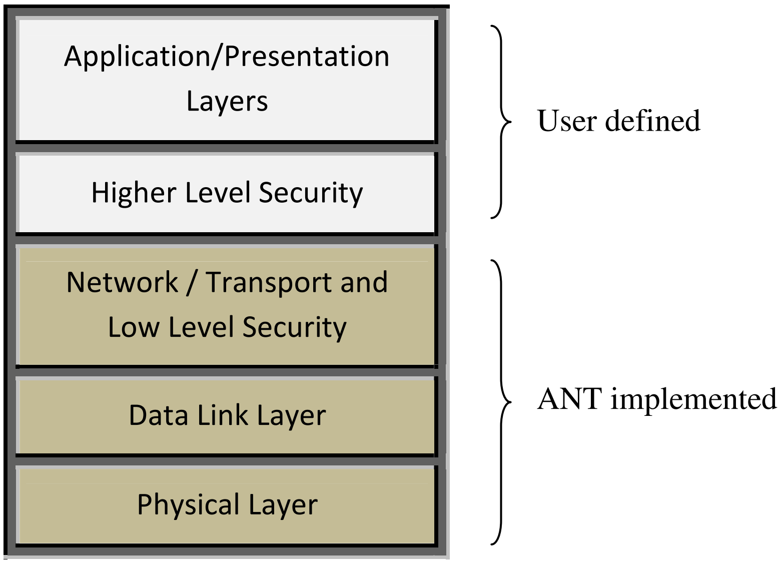


Figure 13: OSI Layer model of ANT.

A typical ANT enabled device consists of an application host microcontroller interfaced with an ANT module, chipset, or chip. The host microcontroller establishes and maintains a communication session to other remote ANT enabled devices through a simple serial message protocol. A typical serial message has the format shown in figure 14.

1	1	1	n	1
SYNC	MSG Length	MSG Id	Payload	Checksum

Figure 14: ANT serial message.

A message begins with a SYNC byte and ends with a checksum. The bytes are sent with the least significant bit transmitted first. Table 3 describes the serial message in more detail. For details on ANT's message protocol see [54]

Table 3: ANT serial message

Byte number	Name	Length	Description
0	Sync	1 Byte	Fixed value of 10100100
1	MSG Length	1 Byte	Number of data bytes in the message 1 < N < 9
2	MSG Id	1 Byte	0: Invalid 1 - 255: Data Type
3 … N+2	Payload	N Byte	Data bytes
N+3	CRC	1 Byte	XOR of all previous bytes including the SYNC byte

2.11.2 Simple Sensor Interface (SSI)

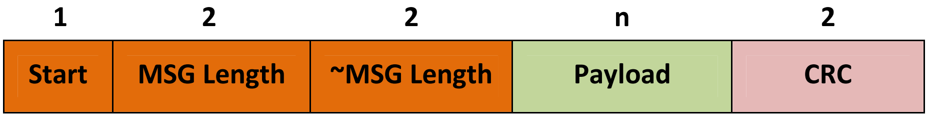
The SSI communications protocol [46] is intended to be used for transferring data between sensor unit(s) and a terminal. There are two modes of operation of the SSI protocol: point-to-point and networking applications.

In the point-to-point case the SSI protocol operates over a serial link*. This can be a physical (wired) or wireless link, such as the Bluetooth serial port profile. The SSI protocol can be used over layer three transport protocols, such as TCP/IP or nanoIP [55]. The SSI protocol is asynchronous and stateless; each frame consists of three parts: header, payload, and an optional CRC checksum. The header structure and length may change from case to case, but the structure of the payload is always the same. The SSI protocol bytes are ordered as Big Endian (i.e., most significant byte first).

A point-to-point connection is the protocol schema used in this project. It will be briefly described here, for more details refer to [46].

* [46] refers to this as the SSI UART protocol, even though it does not involve a universal asynchronous receiver/transmitter.

The **SSI UART** protocol uses a message structure shown in figure 15. All messages use the same frame format: header, message body, and an optional two byte CRC checksum field.



1	2	2	n	2
Start	MSG Length	~MSG Length	Payload	CRC

Figure 15: SSI UART protocol frame structure.

The message **Header** is 5 bytes long: it contains a start byte equal to 0xFE, a length field that describes the message length in two bytes, and a field that is the bitwise complement of the length field. This header is used to identify the start of the payload.

The **Payload** has a variable size. The payload contains the device's address, command code, and other attributes. The payload structure does not depend upon the type of connection. The first byte of the payload is always an address and the second byte a command. These are present within every SSI payload structure. The other parts depend upon the command. The **address** field is required to separate multiple sensor devices on a single communication device. The address field is always present and is one byte long. Address fields are always written as hexadecimal numbers (0x00 – 0xFF). The **command** field is one byte long, this allows 255 different alternatives. However, each command has two variants (with and without a CRC checksum), thus 127 different commands are possible. Within each command the payload field structure remains the same. For further details see [46].

The **CRC** checksum is optional; i.e., is only present in the message if the executed commands specifically request it. The CRC checksum is calculated over the payload. If the CRC is not correct, then the message has to be ignored.

The **SSI Networking Protocol** has the capability to run over layer 3 networking protocols, such as TCP/IP or nanoIP. SSI operates in a similar way over all the compatible socket based network protocols. An example of the message structure used for nanoIP (specifically nanoUDP) is given in figure 16. nanoIP consists of two transport techniques, nanoUDP which is an unreliable simple transport, and nanoTCP which provides retransmissions and flow control with the cost of message size and increased network traffic. [56, 57]

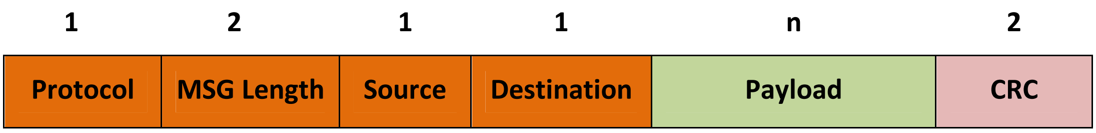


Figure 16: SSI networking protocol, nanoUDP message structure.

Table 4 describes the fields of the message structure showed figure 16.

Table 4: nanoIP message structure.

Byte number	Name	Length	Description
0	Protocol	1 Byte	A protocol and flag byte
1 , 2	MSG Length	2 Byte	Total length, including header and CRC
3	Source	1 Byte	Source port number, port range of 8 bits - 256 ports
4	Destination	1 Byte	Destination port number, port range of 8 bits - 256 ports. The destination port number should be 0x28 for SSI messages
5 … N+4	Payload	N Byte	Data bytes.
N+5, N+6	CRC	2 Byte	Optional 2 bytes used for CRC checksum

Every SSI command is intended for one or more sensors and also for sensor devices. A sensor is identified by a 16-bit value known as the Sensor Id. Sensor devices on the other hand are identified by the address. The direction for each the different commands is identified by the command direction: → means from terminal to the sensor unit and ← vice versa. Table 5 show the commands used for discovering the sensor units and read data from them. The commands expressed in capital letters represent the version without a CRC checksum.

Table 5: SSI commands.

Command	Direction	Description
Q/q (0x51/0x71)	→	Query
A/a (0x41/0x61)	←	Query reply
R/r (0x52/0x72)	→	Request sensor data
V/v (0x56/0x76)	←	Sensor data response

The *Query* commands **Q/q** are executed by the client to obtain information related to the sensor unit, in response to this query the sensor unit replies with a *Query reply* command **A/a**. Figure 17 shows the message direction.

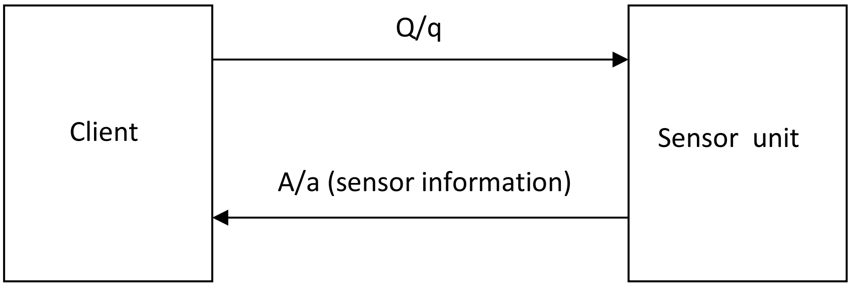


Figure 17: message direction of Q/q and A/a commands.

A **Q** command message could look like the one shown in figure 18. Here the message header starts with the default value 0xFE (to identify the message start). The following message field is the *Length* (MSG Length) field which specifies the total length of the packet in bytes; in this case it is 7 bytes long. After the *Length* field comes the bitwise complement of the *Length* field (~MSG Length), as mentioned before it is used to identify the start of the *Payload*. In the *Payload* we can find the *address* (Addr) of the sensor unit and the *command* (Cmd) identifier. The value 0x51 represents the Q command. In this case we are querying the sensors broadcast address 0x3F, all the adjacent sensors will be able to here and reply to the query, this is used for sensor unit discovery.

Start	MSG Length	~MSG Length	Payload	
FE	0 7	FF F8	3F	51
			Addr	*Cmd*

Figure 18: 'Q' command message (values are shown in hexadecimal).

In response to the *Query* command **Q** the sensor unit replies with a *Query Reply* command **A**. Figure 19 shows the message structure. In the *Payload* we can find the **A** command identifier (0x41), next field is the *Protocol version* (this tells the client application which version of commands the sensor unit supports) and it is described so that first byte is the main version and the second byte is the minor version (i.e. 0x01 0x00 is 1.0). The *Buffer size* is the length of the input buffer in bytes (this fields says how much data can be buffered by the sensor unit on a request), and the *Delay* field tells the delay value between each successive message in milliseconds. A delay equal to zero would mean that messages (generated from different sources querying the sensor would have to wait at least the processing time specified in the *Delay* field) can be sent immediately after each other. The delay value is expressed in hexadecimal, so in this case 0x0064 ($0x0064 = 0\times 16^3 + 0\times 16^2 + 6\times 16^1 + 4\times 16^0 = 100$) is equal to 100 milliseconds. The *Reserve2* field is reserves two bytes for future usage (in case the protocol is extended or modified, but without increasing the amount of destined to the message).

Start	MSG Length	~MSG Length	Payload					
FE	00 0F	FF F0	41	41	01 00	00 FE	00 64	00 00
			Addr	*Cmd*	*Version*	*Buffer size*	*Delay*	*Reserve2*

Figure 19: 'A' command message.

The **R/r** command permits the clients to request sensor data. In response to the sensor data request the sensor unit replies with the **V/v** command. Figure 20 illustrates the message direction.

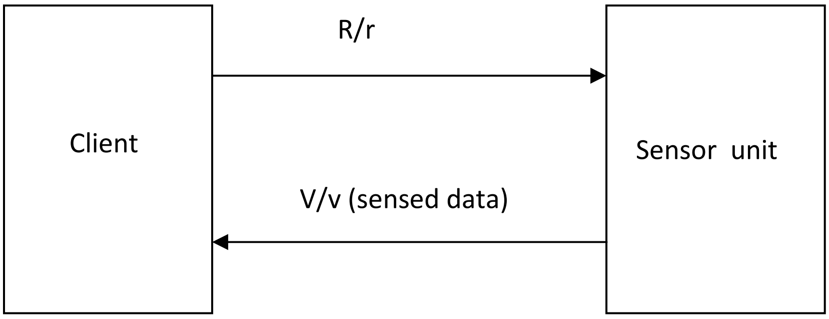


Figure 20: Message direction of R/r and V/v commands.

The *Request Sensor Data* command **R** can request data from one or more sensors within a sensor device. If there is more than a single sensor related to a sensor device, then each sensor is identified by a 2 byte *Sensor ID* field as showed in figure 21.

		Payload		
Addr	*Cmd*	*Sensor ID 1*	*Sensor ID 2*	……

Figure 21: 'R' command message with multiple sensor identifiers.

In our case we only have one sensor in the sensor unit, so no sensor id is needed in our **R** message and it could look like the one shown in figure 22.

Start	MSG Length	~MSG Length	Payload	
FE	0 7	FF F8	41	52
			Addr	*Cmd*

Figure 22: R command message.

The *Sensor data Response* **V** can contain data in its *Payload* data from one or more sensors. For each sensor a four byte data *Value* is present. This is the value of the data expressed in IEEE 754-1985 32 bit floating point (big-endian) format. Figure 23 shows a message received when requesting data from the HRM with an **R** command, the value "42 70 00 00" is equivalent to a heart rate of 60 [beats/minutes], the period of the measurement should typically be below the *Delay* value returned in 'A' command.

Start	MSG Length	~MSG length	Payload			
FE	00 0D	FF F2	41	56	00 01	42 70 00 00
			Addr	*Cmd*	*Sensor Id 1*	*Value 1*

Figure 23: 'V' command message.

3 Related work

This section mentions some of the related work, including existing products on the market and others that are being developed, that could be direct competitors to this system. We will specifically mention some of the research which is being done on sensing within the scope of health care and environmental sensing. Products such as a clinical health monitor used in fixed environments are **not** considered, because they lack the mobility that is one of the important characteristics of this project. No deep technical details about sensors, protocols, or signaling will be given, as little detailed information of this kind has been found (as of the date of writing this report). Additionally, a more rigorous study of these technologies is out of the scope of this thesis project as the field is extremely broad.

3.1 Competing products

There are few directly competing products that have the same objective market and there are also few major players involved. In this section we will primarily focus on the competing products and their main functionalities.

3.1.1 Nokia Eco Sensor Concept

Nokia is developing a system that called the Nokia Eco Sensor Concept. It consists of a wearable sensor device, which will be able to sense and analyze certain environmental variables, as well as monitor the wearer's health and local weather conditions. The sensing devices will be customizable to the user’s needs and desires. The users will be able to choose which sensors they want to have included inside the sensing device. These sensors will interoperate with a mobile phone.

The data collected by the sensor devices can be shared and viewed by other users. This system is intended to help people stay connected to others, while at the same time being aware of their health and local environment. [58]

3.1.2 MiCoach

The Adidas-Samsung collaboration has developed a system called MiCoach that was released in the European market in the middle of March 2008. The system is designed to help, direct, and motivate users in their training by combining a mobile phone, heart rate monitor, stride sensor, MP3 player, and the voice of an electronic "personal coach." The user gets feedback through the mobile phone about speed, distance, and heartbeat rate. If the user selects a training plan, then the “personal coach” will advise the user on how to proceed when running. [59]

3.1.3 Nike+iPod

The Nike+iPod system was annouced in May 2006. The system consists of a small accelerometer attached or embedded in a shoe, which communicates with a receiver plugged into an iPod nano. The iTunes software can be used to view the recorded exercise session. The system is able to store information such as the elapsed time of the workout, the distance traveled, pace, or calories burned by the person wearing the shoes, and display it on the iPod's screen or play it through the headphones attached to an iPod. [60]

This product has a community site called **Runners+**, where users can upload their data and compare it to others training sessions, and results. In the site you can also find running maps, a thriving forums area, groups, videos, and more. [8]

3.1.4 SDA-320

In February of 2008 Spectec Computer Company Ltd. launched the SDA-320 miniSDIO ANT RF card that uses Nordic Semiconductor’s ANT specific nRF24AP1™ [49] 2.4 GHz ultra-low power transceiver, which allows a miniSDIO card slot-equipped smartphone or PDA to wirelessly communicate, collect and analyze data from sports performance and health monitoring sensors such as heart rate straps and speed/distance activity monitors.

The limitation of this system, is that their software runs only on Motorola Q phones using the Windows® CE 6.0 OS, but Spectec is planning to provide support for other smartphones, PDAs, and operating systems. [50]

3.1.5 Comparative analysis

The major advantage of this project compared to the previously mentioned products, besides the offered mobility, data sharing, and real-time communication between the sensors and the data network, is that it uses the IMS infrastructure which has the potential to support a very large devices and a large number of services. These features enable our system to be further developed and incorporated into other IMS services. Because the system uses the SIP Presence it should be fairly easy to incorporate it to another communication services or to add new features.

This project's goal was to enable the introduction of creative and useful mobile applications and web services that build upon the collected sensor data. These services can range from personal health monitoring to large-scale data collection efforts to promote sustainable lifestyle choices.

Based on the previous analysis, the concept that is closest and has the most in common with our project is that of Nokia. However, Nokia has a broader sensing scope in mind; they intend to sense and analyze more data (i.e., both a greater number of sensors and a greater number of values). These sensors are not only for monitoring the person but also environmental conditions. How Nokia will implement their solution is not yet clear, having a technology similar to the SDA-320 card would be the optimal.

Runners+ has also interesting features, for examples it handles data in a great way, and offers an active community site, that can encourage new system users. Some of their ideas are worth analyzing (for future works) as the concepts are very simple, but striking.

The SDA-320 solution for communicating with ANT enabled sensor is probably at this stage the best alternative to build systems that require interaction between sensor nodes and data networks. The SDA-320 technology will most certainly push forward a lot of interesting services, if the SDA-320 project can be further extended to more Smartphones and PDAs.

3.2 Body sensor networks and monitoring systems

Healthcare projects related to body sensing and monitoring are of interest for this thesis work. The study of these projects has provided a broader vision for possible future implementations and improvements, but they will not affect or change the course of the actual project due to company agreements and contracts with partners.

3.2.1 Efforts within the research community

The evolution of sensor networks into wearable platforms and implantable electronics, promises radical changes for applications ranging from healthcare to human-computer interfaces. Many efforts have been made to develop new sensing and monitoring devices. Annually there are several important conferences that should be highlighted, such as the International Symposium on Wearable Computers (ISWC) [4] held since 1997, and the International Workshop on Wearable and Implantable Body Sensor Networks (BSN) [5] held since 2004. In these meetings diverse talents from many fields gather to drive this vision forward.

One of the central focuses in body sensing is to monitor vital signs [61] for example: Heartbeat rate, blood pressure, body temperature, respiration trace and other health indicators. Various systems have been proposed and developed over the years. There are biomedical monitoring systems incorporated into garments, to achieve truly wearable computing. There are other systems that not only read and record vital signs, but can also sense movements of a subject wearing it, an example of such a system is presented in [62], where piezoresistive fabric sensors, made of carbon-loaded rubbers, are used to monitor respire trace and are capable of recording body kinematics. This same system has conductive fabric that makes it possible to implement a wearable electrocardiogram.

Another approach for body sensing and monitoring are implantable devices. This kind of system will definitively solve the wearability issue. There are promising prototypes starting to emerge for managing patients with acute diabetes, for treatment of epilepsy and other debilitating neurological disorders, and for monitoring of patients with chronic cardiac diseases. But many problems are still left to address, such as long-term stability, sensor miniaturization, low-power sensor interface, wireless telemetric links, signal processing, and biocompatibility. [60]

3.2.2 Governmental efforts against CVD

In the western world Cardio-vascular diseases (CVD) are the leading cause of death. Particularly in Europe over 20% of all citizens suffer from a chronic CVD and 45% of all deaths are caused by CVD. Due to this, billions of Euros are spent every year on related treatments, to fight this problem the Information Society Technologies program, of the European Commission's 6th Framework in 2003 funded the **MyHeart** project, which is an integrated research effort of industrial partners, research institutes, academics, and medical hospitals. This consortium consists of 33 different partners from 11 countries. The main idea behind this project is to motivate a healthy and preventive lifestyle combined with early diagnosis; achieving this is expected to result in a systematic decrease of CVD patients, and save millions of life-years. To achieve this goal, knowledge of a person's actual health status must be obtained by frequently collecting their vital signs.

The system to be delivered will be in the form of intelligent biomedical clothes (functional clothes with integrated textile sensors and data processing capabilities). Based upon the collected data, trends could be detected and life-style and medical decisions would be easier to make. Communication devices are a vital part of the system; they will permit the interaction between the patient and the professional medical services which can give personalized guidelines and feedback to the patient, based on the monitoring results or specific queries.

The MyHeart project is expected to find technical solutions for CVD. It is also expected to generate an outcome that will open a new mass market for the European industry, covering the whole value chain from textile research, via fashion and electronic design; towards medical and home-based applications meanwhile it will reduce the overall EU healthcare costs. [64]

3.2.3 Heart Failure Management System

The Heart Failure Management System is one of the systems being proposed within the **MyHeart** project scope; it is a complete monitoring system that has many similarities with this thesis project. This project makes use of the latest technologies to monitor heart condition, both with wearable garments (to measure electrocardiogram and respiration trace); and portable devices (such as weight scale and blood pressure cuff) with Bluetooth capabilities. These devices communicate with a User Interaction System, which is a personal digital assistant (PDA) device that is able to provide Internet connectivity. This interface receives data from the monitoring devices, processes it, and forwards it to a database server, the healthcare centers personnel can later analyze the data from a web portal and take actions based on them. The patients can receive constant feedback through the interface to be encouraged in the daily care for their health. [65]

Note: *Some of the weaknesses stated by the project owners are that the design is not appropriate for hot weather conditions. Moreover, some users have a reluctance to wear tight clothes.*

3.3 Wireless body area sensor network

As mentioned earlier, many efforts are being put into improve the ways of monitoring patients within health care. A concept known as **Wireless body area sensor network**, is proposed in [63] for remote monitoring. This system do not differ very much from the previously mentioned system, but it has some interesting aspects such as the use of ZigBee, Bluetooth, cellular network technologies, and that they state that is a real-time solution, but the system at the time of the publication it is not fully implemented, only the sensor network is completed. For more details refer to [66]

3.4 SensorPlanet

SensorPlanet is a Nokia initiated cooperation resulting in a global research framework. The SensorPlanet project builds an open global mobile device centric research platform for wireless sensor network research. This platform provides the necessary infrastructure for world's top research labs to perform innovative research on wireless sensor networks, where the mobile devices can be seen both as gateways to a mesh of sensor networks and also as sensor nodes.

Nokia expects to collaborate with the best teams in the field around the world, and direct the academic Wireless Sensor Network research globally towards mobile device centric innovation. [67]

3.5 Urban sensing

At the U.S Center of Embedded Networked Sensing (CENS), there are ongoing projects related to environmental sensing in a person's near field environment, using network connected mobile handsets are used as sensor nodes, due to these devices capacity to capture, process, and transmit information. For example microphones and imagers on mobile handsets can record environmental data. Location and time synchronization data can be provided by cell tower positioning, GPS or other technologies.

CENS was an early partner in the SensorPlanet program, which provided over 250 mobile phones and service in 2006-7 for this research. In this project people have been involved defining and participating in their own data collection, from dietary intake studies in large populations to geotagged audio documentary gathering the "sounds of the city" for cultural experience or noise pollution evaluation. This type of sensing requires new algorithms and software mechanisms, because physical inputs and the location of fixed and moving devices become critical data context. ***S*****elective sharing** mechanisms are needed to enable sharing of data in a controlled way while respecting the privacy of those being sensed. **Location and time** are crucial for urban sensing, where they may be equally or more important to data credibility than the gatherer's identity, this increases the utility of sensor data. [68]

4 System description: approach and methodology

This thesis project's main objective is the implementation of a heart rate monitoring system for athletes. This section will explain in detail the different parts of the system, the implementation, and methods chosen.

This heart rate monitoring system is meant to be helpful for persons who want to keep track or get feedback on their performance during a training session, related to a sports activity of any kind (except for underwater sports). The system provides persistent real-time data that can be viewed online, via a web application by a user interested in this information; this user could for example be the athlete's personal trainer or coach. This trainer or coach could analyze the information to be able to give the athlete appropriate feedback. The data can also be downloaded from the web application and be analyzed with whatever tools that the users considers suitable. This information can be of great help for athletes to structure their training according to results, performance, and trend; facilitating the achievement of their goals.

4.1 System architecture

The heart rate monitoring system is based upon interoperation of several physical and logical devices (as shown in figure 24). The sensor node is a high precision *heart rate monitor* from SUUNTO model T6 [44]. This sensor has a local processing unit that can process and respond to queries in the form of ANT protocol messages (see section 2.11.1), and it communicates wirelessly with other devices through ANT radio technology (see section 2.11.1). In this way the sensor communicates with the system's *signaling and processing unit (SPU)*, which can retrieve heart rate information from the HRM. Once the heart rate data is obtained by the SPU, it processes it and stores it locally, then publishes it to the PGM via IMS. The SPU interacts with the IMS network through SIP and XCAP. Every time the PGM is updated with new information it will notify the subscribers of the corresponding presence list, according to SIP's notification framework. In this case the subscriber is an application server that is running a web application somewhere on the Internet. This permits the users of the web application to follow a user's performance, to store and retrieve the information related to a training session.

This system has been implemented in two variants, in a mobile and fixed solution (each will of them be described in the following sections). The only difference between the two systems, is the SPU platform, formed by different hardware and software components.

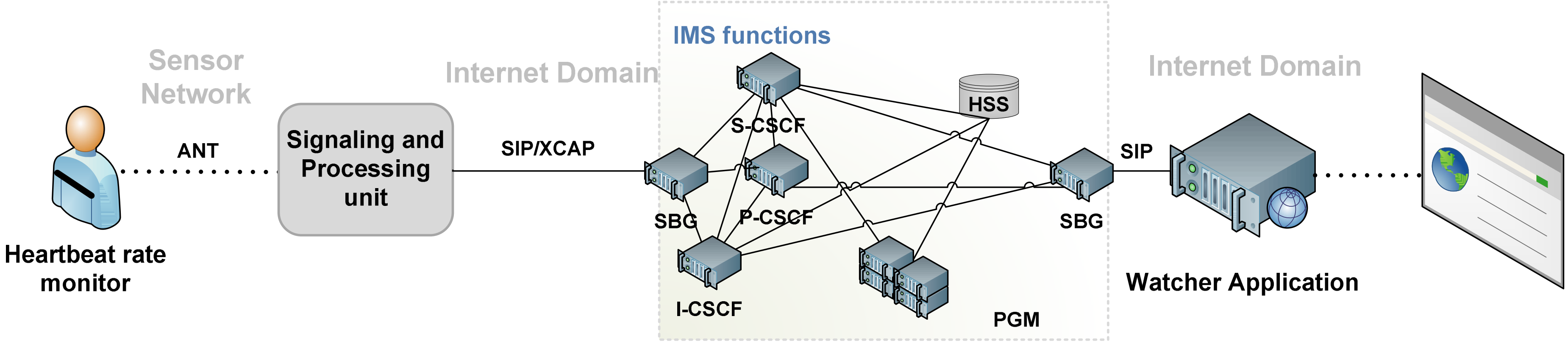


Figure 24: system architecture.

Note: *In our system the S-CSCF, the P-CSCF, and the I-CSCF are in the same physical node. The Session Border Gateway (SBG) effects similar functions to the IBCF explained in section 2.1.3.*

4.2 Mobile solution

The *mobile solution* is intended to be used for outdoor sports activities such as running, cross country skiing, biking, etc. The principal goal of this solution is to offer mobility.

In this alternative solution of the monitoring system, the SPU is formed by the *All-in-one* (ANT-to-Bluetooth/SSI Bridge) module, a Bluetooth enabled mobile phone with internet connectivity, and a software application that runs on top of the mobile phone (this application requests and processes sensor data, and it also acts as a PUA). Figure 25 illustrates the mobile SPU platform, with its interacting components and involved protocols.

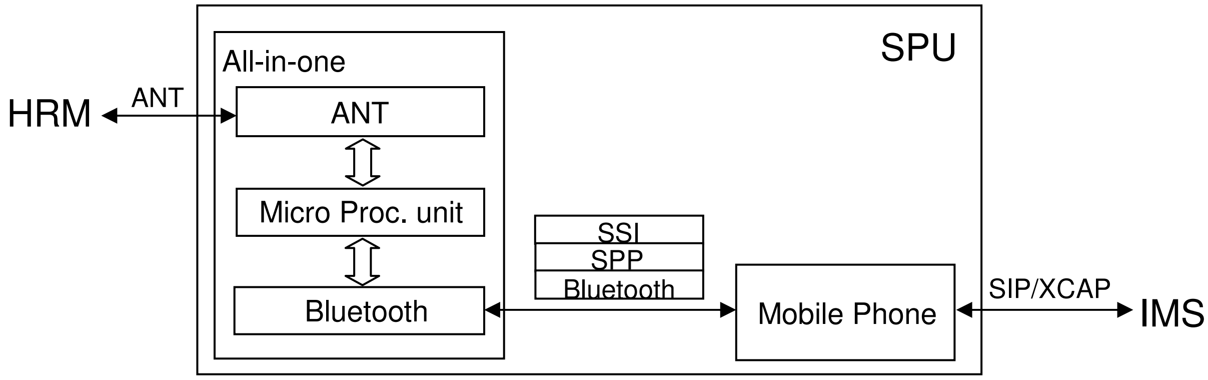


Figure 25: SPU for mobile solution.

4.2.1 The mobile SPU's signaling interaction

The mobile phone application (MPA) is the heart of the SPU platform. It is the MPA that normally initiates the interaction within the SPU. Figure 26 show an example of how this interaction might look. The different SPU components start to interact when the MPA searches for and discovers the available Bluetooth services. If there are services available, then a list of Bluetooth devices will be generated. The user will select the SPU Bluetooth module from the list, then the MPA will create a serial port profile (SPP) connection with the Bluetooth device (1). After this serial connection is established (3) the MPA registers with the IMS network and subscribes to the presentity's watcher list; this is done by a SIP REGISTER (4) and a SIP SUBSCRIBE request (6) respectively. Later the application starts to query the sensor for data. Every time the MPA queries the HRM for data, it sends SSI command messages over the SPP connection (10), this messages are converted into the corresponding ANT specific message by the *All-in-one* microprocessor. After this conversion process the command messages are forwarded to the HRM via ANT radio technology (11). When the HRM responds, the SPU receives an ANT message (12) converts it to an SSI message and transmits this message to the MPA over the already established Bluetooth SPP connection. Finally the MPA receives the SSI message (13) and interprets it as described in section 2.11.2.

A valid message from the HRM for this solution is either a *Query reply* or a *Sensor data response*. If the received messages contains sensor measurements, then the MPA generates a PUBLISH request (14) that will be forwarded to the PGM via IMS. This PUBLISH request contains the HRM data as a value field in the presence document. The MPA has additional functionalities such as watcher list management (performed through XCAP)[43].

Note: *Once the Bluetooth connection is established it remains open for as long as the session lasts, the sequences numbered 10 to 15 in figure 26 are executed in a asynchronous cycle (that is established by the delay of the 200 OK response of the PUBLISH request and configurable sleep timer managed by the application), this cycle is executed for as long as the user wants to publish his heartbeat rate. The sequences numbered 1 to 9 are mandatory before the querying and publishing procedure begins, if one of this processes fails, then the MPA must re-execute them.*

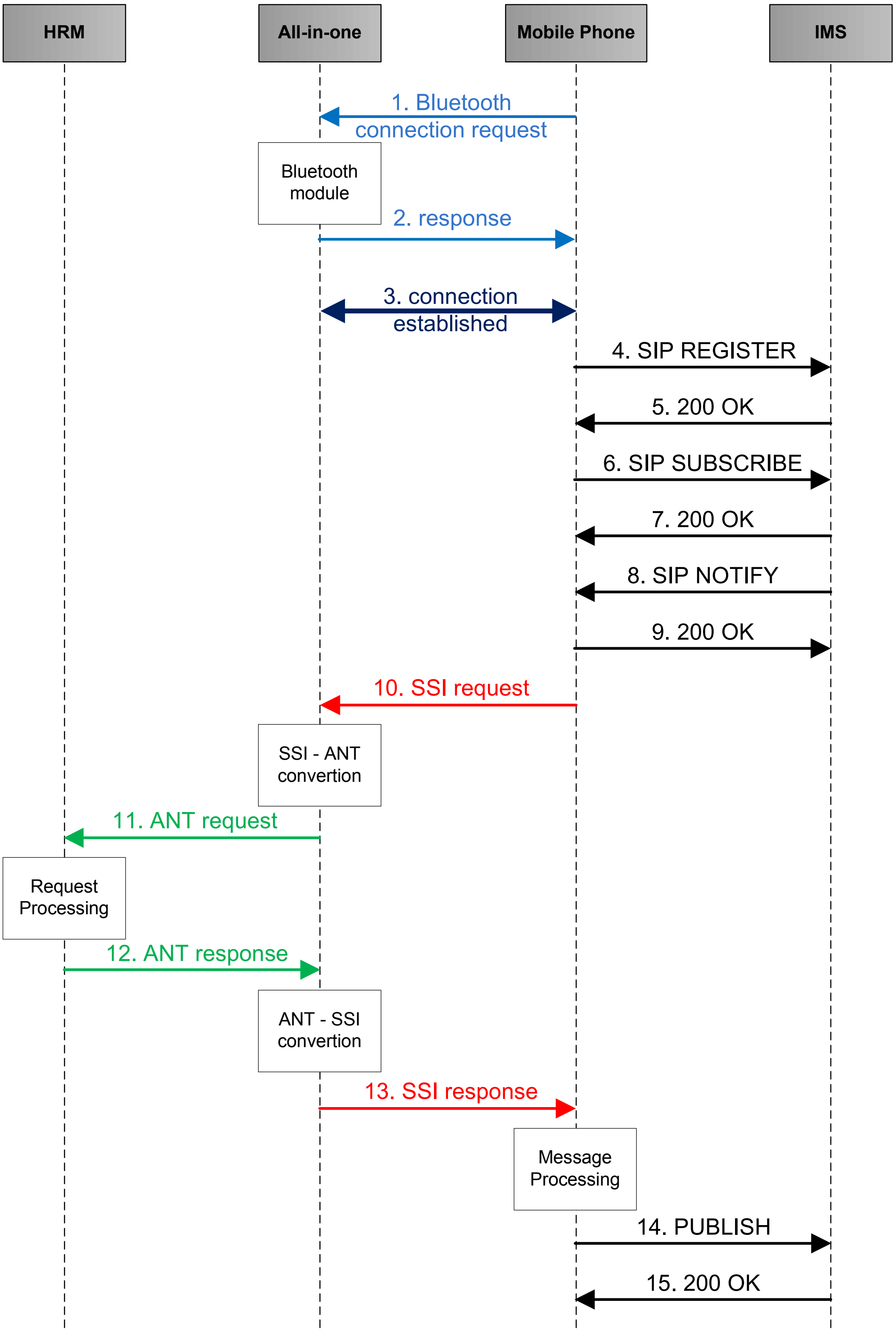


Figure 26: the mobile SPU's general signaling.

4.2.2 Description of the mobile phone application

As mentioned earlier the MPA is the core of the SPU platform, since it provides the Bluetooth and Internet connectivity, generates requests and processes information, is responsible for most of the incoming and outgoing signaling from the SPU, and provides a friendly interface for managing the client service. This application is based upon the modules shown in figure 27. Each of these modules is described below.

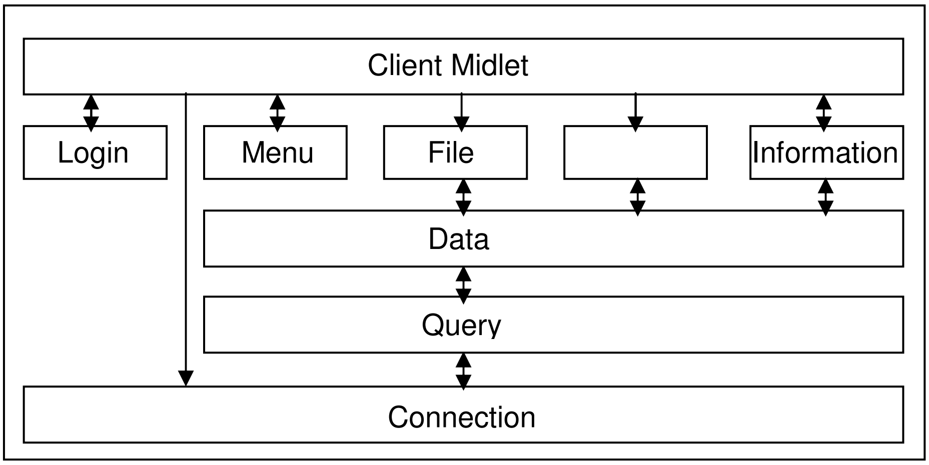


Figure 27: the MPA modules.

The **Client Midlet** implements the application's state machine (utilizing Java ME technology) [69], manages the midlet's life cycle, and the mobile phone's display. This is the program's main class. As such it initializes most of the application's modules.

The **Information module** manages the information displayed on the mobile phone's screen regarding the measured data. It displays the current heartbeat rate, along with the minimum and maximum heart rate values for the ongoing session. It also displays the total elapsed session time.

The **Menu module** interacts closely with the *Client Midlet*, it provides all the menus, lists and forms that are presented to the user during the program's execution. The *Menu module* creates the system's command listeners, which trigger the different operations and cause the transition to the various states of the midlet.

The **Presence module** is the module that manages all the IMS related operations, such as registration, subscription, publishing, and watcher list management. It instantiates the *Data module*.

The **Login module** instance retrieves and stores user login information for registration and authentication to the IMS system.

The **File module** stores sensor data locally in system for later use. This data can be transferred to a computer and analyzed with other tools.

The **Connection module** manages the Bluetooth serial connection. It involves device discovery, service search, connection setup, and connection closing.

The **Query module** manages the SSI command interaction. It generates and sends SSI command messages via the Bluetooth SPP connection (note: it retrieves the connection identifier from the *Connection module*), and it also processes the response messages content. This module also decodes the SSI message's *Value* measurement field (i.e., it performs the decoding from floating point 32 to integer, this value was chosen to be truncated to integer, just to have a nicer output).

The **Data module** instantiates the *Query module* to manage the query triggering and current heart rate value. The *Data module* computes statistics about the minimum and maximum heartbeat rate, as well as recording the total elapsed session time.

4.2.3 Execution on the MPA

In this subsection we will describe the complete execution sequence for the MPA. When the users start the application they are prompt with an *Execution Option* menu, from which they chose between storing data locally or publishing it on the web. If they chose to publish the information, then the information will be sent to the PGM via IMS, and the PGM will make the data available for other users. This process will be described from when the user runs the program to the point where information is published to the PGM. This will involve all the functions described in the previous subsection. Figure 28 shows the sequence diagram. Following this figure all of the different steps are explained.

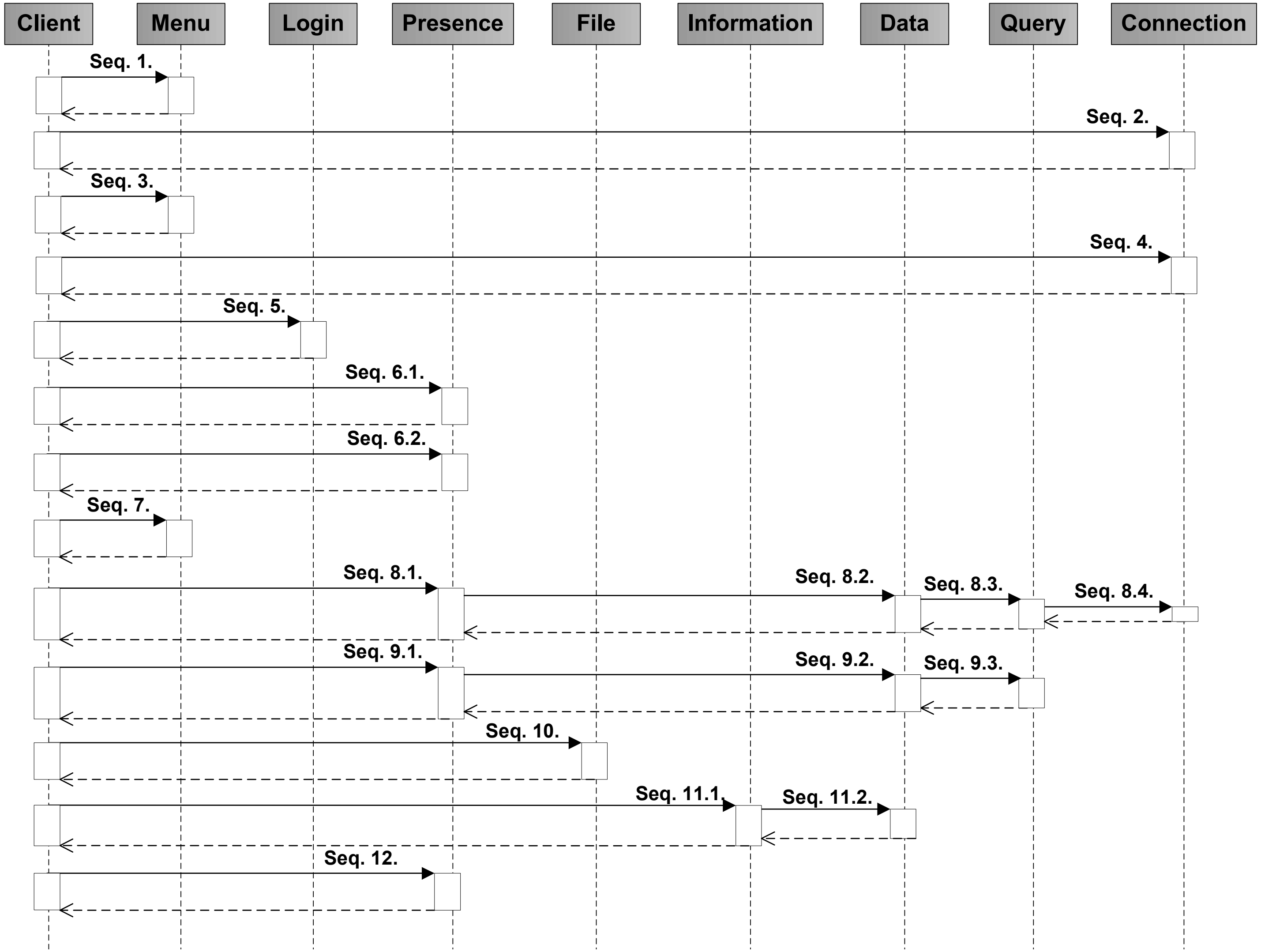


Figure 28: general sequence diagram for the MPA.

Step 1: When the program start execution, the first thing that will happen is that the *Client Midlet* will call the *Menu module* to create and display the execution menu. Figure 29 show the *Execution Options* menu.

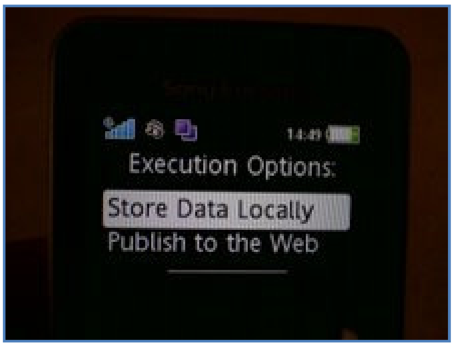


Figure 29: execution options menu.

Step 2: Once the option is selected by the user (in this example "*Publish to the web*"), then the *Client Midlet* will instantiate the *Connection module* which will initiates the Bluetooth device discovery process.

Step 3: The *Menu module* will display a list of available Bluetooth services discovered (in the previous step), with the equipment's name [70]. In this step, the user must select a devices to connect to from the list. Figure 30 shows the *List of Devices* that were found, that have some available service according to what is defined in [70].

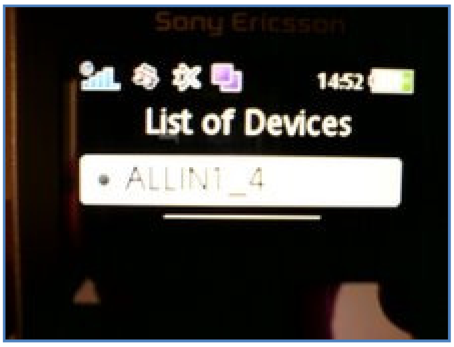


Figure 30: list of devices.

Step 4: The *Connection module* creates a connection request to the selected device based on the service URL. The user will be prompt for a password to connect to the device, once authorized the connection will be established. The connection identifier will be retained by the *Connection module.*

Step 5: The *Login module* prompts the user for his or her IMS credentials, this information will be used when registering with the IMS network.

Step 6: The IMS registration (in step Seq. 6.1.), and watcher list subscription (Seq. 6.2) are executed. This is done by the *Presence module*, which accesses the data credentials stored by the Login module in the phone's persistent memory through a *Recordstore* operation [69].

Step 7: Once the previous process has completed successfully, then the *Menu module* changes the present connection menu into a menu for viewing and sending HRM information.

Step 8: The *Presence module* instantiates the *Data module*, which calls the *Query module* which uses the connection identifier, stored by the *Connection manager* to send and receive messages from the HRM.

Step 9: The *Presence module* calls the *Data module* to trigger a query from the *Query module* to retrieve the current HRM value. The *Presence module* receives the latest sensor data and the related statistics from the *Data module* (these values can be accessed statically from the other modules), and generates the PUBLISH request, which is sent via IMS.

Step 10: The *File module* stores the sensor data in a file together with the current time stamp.

Step 11: The *Information module* displays on the mobile phone's screen the current measured HRM value, and the minimum, and maximum values for the ongoing session, together with the elapsed session time. Figure 31 shows the HRM information as displayed on a mobile phone.

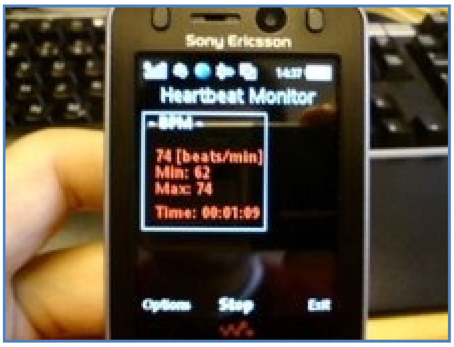


Figure 31: HRM Information displayed on a mobile phone.

Note: *When a 200 OK is received in response to the PUBLISH request, then the steps from 9 to 11 will be re-executed. This will continue until the user decides to stop the application or fail response is received. So far only 403 responses are handled (with a re-registering operation).*

Step 12: After terminating the execution of the program, the *Presence module* will unregister from the IMS network by sending a REGISTER request with the *Expires* field equal to zero.

4.2.4 Hardware used in the mobile SPU

The **mobile phone** used in the implementation and testing of the prototype was a Sony Ericsson W910i. This phone is Bluetooth enabled, with 1 GB of memory, and support for GPRS, EDGE, UMTS, and HSDPA. The **All-in-one** module has a Bluetooth transceiver, an ANT transceiver, a micro processing unit, and a rechargeable battery.

4.2.5 Tools used for developing the MPA

The tools used for developing the MPA will be briefly described in this section. We will begin with the programming language and move on to the integrated development environment.

The **Java Platform, Micro Edition (Java ME)** was used for programming and is a collection of technologies and specifications that provides a robust, flexible environment for building applications that will run on mobile phones, PDAs, TV set-top boxes, printers, and other embedded devices. Java ME includes flexible user interfaces, robust security, built-in network protocols, and support for networked and offline applications that can be downloaded dynamically. Applications based on Java ME are portable across many devices, while often able to utilize a device's native capabilities.[71] In addition to the Java ME standard libraries, we used an Ericsson early version of the **JSR 281** [72] (developed within the scope of the HiFive project [7]). This library provides a high-level API for IMS.

The integrated (program) development environment (IDE) used was the **Eclipse Java IDE** version 3.3.1.1. This is an extensible open source development platform that is part of the Eclipse community project. These projects are focused on creating a development platform, runtime libraries, and application frameworks for building, deploying, and managing software across the entire software lifecycle. [73] When developing Java ME applications it necessary to install the **Sun Java Wireless Toolkit for CLDC** (we used version 2.5.2) [74]. This toolkit is designed to facilitate development of wireless applications based on Java ME's Connected Limited Device Configuration (CLDC) and Mobile Information Device Profile (MIDP). The toolkit includes the relevant Java ME libraries, emulation environments, performance optimization, and tuning features. This toolkit cannot be used as a standalone development environment (as it does not include a text editor). In order to use the Eclipse Java IDE together with Sun’s Java Wireless Toolkit it is necessary to install **EclipseME** version 1.7.9, a plugin for Eclipse that helps developing Java ME MIDlets. This plugin connects the Sun Java Wireless Toolkit to the Eclipse development environment, facilitating working with Java ME. [75]

4.3 Fixed solution

The *fixed solution* developed in this thesis project was targeted for indoor activities that are limited to smaller spaces and more limited mobility, such as spinning, aerobics, etc. Having this kind of scenario in mind the PUA can run on a fixed terminal.

Figure 32 illustrates the fixed SPU platform structure. The architecture of the fixed SPU platform is less complex than that used in the mobile SPU. The components are, an ANT transceiver in the form of a USB stick, a USB enabled PC with Internet access, and a software application that runs on the PC. This application provides the same general functions as the application utilized in the mobile solution (explained in the previous section). One of the biggest differences is that SSI commands are no longer needed to query the sensor node; since the communication between the HRM and the PC is purely ANT. Thus the interaction between the application and the HRM is more efficient in this solution, than when using a ANT to Bluetooth bridge.

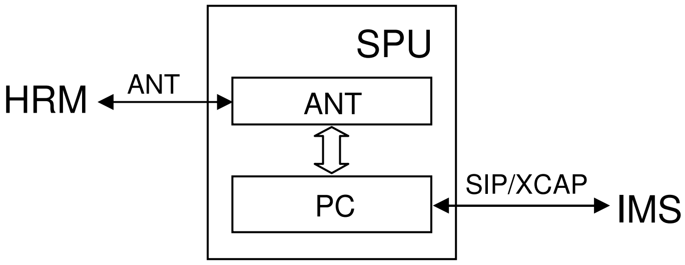


Figure 32: SPU for fixed solution.

4.3.1 The fixed solution's signaling interaction

Figure 33 shows a scenario of the signaling between the HRM, SPU, and the IMS network. As previously mentioned, the communication between the HRM and SPU is directly via ANT. The signaling in this solution are different from the mobile solution; since there is less equipment necessary and there is only one radio technology (ANT) required rather than an ANT to Bluetooth bridge. As in the mobile solution, the software acts as a PUA, and registers with the IMS network, subscribes to the presentity's watcher list, and publishes sensor data. Thus the application send a SIP REGISTER (message 1), a SIP SUBSCRIBE (message 3), and a SIP PUBLISH (message 9) respectively. The data communication from the PC application to the HRM (message 7) and vice versa (message 8) is directly via ANT. The response messages received by the SPU from the HRM are processed by the PC application. If they contain valid measurement data, then this data is inserted in the presence document that is attached to the PUBLISH request (message 9) and sent to the PGM via IMS.

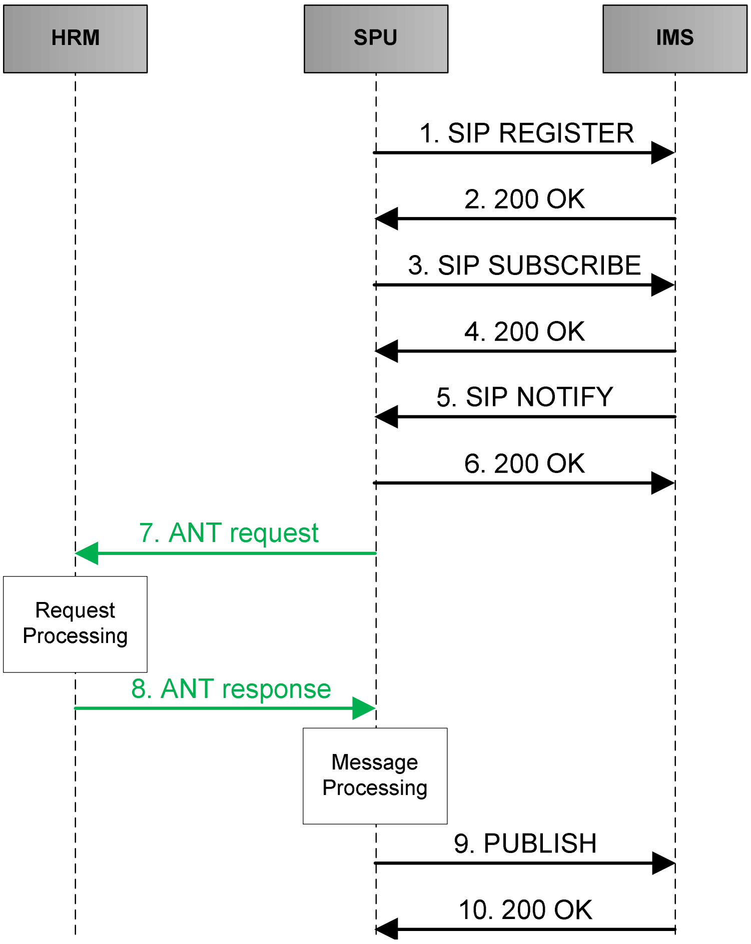


Figure 33: the fixed SPU's general signaling.

4.3.2 Description of the Desktop application

The *desktop application* offers a GUI with several functions, among them user management, data storage, a screen that displays the sensed data, minimums, maximums, and the total elapsed time of each session. The application interacts with the HRM through a thin low level layer module (*Query module*) written in C that uses the ANT API made by SUUNTO to request and receive sensor data from the HRM. This low level module interacts with the J2SE modules through the Java Native Interface (JNI). The *presence* related operations are the same as in the mobile application. The desktop application registers with the IMS network through a SIP REGISTER request, and then subscribes to a presentity's watcher list with a SIP SUBSCRIBE request. On each new sensed value the application publishes the data to the PGM and stores the values into a file. This file can be retrieved by the user and used with other tools. Figure 34 shows the application's module structure. The functions of each module are briefly described below.

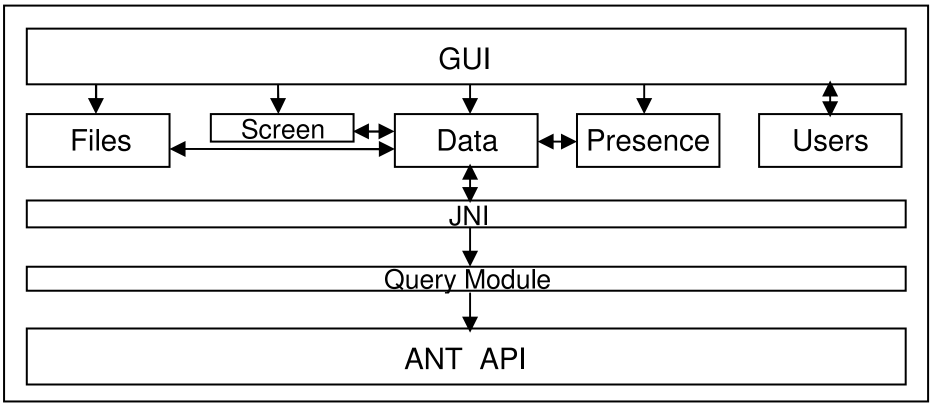


Figure 34: desktop application's module structure 3

The **ANT API** provides driver routines for interacting with the USB ANT transceiver. It also provides methods for detecting ANT sensor units and for querying them.

The **Query module** uses the discovery and query methods present in the ANT API, to the HRM based upon its sensor address (discovered by querying the broadcast address 0x3F), then to request sensor information and measurement data from it.

The **JNI module** enables the J2SE methods to interact with the *Query module* that is written in C.

The **Users module** administers the system users, basic data (specifically the information need to login to the IMS network, such as Public User Identity, Private User Identity, and password. These parameters are used to emulate the subscriber's ISIM credentials, as today there are no ISIM available in the market). Through this module a user's data can be added, deleted, or edited. This module interacts only with the GUI.

The **Files module** stores the sensed data in a simple two column format (value/timestamp, the timestamp is expressed as "yyyy-MM-dd HH:mm:ss.SS" format, which represents the time in which the *Data module* got the heart rate value). Each new measured value the data is stored to a file, transparently to the user. Before exiting or when starting a new measurement session the user is asked via the GUI if they want to store the measured data. If not, then the background processing of the file will not take place. The *Files module* interacts with both the *Data* and *GUI* modules.

The **Data module** communicates with JNI in order to make the sensor values available to the rest of the modules (*GUI*, *Files*, and *Presence*) in a cyclic operation, the sensor values are kept in a static variable. This module also computes statistics, such as minimum and maximum heart rate per session, as well as keeping track of the total elapsed time of a session.

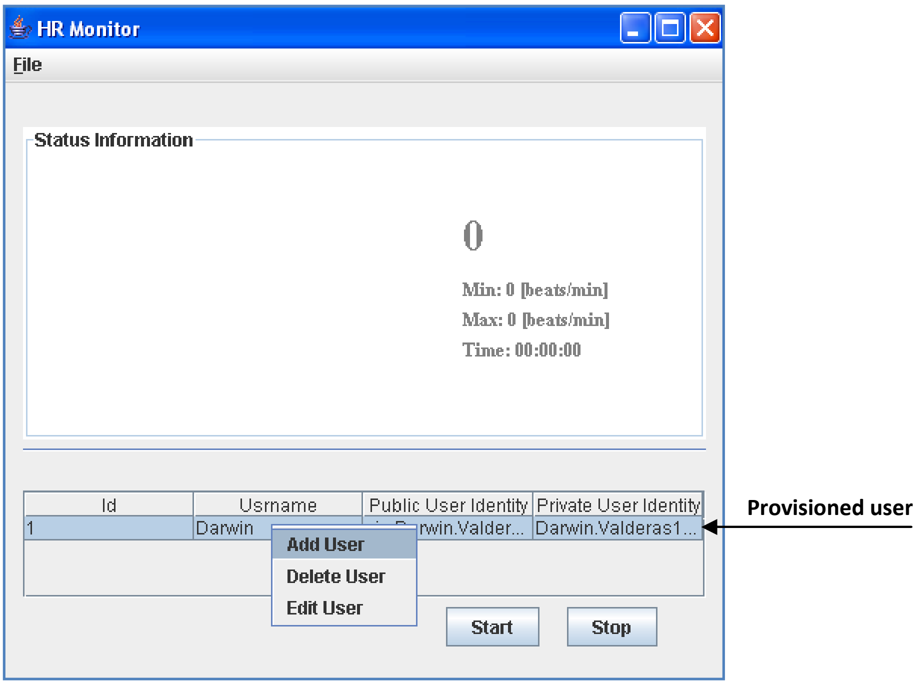
The **Presence module** is the module that makes it possible for the application to connect to the IMS network. This module implements the PUA related features: REGISTER, SUBSCRIBE, PUBLISH, and administer watcher lists. Through this module the data is published to the PGM via IMS. This module interacts with the *GUI* when the session is initiated and ends, it receives the sensor data from the *Data module* and uses the user's credentials to register when it initialized**.**

The **GUI module** is the main class of the program. This module it interacts with all the higher level modules and acts as a user interface for each one of them. The GUI offers user administration menu, along with displaying the data and statistics related to the session. It also provides a menu for retrieving and publishing the collected data.

4.3.3 Execution sequences of the desktop application

In this subsection, we will show the interaction between the different modules within the application through an example. The purpose is to present their general functionalities.

When a user first runs the application, the first thing that he or she should do is to configure a profile. This is done by selecting the *User add* option from the *File menu* or by right clicking over the profiles tables and entering the requested data, after adding the user credentials the system will store them persistently. This user profile will now be visible in the applications display as a valid profile, which can now be used to connect with the IMS network. Figure 35 shows the desktop client and the *Add user* menu.



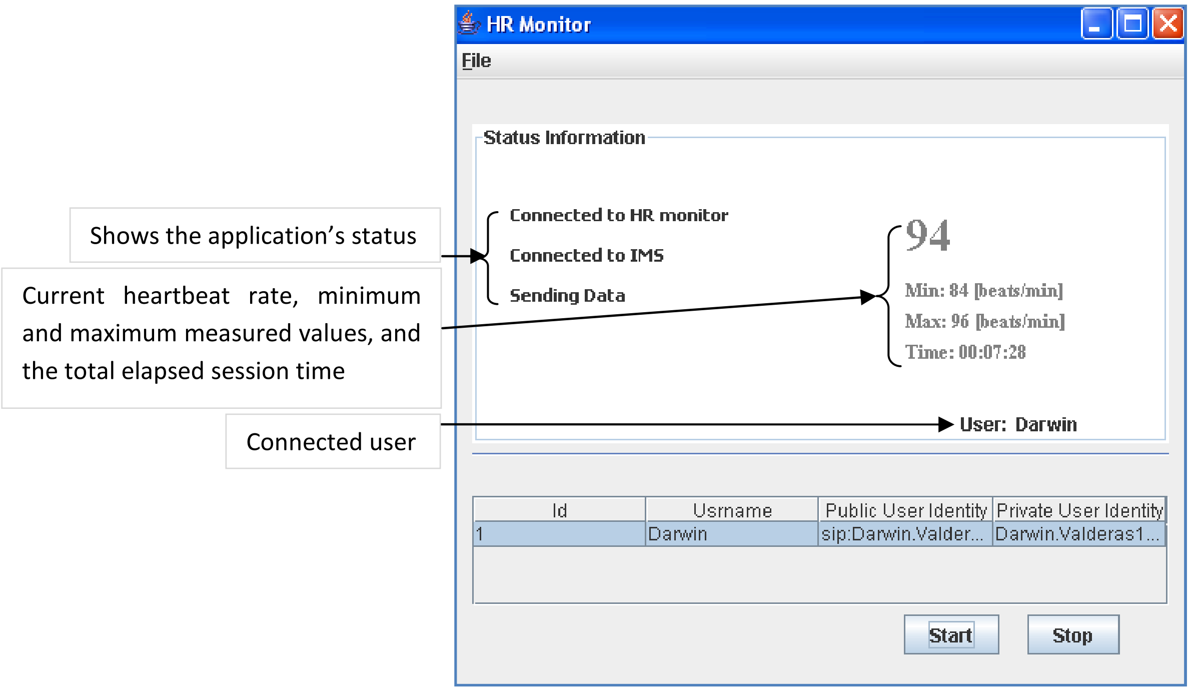
0

Min: 0 [beats/min]
Max: 0 [beats/min]
Time: 00:00:00

Id	Usrname	Public User Identity	Private User Identity
1	Darwin	rwin.Valder...	Darwin.Valderas1...

Figure 35: desktop application, adding user operation.

When the user decides to initiate the measurement procedure, he or she must select a user profile from the existing ones to begin a new session, then press the *Start* (session) button. The IMS connection procedure will begin. When there is sensor data it will be displayed in the visual information screen, and at the same time it will be published to the PGM via IMS. Figure 36 shows the information displayed by the desktop client.


Shows the application’s status
Current heartbeat rate, minimum and maximum measured values, and the total elapsed session time
Connected user
HR Monitor
File
Status Information
Start
Stop

Connected to HR monitor
Connected to IMS
Sending Data

94
Min: 84 [beats/min]
Max: 96 [beats/min]
Time: 00:07:28

User: Darwin

Id	Usrname	Public User Identity	Private User Identity
1	Darwin	sip:Darwin.Valder...	Darwin.Valderas1...

Figure 36: desktop application, publishing measurement information.

Note: *This figure caption was taken right after lunch. I climb 5 stares to get back to my office.*

When the user wishes to stop the measurements, the user presses the "Stop" button; then a popup menu will query the user, to ask if they wish to store the session data permanently, if so a file manager window will be shown and the user will be able to save the file as *user-name-date-starting-time-of-session.txt*. Once the measurement session has stopped no additional data is retrieved from the HRM nor is any data published. Figure 37 shows the sequence diagram for this example, and each step in the sequence is described below.

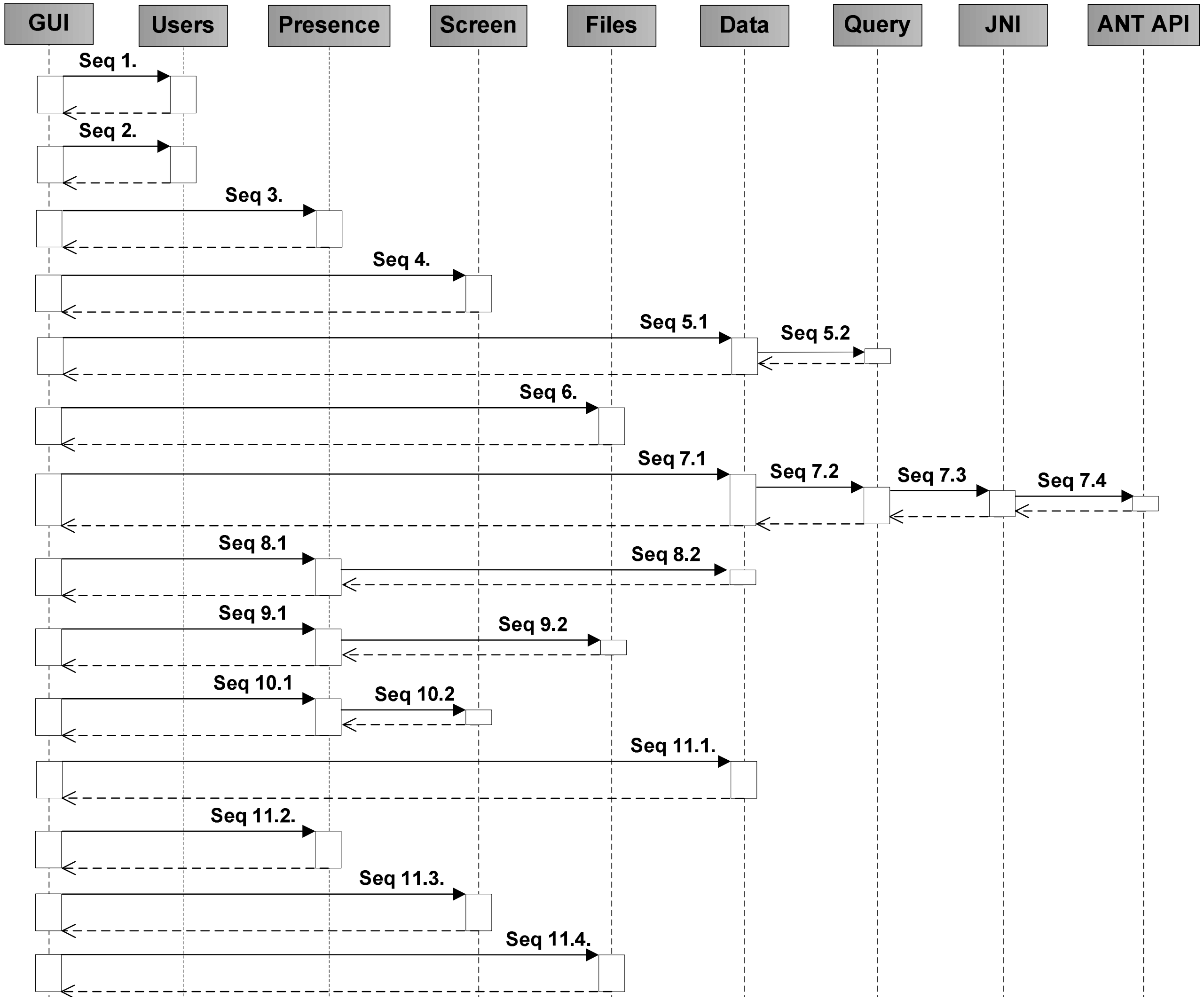


Figure 37: desktop application's example sequence diagram.

Step 1: The *GUI module* creates an instance of the *User module*, and adds the user's credentials, then stores this user data in non-volatile storage, as a property file in the local file system.

Step 2: After adding a new user, the GUI reloads the list of available user profiles with help of the *User module*. Now the new user is displayed in the profile table.

Step 3: A user profile is selected from the list and the *Start* button is pressed to initiate the session. The GUI reads the selected table field and extracts the name of the selected user profile from there. With this data it initializes the *Presence module*. The presence module performs the presentity's registration and subscribes to its watcher list.

Step 4: The GUI creates an instance of the *Screen module* in which the measurement information will later be displayed.

Step 5: The data measurement procedure is initiated. The GUI creates an instance of the *Data module* which in his turn creates an instance of the *JNI module*.

Step 6: The GUI creates an instance of the *Files module*.

Step 7: The *Data module* performs measurement queries and stores the measurement value in a local variable, updates the statistics (such as minimum, maximum measured values), and records the total elapsed time of the session. After this the thread sleeps - awaiting another measurement event.

Step 8: The *Presence Module* extracts the measured values along with the statistical data from the *Data module* through a static method, then it generates and sends the PUBLISH message with this information to the PGM via IMS. When it receives a 200 OK response, this process sleeps for a configurable time period, this can be used to handle the frequency in which the publish messages are sent, this time is additional to the response delay that is not manageable.

Step 9: The *Files module* also retrieves the measured value and the timestamp from the *Data module*, stores the data in a temporary session file as a value and timestamp; with a tab between the values. Entries are stored with one line per measurement.

Step 10: The *Screen module* reads the data from the Data module and displays it on the information screen.

Note: *The Data and Presence processes are run by the GUI in different threads. The Files and Screen modules are run by the same thread. First the Data module is initialized,* and then the *Presence module, and finally the Files and the Screen module. These threads are asynchronous to each other. The Presence and Files threads will assume there is new data when the session's timestamp, kept by the Data module has changed. This processes are executed in a cycle.*

Step 11: When the user presses the Stop session button, all processing stops, this includes the Data, Presence, Files, and Screen modules.

Step 11.1: When the *Data module* receives the stop signal it will terminate the query process and fall sleep.

Step 11.2: Upon a received stop signal the *Presence module* will sleep.

Step 11.3: The *Screen module* sleeps after receiving the stop signal.

Step 11.4: When the *Files module* receives the stop signal it will popup a menu querying, allowing the user to store the session file, if so, then the user gets to name the previously stored temporary file otherwise the temporary file is removed. Following this the module sleeps.

4.3.4 Hardware used in the fixed SPU

A laptop computer, specifically a HP Compaq nv8240 was used as the SPU. This computer is equipped with an Intel Pentium Mobile 2 GHz processor, 2 GB of RAM, and a USB master interface. An ANT transceiver in the form of a USB stick was inserted into the computer's USB socket.

4.3.5 Tools used for developing the desktop application

The tools used for developing the desktop application are different from the ones chosen for the MPA, as both the needs and the hardware platform were different.

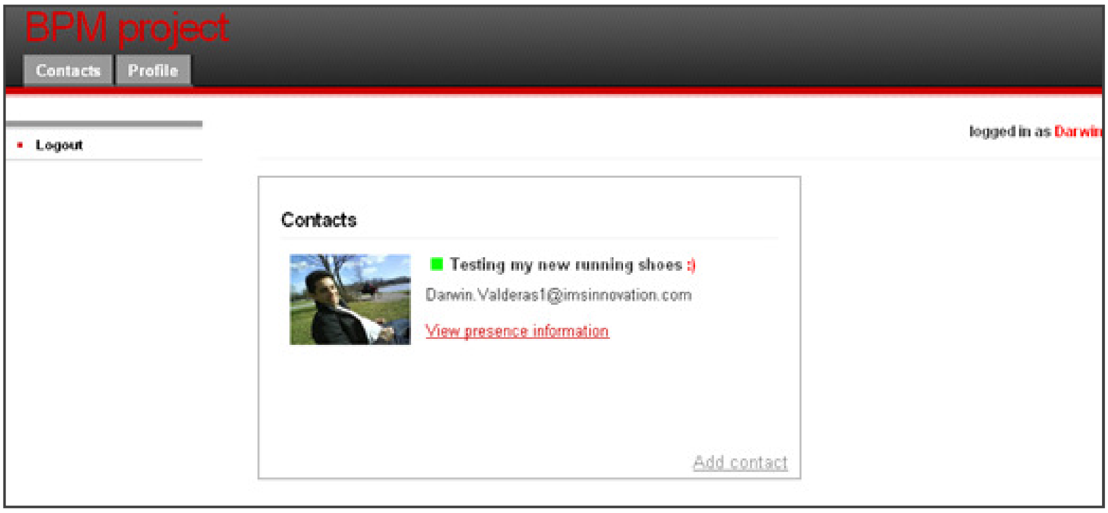
When developing the desktop application we used both C and J2SE version 1.5. The resulting code in these two languages interacts through J2SE's Java Native Interface (JNI) technology [76]. C was used in the programming related to the ANT transceiver and HRM query operations. J2SE was used for the remainder of the solution (i.e., for the user interface, network operations related to SIP and XCAP, etc). In this solution did not use the IMS API as none was available for this platform. Note that the API used in the mobile client was not possible to use as it was built Java ME specific, which is not upward compatible with J2SE (As the network, and connector classes, among others are defined in the javax.microedition.* packet which is only available in Java ME). Instead we used the SIP API's from JAIN-SIP [77], an open-source project that provides a standard portable interface to share information between SIP Clients and SIP Servers according to the RFC 3261 [20]. The JAIN-SIP specifications can be found in the JSR 32 [78].

The programming environment used for developing the desktop application was the **Netbeans IDE** version 6.1 [79]. This is an open-source IDE, with all the tools needed to create desktop, enterprise, web, and mobile applications with Java, C/C++, and Ruby. It is integrated with databases (e.g., MySQL and Apache Derby) and application servers (e.g., Tomcat, Glassfish, and Sailfin). Netbeans offers many plugins, which facilitated our multilanguage project. It also has great features for database management) and was more intuitive to use than Eclipse.

4.4 Watcher application

The Watcher application enables people interested in following the real-time performance of a HRM user during their sports activities. The watcher is a web application that can be viewed from anywhere in the world. It provides a graphical display of the HRM user's results, from as a chart, with a table of minimums and maximum values measured during the sessions, and each session's duration. The web application is also able to store measurement data permanently. The data is stored in *.txt* format in two columns (value/timestamp) separated by a tab, so that this data can easily be manipulated with external programs (for example Excel or Matlab).

The web application acts as a watcher for an HRM user's presence information. This means that the application subscribes to the HRM user's presence information (the application's subscription to the different presentity's must first be approved by the subscriber, before the application can receive any information. The PUA allows or denies the access to a presentity's presence information by managing its watcher list). Figure 38 shows a screen-shot of the web application, in which the application user has already subscribed to a HRM user's presence information and the HRM user is online.

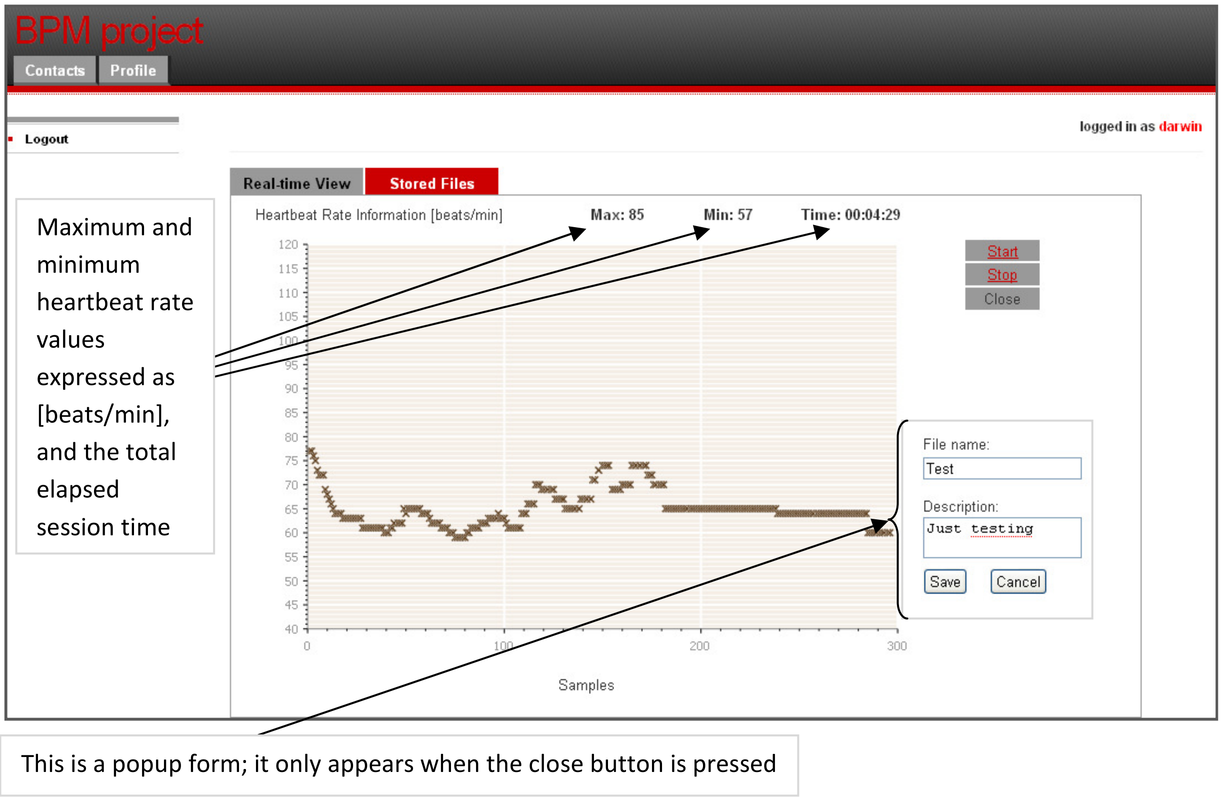


🟩 Testing my new running shoes :)

Darwin.Valderas1@imsinnovation.com

Figure 38: user contacts in web application

If the user of the web application wants to view the presence information of any of his contacts, he can do so by pressing on the link *View presence information*. This will open the contact's presence information page, see figure 39.



File name: Test

Description: Just testing

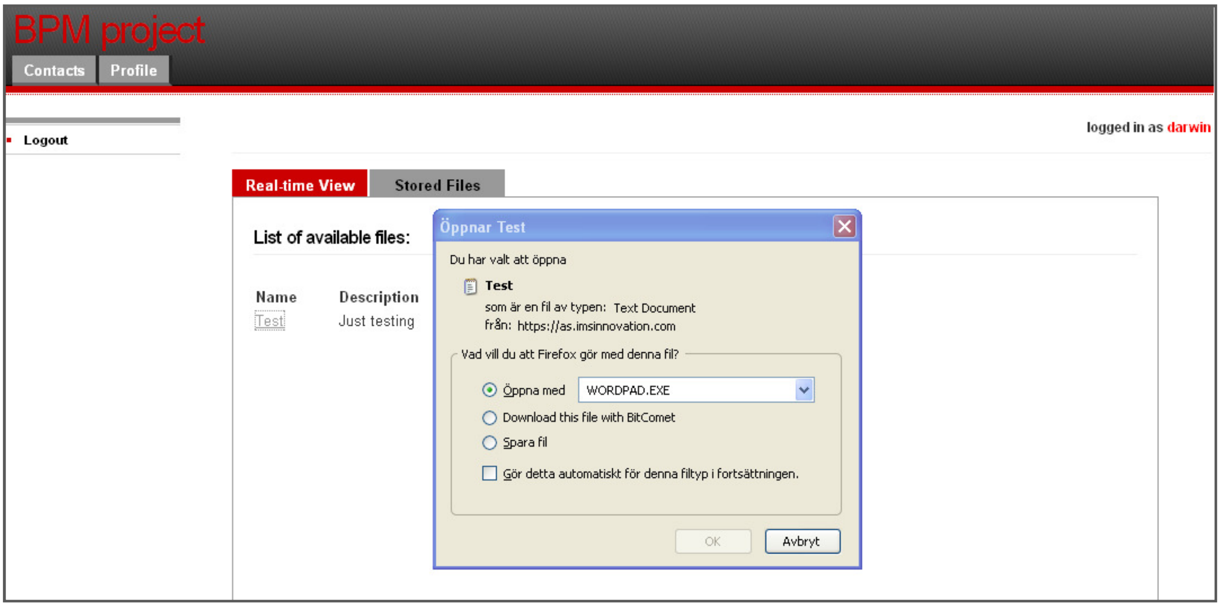
Maximum and minimum heartbeat rate values expressed as [beats/min], and the total elapsed session time

This is a popup form; it only appears when the close button is pressed

Figure 39: a contact's presence information page

Note: *The X axe is expressed in samples, as the axe grows dynamically it would be awkward to express it as time, because we need more space for this. That's why the elapsed time is displayed in the charts upper right corner. Also if more detail is needed the session can be saved and you can see each sample expressed as a two column value (Heart rate versus timestamp).*

In the contact's presence information page there are two views one is for watching the real-time information and the other is for viewing stored session. The application starts drawing the data into the real-time view chart when the user presses the *Start* button, while the session is ongoing the data chart scales. After pressing *Stop* no more data will be drawn on the chart. When the user wants end their collection of the measurements, he or she must press *Close*, then a prompt form (name and file description) is presented to enable the user to save the measured data in a file. This file name will later be presented in the *Stored Files* tab (Figure 40 shows this view).



logged in as darwin

List of available files:

Name	Description
Test	Just testing

Du har valt att öppna

Test

som är en fil av typen: Text Document

från: https://as.imsinnovation.com

Vad vill du att Firefox gör med denna fil?

● Öppna med WORDPAD.EXE

○ Download this file with BitComet

○ Spara fil

□ Gör detta automatiskt för denna filtyp i fortsättningen.

Figure 40: *Stored Files* tab in the contact's presence information page

4.4.1 The Watcher application's signaling interaction

The watcher application's signaling uses only SIP, it registers with the IMS network using a SIP REGISTER request, and subscribes to a HRM user's presence information with the PGM using a SIP SUBSCRIBE request. Each time the presence information is updated the PGM will notify it of changes through a SIP NOTIFY request. Figure 41 shows the signaling process in which the watcher application is involved.

The watcher application sends a SIP REGISTER to the SBG, this forwards it to the S-CSCF who must authenticate the user, for this the S-CSCF communicates with the HSS to get the watchers credentials. Once the watcher is authenticated, then the S-CSCF replies with an 200 OK (messages numbered 1 to 6).

When the watcher subscribes to the presentity's presence information it sends a SIP SUBSCRIBE request to the SBG which routes the request to the S-CSCF, which in turn forwards it to the PGM, the PGM adds the presentity to the watcher's presentity list and sends back a 200 OK (this process includes the messages numbered 7 to 12).

Before the watcher application starts receiving any NOTIFY requests from the PGM, the presentity's PUA must allow the watcher's subscription. Once the watcher is authorized it will start receiving notifies (this sequence includes the authorization process; messages numbered 13 to 18).

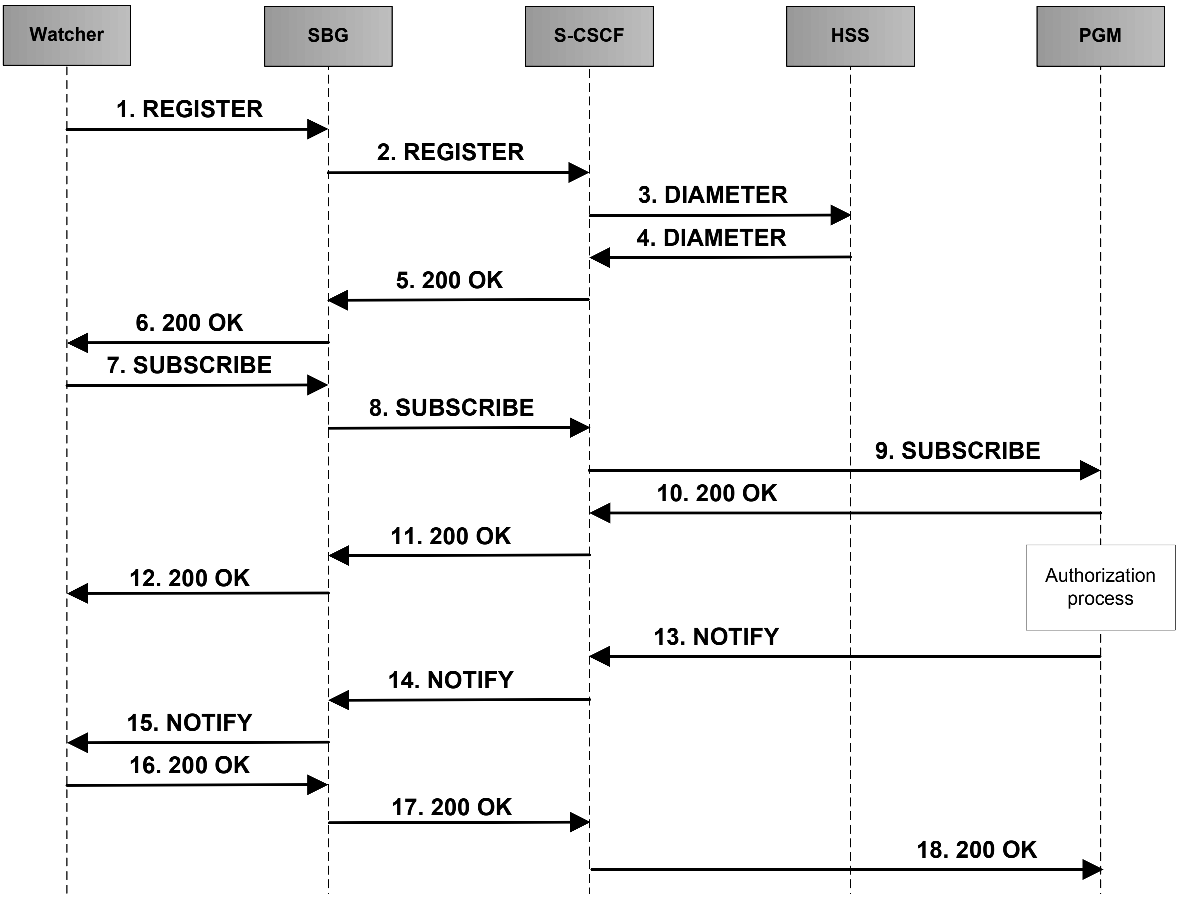


Figure 41: watcher application's signaling interaction

4.4.2 Description of the watcher application

In this section we briefly explain the functionalities of each of the modules involved in the watcher application and their interaction. Figure 42 shows the modules that forms the web application.

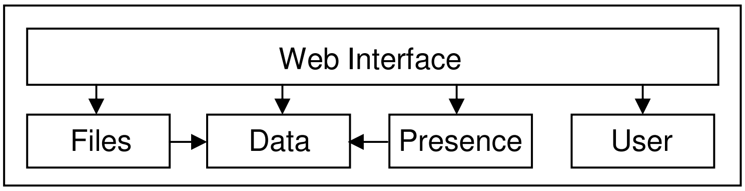


Figure 42: watcher application modules

The **Web interface** gives the application user a means to follow the performance of an athlete during their sports activity. Using this system a user can access several different functions, such as subscription to the HRM user's presence information, view in real-time data coming from an HRM user's PUA. The web interface enables the viewed data to be stored into files for later analysis.

The **User module** handles the data to be presented to the application user and the information about their contacts. This module administers three database tables: one for storing the application user's information, the second to store the user's contact information, and the third to map the users to their contacts (this table is use to not have redundant contact information, because several users can have the same contact). This module handles all the queries related to these tables.

The **Data module** handles all the data related to the measurements, its statistical data, and total elapsed session time. The measured values are stored in an array list together with their timestamp. The statistical data is kept in static variables.

The **Files module** manages the permanent data storage and the downloading processes (which includes generating a file from the data stored in the database, and makes it available for the user). This module handles all the database queries related to stored data. When storing the measured data, the *Files module* must transforms the array kept by the *Data module* into binary data, before storing it to a database table, and for downloading the data it must convert it back to String format to stream the content as a file.

Note: *The data is stored as binary fields in the database tables because the application has no write permission in the servers file system, the only persistent storage available are the database tables.*

The **Presence module** is built on top of the HiFive [7] IMS API. This module generates all the SIP requests performed by the watcher application and receives all the responses. Based on these responses this module takes various actions, such as calling the *Data module* for example, to store statistical data.

4.4.3 Execution sequences of the watcher application

In this section we will describe the interaction between the application modules, through an example:

a user logs in to the system and wishes to view the presence information of one of his contacts, so he presses the *View presence information* link. Once he or she has reached the contact's personal page, he presses the *Start* button to view the *Real-time* chart, after some time the user wishes to end the data displaying, so he presses *Close*, he saves the data with a name and a description (the measured data is save in a database table as binary data), to be able to identify it later. Later the user downloads the data to analyze it using Matlab in a PC, to do this the user clicks on the *Stored Files* tab, selects the name that identifies the data for download, and initiates the download. Figure 43 illustrates the sequence diagram of this example. A description of the steps in this sequence is given below.

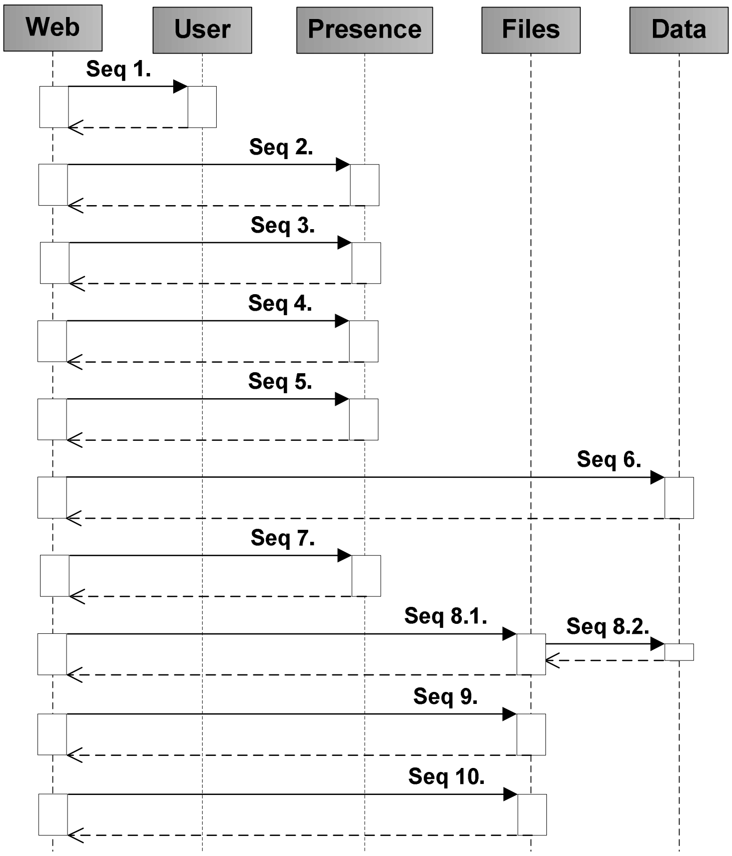


Figure 43: Watcher application general interaction.

Step 1: When the user logs in to the system the *Web interface* module instantiates the *User module*, verifies the users credentials, and the users contacts.

Step 2: Based on the user's credentials, the *Web interface* module instantiates the *Presence module*, and registers with the IMS system.

Step 3: The *Presence module* subscribes to the user contacts, based on the information passed by the *Web interface.*

Step 4: When the user selects the presence information of one of his or her contacts the *Presence module* receives the public user identity that it should listen for.

Step 5: When the user press *Start* to view the chart, the *Web module*, sets a flag in the *Presence module* so that the data is stored in the *Data module*.

Step 6: The *Web module* starts to pull data from the *Data module*, through an Ajax module called *Prototype* [80] that permits the generation of a real-time chart without having to refresh the browser.

Step 7: When the user press the *Stop* button, the *Web module*, resets the flag in the *Presence module*, so no more data is stored by the *Data module*. No more data pulling is performed.

Step 8: After pressing *Close* and save, the *Web module* performs a save data operation using the *Files module*, which in turn must interact with the *Data module* to retrieve the measured values and convert them into binary and store them in a database table, with the attributes of name and description (together with other parameters such user's ID, contact's ID and timestamp) entered by the user.

Step 9: When the user presses the *Stored Files* tab, the *Web module* queries the database table through the *Files modules*, for all measurement sessions stored in the system available to this user and contact, generating a list of these measurement sessions (files).

Step 10: The user chooses a file to download. The *Web module,* through the *Files modules* converts the binary data into a file in tab separated columns (*.txt* format) when downloading.

4.4.4 Tools used for developing the watcher application

The development environment was Neatbeans [79]. This tool was chosen rather than Eclipse, because it has good database support and it is also well integrated with the Sailfin application server [81]. Sailfin is being used as the AS in the production platform. Neatbeans facilitates the deployment of the application, this helps in debugging. The database used for this project was MySQL version 5.0.51b of the Community Server [82].

The programming technologies and languages used for developing the application, were Java Enterprise Edition (Java EE), Prototype, Dojo, JavaScript, and SQL.

- Java EE version 5.0 was the base technology for developing the application. The IMS API's used in the Presence module are solely Java EE [7].
- Prototype [80] is a JavaScript framework that facilitates the development of dynamic web applications. Prototype was used in the data pulling to generate the chart and the statistics where output from the Java EE classes running on the server.
- Dojo [83] is also a JavaScript toolkit that has a lot of great features. In this implementation we used dojo to generate the dynamic chart.
- We used SQL, to query the database from the java classes.

5 Tests and discussion of the results

5.1 Functional tests

In this section we will evaluate the fundamental functionalities of our prototype. The following four cases were analyzed:

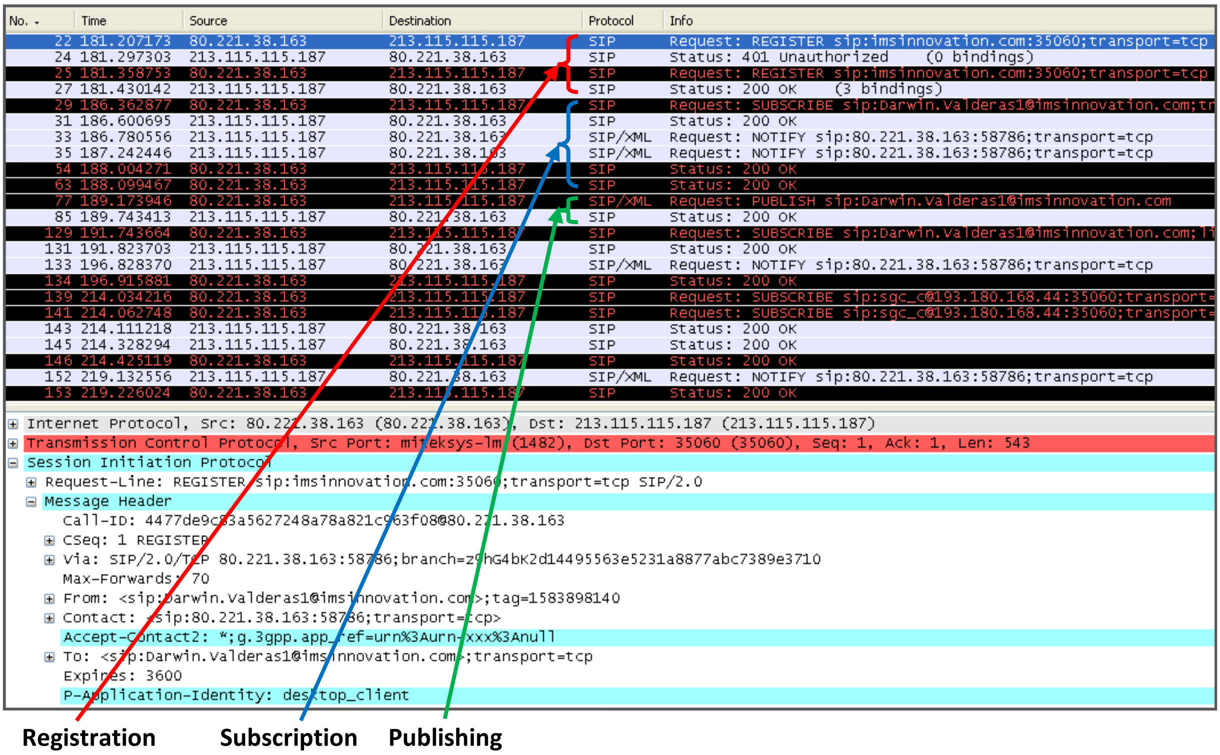
i. A PUA's registration, subscription, and publishing process.
ii. A watcher subscribing to a presentity's presence information.
iii. Adding a new watcher to the system.
iv. Two users subscribing to a presentity's presence information.

All of the use cases were executed over real production environments. The AS, the PGM and the IMS core network are physically located in Sweden. Our mobile phone subscription is with the local Finish telecommunication operator DNA, who provides us with mobile Internet access.

5.1.1 A PUA's registration, subscription, and publishing process

The registration, subscription, and publish process, performed by both the mobile application and the desktop application are the same. For this reason, and also the fact that we are not able to sniff the mobile phones SIP traffic with the tools that we have available, we will only show this process for the desktop client application. For inspection of the SIP traffic we used Wireshark version 1.0.0 [84], running locally in the same computer as the desktop application.

From figure 44 we can see that the results of the experiment were positive, the three evaluated operation were successful, to the details of the SIP signaling messages between the PGM and the PUA refer to the logs in the appendix A section A.1.



```
No.   Time        Source           Destination      Protocol  Info
 22 181.207173  80.221.38.163    213.115.115.187  SIP       Request: REGISTER sip:imsinnovation.com:35060;transport=tcp
 24 181.297303  213.115.115.187  80.221.38.163    SIP       Status: 401 Unauthorized    (0 bindings)
 25 181.358753  80.221.38.163    213.115.115.187  SIP       Request: REGISTER sip:imsinnovation.com:35060;transport=tcp
 27 181.430142  213.115.115.187  80.221.38.163    SIP       Status: 200 OK    (3 bindings)
 29 186.362877  80.221.38.163    213.115.115.187  SIP       Request: SUBSCRIBE sip:Darwin.Valderas1@imsinnovation.com;tr
 31 186.600695  213.115.115.187  80.221.38.163    SIP       Status: 200 OK
 33 186.780556  213.115.115.187  80.221.38.163    SIP/XML   Request: NOTIFY sip:80.221.38.163:58786;transport=tcp
 35 187.242446  213.115.115.187  80.221.38.163    SIP/XML   Request: NOTIFY sip:80.221.38.163:58786;transport=tcp
 54 188.004271  80.221.38.163    213.115.115.187  SIP       Status: 200 OK
 63 188.099467  80.221.38.163    213.115.115.187  SIP       Status: 200 OK
 77 189.173946  80.221.38.163    213.115.115.187  SIP/XML   Request: PUBLISH sip:Darwin.Valderas1@imsinnovation.com
 85 189.743413  213.115.115.187  80.221.38.163    SIP       Status: 200 OK
129 191.743664  80.221.38.163    213.115.115.187  SIP       Request: SUBSCRIBE sip:Darwin.Valderas1@imsinnovation.com;li
131 191.823703  213.115.115.187  80.221.38.163    SIP       Status: 200 OK
133 196.828370  213.115.115.187  80.221.38.163    SIP/XML   Request: NOTIFY sip:80.221.38.163:58786;transport=tcp
134 196.915881  80.221.38.163    213.115.115.187  SIP       Status: 200 OK
139 214.034216  80.221.38.163    213.115.115.187  SIP       Request: SUBSCRIBE sip:sgc_c@193.180.168.44:35060;transport=
141 214.062748  80.221.38.163    213.115.115.187  SIP       Request: SUBSCRIBE sip:sgc_c@193.180.168.44:35060;transport=
143 214.111218  213.115.115.187  80.221.38.163    SIP       Status: 200 OK
145 214.328294  213.115.115.187  80.221.38.163    SIP       Status: 200 OK
146 214.425119  80.221.38.163    213.115.115.187  SIP       Status: 200 OK
152 219.132556  213.115.115.187  80.221.38.163    SIP/XML   Request: NOTIFY sip:80.221.38.163:58786;transport=tcp
153 219.226024  80.221.38.163    213.115.115.187  SIP       Status: 200 OK

⊞ Internet Protocol, Src: 80.221.38.163 (80.221.38.163), Dst: 213.115.115.187 (213.115.115.187)
⊞ Transmission Control Protocol, Src Port: miteksys-lm (1482), Dst Port: 35060 (35060), Seq: 1, Ack: 1, Len: 543
⊟ Session Initiation Protocol
  ⊞ Request-Line: REGISTER sip:imsinnovation.com:35060;transport=tcp SIP/2.0
  ⊟ Message Header
      Call-ID: 4477de9c83a5627248a78a821c963f08@80.221.38.163
    ⊞ CSeq: 1 REGISTER
    ⊞ Via: SIP/2.0/TCP 80.221.38.163:58786;branch=z9hG4bK2d14495563e5231a8877abc7389e3710
      Max-Forwards: 70
    ⊞ From: <sip:Darwin.Valderas1@imsinnovation.com>;tag=1583898140
    ⊞ Contact: <sip:80.221.38.163:58786;transport=tcp>
      Accept-Contact2: *;g.3gpp.app_ref=urn%3Aurn-xxx%3Anull
    ⊞ To: <sip:Darwin.Valderas1@imsinnovation.com>;transport=tcp
      Expires: 3600
      P-Application-Identity: desktop_client
```

Figure 44: registration, subscription, and publish process.

The **registration** process involves authentication and authorization, this is described in section 2.5.2. In the **subscription** process that we are pointing out here is when the PUA subscribes to his watcher list, to be able to get notifications to changes in the watcher list. The **publication** process involves sending the actual heartbeat rate, minimum, maximum, and total elapsed session time which are embedded in the *note* field as shown in figure 45. No new xml schemas (this will be done in the future work) were defined for this matter.

```
<pdm:note>Heartbeat_rate;Minimum;Maximum;Session_time</pdm:note>
```

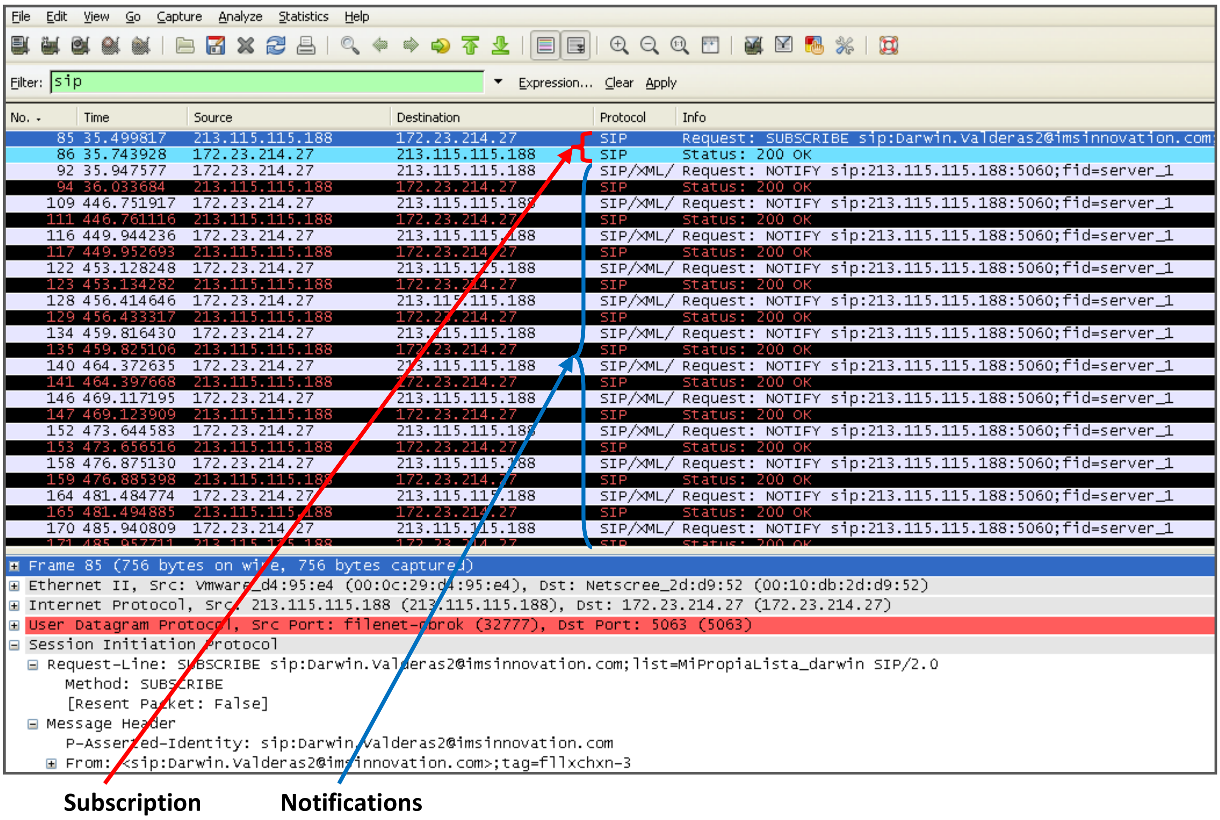
Figure 45: format for sending the HRM data.

5.1.2 A watcher subscribing to a presentity's presence information

For the watcher to be able to access a presentity's presence information he must first subscribe to it and get authorization from the presentity's PUA. In this evaluation scenario our watcher is already authorized. In the coming example, when showing the creation of a new watcher we will show what happens when a watcher subscribes for the first time a to a presentity's presence information.

When doing this test we used the mobile application as the PUA. The data gathered is from the AS. The traffic that will be shown is from the interaction between the watcher application and the PGM.

From figure 46 we can see that the subscription went fine and that the watcher starts to receive notify messages after getting the 200 OK response of the SUBSCRIBE request. To view the SIP signaling logs related to this transaction refer to section A.2 in the appendix A.



Filter: sip

```
No. -   Time        Source            Destination       Protocol  Info
    85 35.499817   213.115.115.188   172.23.214.27     SIP       Request: SUBSCRIBE sip:Darwin.Valderas2@imsinnovation.com;
    86 35.743928   172.23.214.27     213.115.115.188   SIP       Status: 200 OK
    92 35.947577   172.23.214.27     213.115.115.188   SIP/XML/  Request: NOTIFY sip:213.115.115.188:5060;fid=server_1
    94 36.033684   213.115.115.188   172.23.214.27     SIP       Status: 200 OK
   109 446.751917  172.23.214.27     213.115.115.188   SIP/XML/  Request: NOTIFY sip:213.115.115.188:5060;fid=server_1
   111 446.761116  213.115.115.188   172.23.214.27     SIP       Status: 200 OK
   116 449.944236  172.23.214.27     213.115.115.188   SIP/XML/  Request: NOTIFY sip:213.115.115.188:5060;fid=server_1
   117 449.952693  213.115.115.188   172.23.214.27     SIP       Status: 200 OK
   122 453.128248  172.23.214.27     213.115.115.188   SIP/XML/  Request: NOTIFY sip:213.115.115.188:5060;fid=server_1
   123 453.134282  213.115.115.188   172.23.214.27     SIP       Status: 200 OK
   128 456.414646  172.23.214.27     213.115.115.188   SIP/XML/  Request: NOTIFY sip:213.115.115.188:5060;fid=server_1
   129 456.433317  213.115.115.188   172.23.214.27     SIP       Status: 200 OK
   134 459.816430  172.23.214.27     213.115.115.188   SIP/XML/  Request: NOTIFY sip:213.115.115.188:5060;fid=server_1
   135 459.825106  213.115.115.188   172.23.214.27     SIP       Status: 200 OK
   140 464.372635  172.23.214.27     213.115.115.188   SIP/XML/  Request: NOTIFY sip:213.115.115.188:5060;fid=server_1
   141 464.397668  213.115.115.188   172.23.214.27     SIP       Status: 200 OK
   146 469.117195  172.23.214.27     213.115.115.188   SIP/XML/  Request: NOTIFY sip:213.115.115.188:5060;fid=server_1
   147 469.123909  213.115.115.188   172.23.214.27     SIP       Status: 200 OK
   152 473.644583  172.23.214.27     213.115.115.188   SIP/XML/  Request: NOTIFY sip:213.115.115.188:5060;fid=server_1
   153 473.656516  213.115.115.188   172.23.214.27     SIP       Status: 200 OK
   158 476.875130  172.23.214.27     213.115.115.188   SIP/XML/  Request: NOTIFY sip:213.115.115.188:5060;fid=server_1
   159 476.885398  213.115.115.188   172.23.214.27     SIP       Status: 200 OK
   164 481.484774  172.23.214.27     213.115.115.188   SIP/XML/  Request: NOTIFY sip:213.115.115.188:5060;fid=server_1
   165 481.494885  213.115.115.188   172.23.214.27     SIP       Status: 200 OK
   170 485.940809  172.23.214.27     213.115.115.188   SIP/XML/  Request: NOTIFY sip:213.115.115.188:5060;fid=server_1
   171 485.957711  213.115.115.188   172.23.214.27     SIP       Status: 200 OK
```

```
⊞ Frame 85 (756 bytes on wire, 756 bytes captured)
⊞ Ethernet II, Src: Vmware_d4:95:e4 (00:0c:29:d4:95:e4), Dst: Netscree_2d:d9:52 (00:10:db:2d:d9:52)
⊞ Internet Protocol, Src: 213.115.115.188 (213.115.115.188), Dst: 172.23.214.27 (172.23.214.27)
⊞ User Datagram Protocol, Src Port: filenet-rpc
```

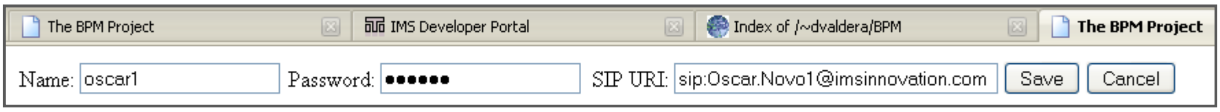
Figure 46: watcher subscribing to a presentity's presence information.

Description of the process: a watcher subscribes to a presentity's presence information. The watcher is then updated with the presentity's most recent presence information (if any available). After a while the presentity's PUA gets online, and started to publish its HRM information, the PGM notifies the watcher in every new update of the presence information related to his subscription.

5.1.3 Adding a new watcher

We will now add a new watcher to the system. We will describe the process as we go through the results. We start by creating a new user in the watcher application. Our new user is *oscar1* (watcher) and his SIP URI is *sip:Oscar.Novo1@imsinnovation.com*. This watcher has interests in viewing *sip:Darwin.Valderas1@imsinnovation.com* presence information, so he adds this presentity to his presence list and subscribes to it. The presentity's PUA who is subscribed to its own watcher list, will be notified and proceed to authorize this subscription, removing the status of *pending* and putting it to *allow* (this is done through XCAP). After this the watcher will be able to receive notifications related to *sip:Darwin.Valderas1@imsinnovation.com* presence.

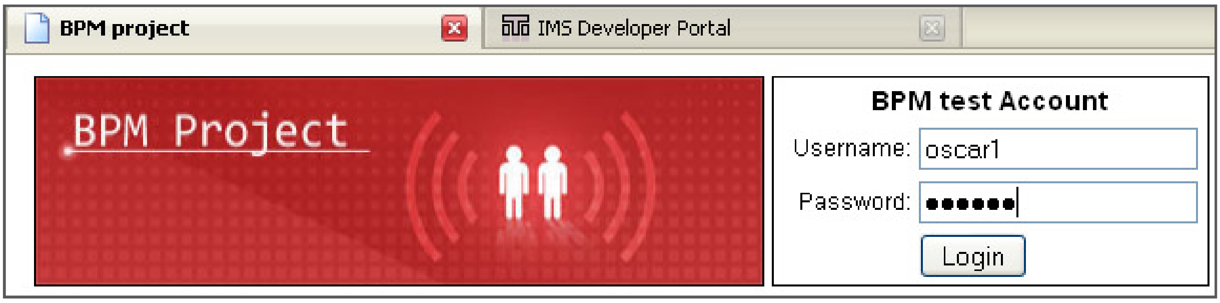
For creating a new user we click on the front page's *Register* link. Here we type the name, password, and SIP URI of the new user. Figure 47 illustrates this.



Name: oscar1 Password: •••••• SIP URI: sip:Oscar.Novo1@imsinnovation.com

Figure 47: creating a new watcher application user.

Once the new user is created we have to login to the new account to create the user's contacts, these are the presentity's that the user (watcher) will be subscribing to. Figure 48 shows the login page.



BPM test Account

Username: oscar1

Password: ••••••

Figure 48: watcher application's login page.

When logged in, we click on the *Add contact* (figure 49).

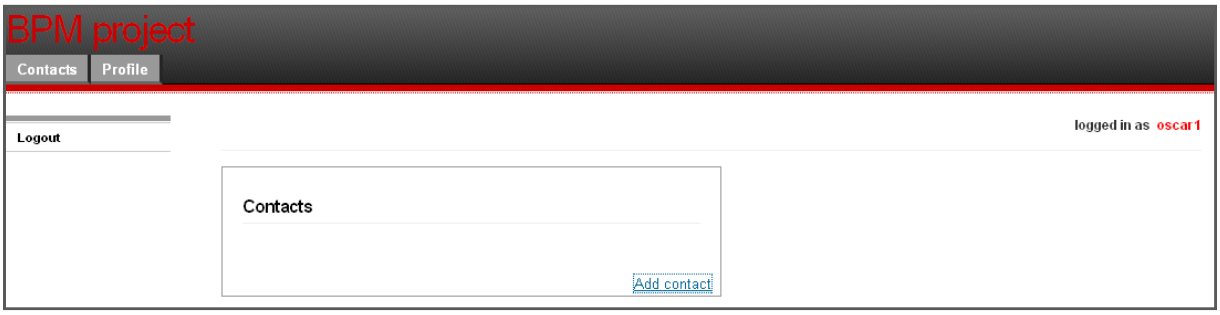
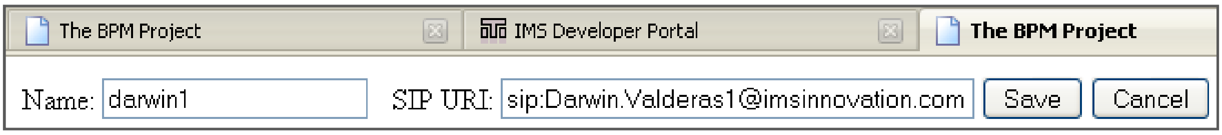


Figure 49: *Contacts* page.

When adding a new contact, only the name by which we will identify the contact and a valid SIP URI (as in figure 50) are needed.



Name: darwin1

SIP URI: sip:Darwin.Valderas1@imsinnovation.com

Figure 50: adding a new contact.

Once the contact is provisioned it will be visible in the *Contacts* page as shown in figure 51. This contact is now also added to the user's presence list (this presentity is perceived as offline right now, that's why the red square is on. Once notify messages starts to come this square will change to green in sign of online).

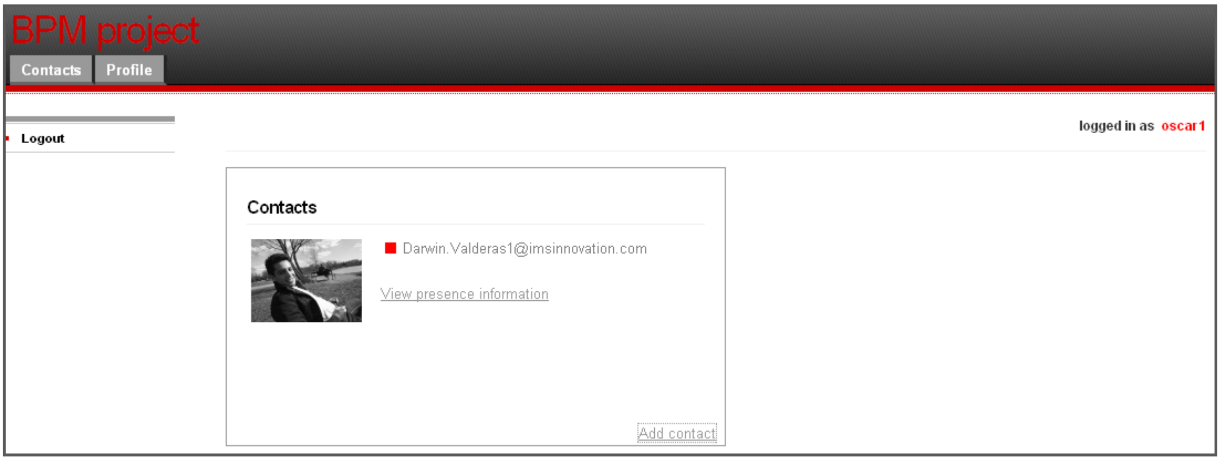
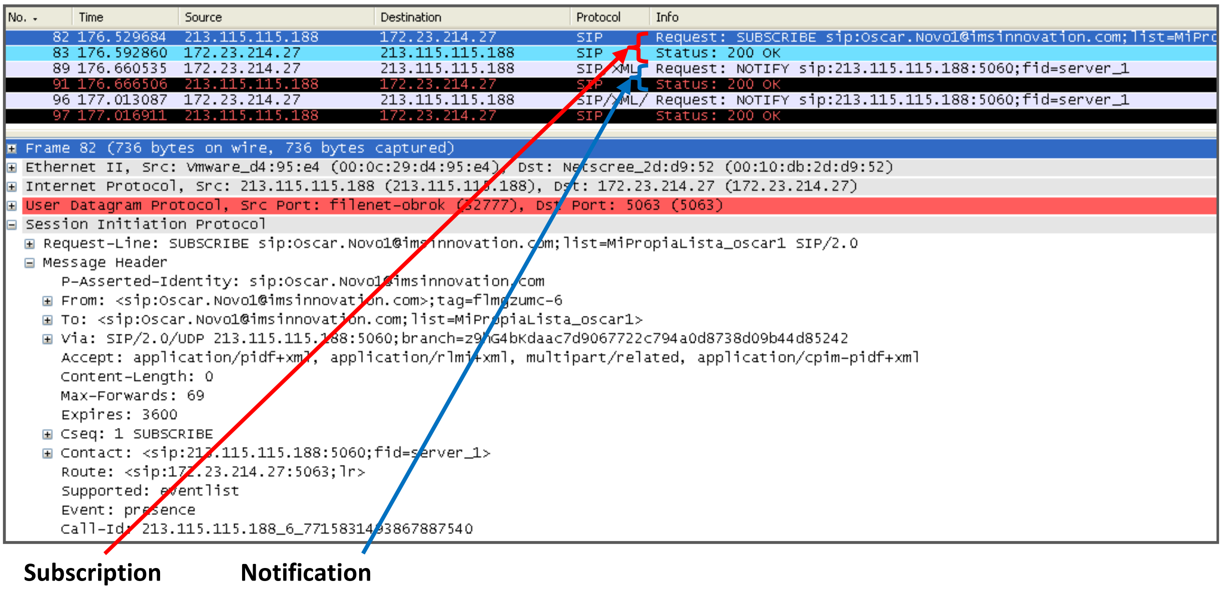


Figure 51: new contact.

Note: *The contact sip:Darwin.Valderas1@imsinnovation.com is a dummy contact, if a different contact is added to the system it will appear without a presentation picture.*

The SIP signaling that was originated by this process can be viewed from figure 52 that shows the capture made with *tcpdump* [85] in the AS. From this capture we can see the subscribe message to the presence list from the watcher, this includes the newly defined contact (*sip:Darwin.Valderas1@imsinnovation.com*).

The first notification shows that the watcher is in a *pending* state, waiting to be authorized by the PUA. When authorized he receives a second message that holds current presence information. For viewing the signaling logs in detail refer to section A.3 in the appendix A.

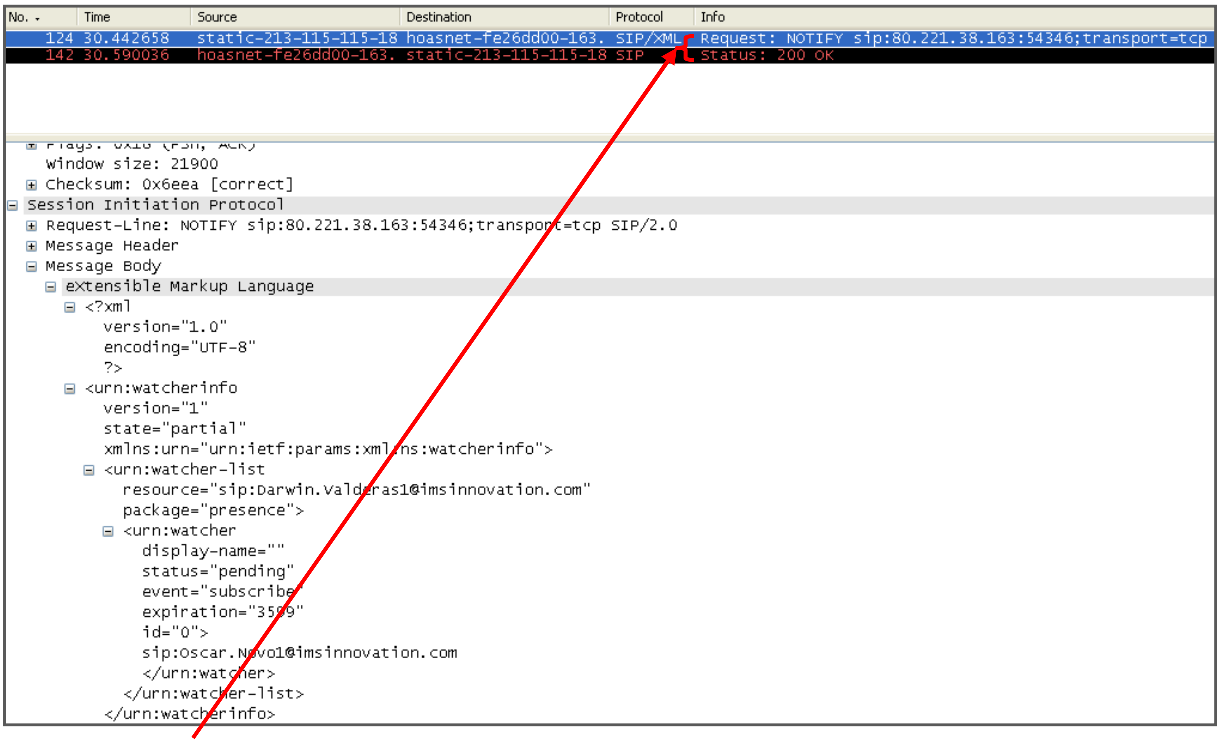


```
No. -   Time         Source            Destination       Protocol   Info
     82 176.529684   213.115.115.188   172.23.214.27     SIP        Request: SUBSCRIBE sip:Oscar.Novo1@imsinnovation.com;list=MiPro
     83 176.592860   172.23.214.27     213.115.115.188   SIP        Status: 200 OK
     89 176.660535   172.23.214.27     213.115.115.188   SIP/XML    Request: NOTIFY sip:213.115.115.188:5060;fid=server_1
     91 176.666506   213.115.115.188   172.23.214.27     SIP        Status: 200 OK
     96 177.013087   172.23.214.27     213.115.115.188   SIP/XML/   Request: NOTIFY sip:213.115.115.188:5060;fid=server_1
     97 177.016911   213.115.115.188   172.23.214.27     SIP        Status: 200 OK

⊞ Frame 82 (736 bytes on wire, 736 bytes captured)
⊞ Ethernet II, Src: Vmware_d4:95:e4 (00:0c:29:d4:95:e4), Dst: Netscree_2d:d9:52 (00:10:db:2d:d9:52)
⊞ Internet Protocol, Src: 213.115.115.188 (213.115.115.188), Dst: 172.23.214.27 (172.23.214.27)
⊞ User Datagram Protocol, Src Port: filenet-obrok (32777), Dst Port: 5063 (5063)
⊟ Session Initiation Protocol
  ⊞ Request-Line: SUBSCRIBE sip:Oscar.Novo1@imsinnovation.com;list=MiPropiaLista_oscar1 SIP/2.0
  ⊟ Message Header
      P-Asserted-Identity: sip:Oscar.Novo1@imsinnovation.com
    ⊞ From: <sip:Oscar.Novo1@imsinnovation.com>;tag=flmgzumc-6
    ⊞ To: <sip:Oscar.Novo1@imsinnovation.com;list=MiPropiaLista_oscar1>
    ⊞ Via: SIP/2.0/UDP 213.115.115.188:5060;branch=z9hG4bKdaac7d9067722c794a0d8738d09b44d85242
      Accept: application/pidf+xml, application/rlmi+xml, multipart/related, application/cpim-pidf+xml
      Content-Length: 0
      Max-Forwards: 69
      Expires: 3600
    ⊞ Cseq: 1 SUBSCRIBE
    ⊞ Contact: <sip:213.115.115.188:5060;fid=server_1>
      Route: <sip:172.23.214.27:5063;lr>
      Supported: eventlist
      Event: presence
      Call-Id: 213.115.115.188_6_7715831493867887540
```

Figure 52: SIP signaling for a new watcher.

Figure 53 shows the notify message received by the PUA, informing that its watcher list has changed, the PUA proceeds to verify and authorize the new watcher in the watcher list. The SIP signaling logs for this interaction can be found in appendix A section A.3.2



```
No.    Time        Source                 Destination            Protocol  Info
   124 30.442658   static-213-115-115-18  hoasnet-fe26dd00-163.  SIP/XML   Request: NOTIFY sip:80.221.38.163:54346;transport=tcp
   142 30.590036   hoasnet-fe26dd00-163.  static-213-115-115-18  SIP       Status: 200 OK
```

```
 ⊞ Flags: 0x18 (PSH, ACK)
   Window size: 21900
 ⊞ Checksum: 0x6eea [correct]
⊟ Session Initiation Protocol
 ⊞ Request-Line: NOTIFY sip:80.221.38.163:54346;transport=tcp SIP/2.0
 ⊞ Message Header
 ⊟ Message Body
   ⊟ eXtensible Markup Language
     ⊟ <?xml
         version="1.0"
         encoding="UTF-8"
         ?>
     ⊟ <urn:watcherinfo
         version="1"
         state="partial"
         xmlns:urn="urn:ietf:params:xml:ns:watcherinfo">
       ⊟ <urn:watcher-list
           resource="sip:Darwin.Valderas1@imsinnovation.com"
           package="presence">
         ⊟ <urn:watcher
             display-name=""
             status="pending"
             event="subscribe"
             expiration="3599"
             id="0">
             sip:Oscar.Novo1@imsinnovation.com
             </urn:watcher>
           </urn:watcher-list>
         </urn:watcherinfo>
```

Watcher list notification

Figure 53: notification for changes in a watcher list.

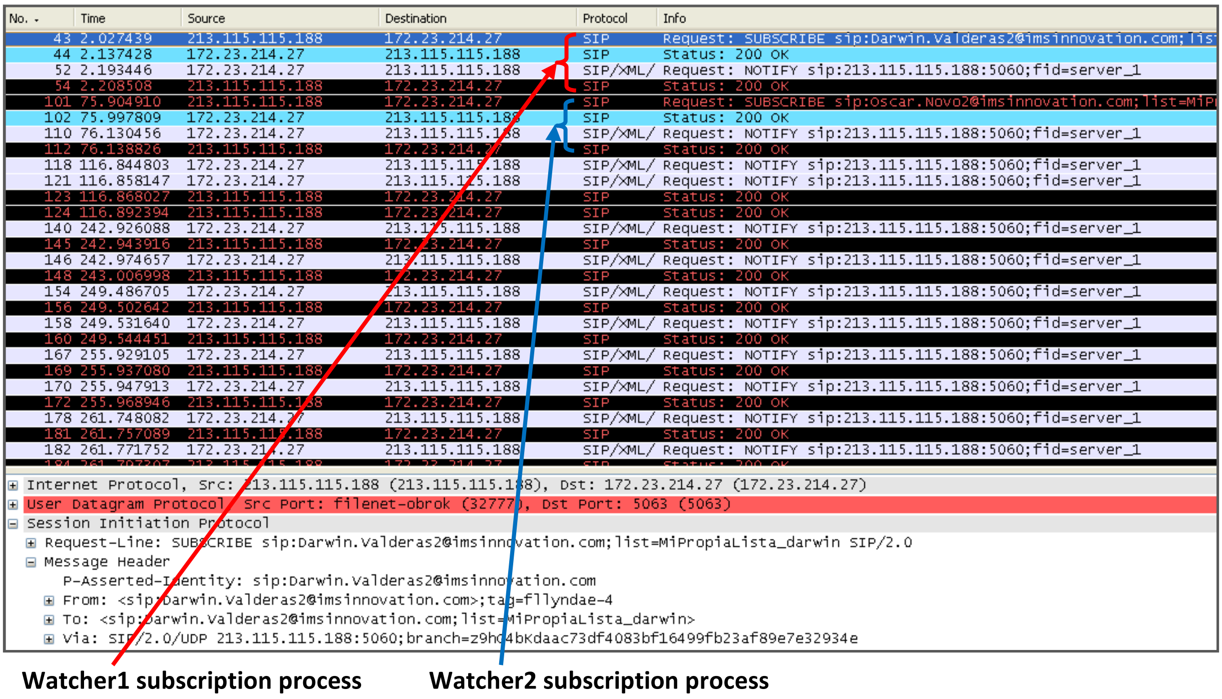
5.1.4 Two watchers subscribing to the same HRM user's presence information

In this case we will show that the system is capable of handling more than one watcher at the same time. Two watchers *sip:Darwin.Valderas2@imsinnovation.com* (watcher1) and *sip:Oscar.Novo2@imsinnovation.com* (watcher2) will be subscribing to *sip:Darwin.Valderas1@imsinnovation.com* presence information.

Note: *the system that we are using for running our prototype is a real production system, so each user has to be provisioned in the HSS (we have only 4 URI's that have been provisioned for testing), that's why we only used two watchers and not more for this testing.*

When executing this evaluation test we used the desktop client application as the PUA, and run Wireshark on the same computer to view the outgoing SIP PUBLISH requests and compare them with the ones captured in the AS with *tcpdump* in *.pcap* format compatible with Wireshark.

Evaluation test description: first the two watchers subscribed to the presentity's (*sip:Darwin.Valderas1@imsinnovation.com*) presence information by adding it to their presence list and subscribing to the list. After the subscription, the watchers are notified with status of the presentity's in the presence list. Some seconds later *sip:Darwin.Valderas1@imsinnovation.com* registers, and later he starts to send HRM information to the PGM. The PGM then notifies all the authorized watchers with *sip:Darwin.Valderas1@imsinnovation.com* presence information updates. Figure 54 shows the data capture taken from the AS, the SIP signaling logs can be found in the appendix A section A.4.

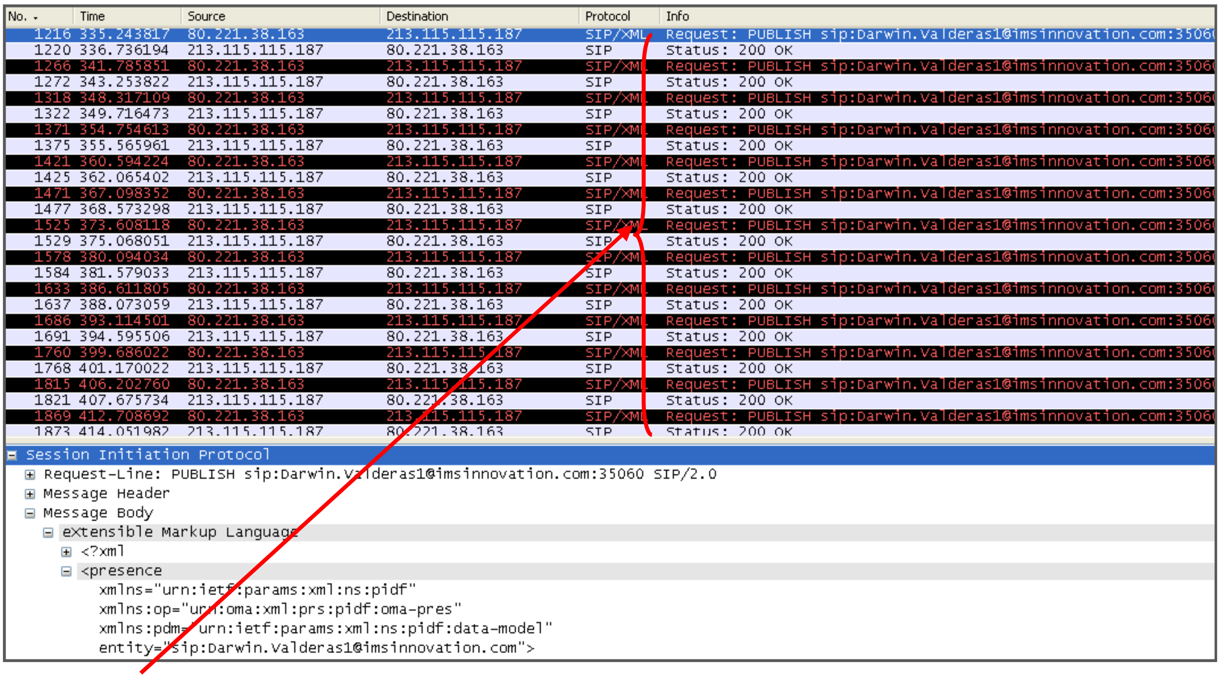


```
No. -  Time        Source            Destination       Protocol  Info
   43 2.027439     213.115.115.188   172.23.214.27     SIP       Request: SUBSCRIBE sip:Darwin.Valderas2@imsinnovation.com;lis
   44 2.137428     172.23.214.27     213.115.115.188   SIP       Status: 200 OK
   52 2.193446     172.23.214.27     213.115.115.188   SIP/XML/  Request: NOTIFY sip:213.115.115.188:5060;fid=server_1
   54 2.208508     213.115.115.188   172.23.214.27     SIP       Status: 200 OK
  101 75.904910    213.115.115.188   172.23.214.27     SIP       Request: SUBSCRIBE sip:Oscar.Novo2@imsinnovation.com;list=MiPr
  102 75.997809    172.23.214.27     213.115.115.188   SIP       Status: 200 OK
  110 76.130456    172.23.214.27     213.115.115.188   SIP/XML/  Request: NOTIFY sip:213.115.115.188:5060;fid=server_1
  112 76.138826    213.115.115.188   172.23.214.27     SIP       Status: 200 OK
  118 116.844803   172.23.214.27     213.115.115.188   SIP/XML/  Request: NOTIFY sip:213.115.115.188:5060;fid=server_1
  121 116.858147   172.23.214.27     213.115.115.188   SIP/XML/  Request: NOTIFY sip:213.115.115.188:5060;fid=server_1
  123 116.868027   213.115.115.188   172.23.214.27     SIP       Status: 200 OK
  124 116.892394   213.115.115.188   172.23.214.27     SIP       Status: 200 OK
  140 242.926088   172.23.214.27     213.115.115.188   SIP/XML/  Request: NOTIFY sip:213.115.115.188:5060;fid=server_1
  145 242.943916   213.115.115.188   172.23.214.27     SIP       Status: 200 OK
  146 242.974657   172.23.214.27     213.115.115.188   SIP/XML/  Request: NOTIFY sip:213.115.115.188:5060;fid=server_1
  148 243.006998   213.115.115.188   172.23.214.27     SIP       Status: 200 OK
  154 249.486705   172.23.214.27     213.115.115.188   SIP/XML/  Request: NOTIFY sip:213.115.115.188:5060;fid=server_1
  156 249.502642   213.115.115.188   172.23.214.27     SIP       Status: 200 OK
  158 249.531640   172.23.214.27     213.115.115.188   SIP/XML/  Request: NOTIFY sip:213.115.115.188:5060;fid=server_1
  160 249.544451   213.115.115.188   172.23.214.27     SIP       Status: 200 OK
  167 255.929105   172.23.214.27     213.115.115.188   SIP/XML/  Request: NOTIFY sip:213.115.115.188:5060;fid=server_1
  169 255.937080   213.115.115.188   172.23.214.27     SIP       Status: 200 OK
  170 255.947913   172.23.214.27     213.115.115.188   SIP/XML/  Request: NOTIFY sip:213.115.115.188:5060;fid=server_1
  172 255.968946   213.115.115.188   172.23.214.27     SIP       Status: 200 OK
  178 261.748082   172.23.214.27     213.115.115.188   SIP/XML/  Request: NOTIFY sip:213.115.115.188:5060;fid=server_1
  181 261.757089   213.115.115.188   172.23.214.27     SIP       Status: 200 OK
  182 261.771752   172.23.214.27     213.115.115.188   SIP/XML/  Request: NOTIFY sip:213.115.115.188:5060;fid=server_1

⊞ Internet Protocol, Src: 213.115.115.188 (213.115.115.188), Dst: 172.23.214.27 (172.23.214.27)
⊞ User Datagram Protocol, Src Port: filenet-obrok (32777), Dst Port: 5063 (5063)
⊟ Session Initiation Protocol
  ⊞ Request-Line: SUBSCRIBE sip:Darwin.Valderas2@imsinnovation.com;list=MiPropiaLista_darwin SIP/2.0
  ⊟ Message Header
      P-Asserted-Identity: sip:Darwin.Valderas2@imsinnovation.com
    ⊞ From: <sip:Darwin.Valderas2@imsinnovation.com>;tag=fllyndae-4
    ⊞ To: <sip:Darwin.Valderas2@imsinnovation.com;list=MiPropiaLista_darwin>
    ⊞ Via: SIP/2.0/UDP 213.115.115.188:5060;branch=z9hG4bKdaac73df4083bf16499fb23af89e7e32934e
```

Figure 54: two watcher's subscribing to the same presentity's presence information.

Figure 55 shows the publish messages sent by the desktop client application to the PGM, who will later notify the subscribed users about the new presence information. The SIP signaling logs related to these publish operation from the client and the notifications received by the watchers due to these (publish messages) can be found in appendix A section A.4.2.



```
No.   Time        Source          Destination      Protocol  Info
 1216 335.243817  80.221.38.163   213.115.115.187  SIP/XML   Request: PUBLISH sip:Darwin.Valderas1@imsinnovation.com:3506
 1220 336.736194  213.115.115.187 80.221.38.163    SIP       Status: 200 OK
 1266 341.785851  80.221.38.163   213.115.115.187  SIP/XML   Request: PUBLISH sip:Darwin.Valderas1@imsinnovation.com:3506
 1272 343.253822  213.115.115.187 80.221.38.163    SIP       Status: 200 OK
 1318 348.317109  80.221.38.163   213.115.115.187  SIP/XML   Request: PUBLISH sip:Darwin.Valderas1@imsinnovation.com:3506
 1322 349.716473  213.115.115.187 80.221.38.163    SIP       Status: 200 OK
 1371 354.754613  80.221.38.163   213.115.115.187  SIP/XML   Request: PUBLISH sip:Darwin.Valderas1@imsinnovation.com:3506
 1375 355.565961  213.115.115.187 80.221.38.163    SIP       Status: 200 OK
 1421 360.594224  80.221.38.163   213.115.115.187  SIP/XML   Request: PUBLISH sip:Darwin.Valderas1@imsinnovation.com:3506
 1425 362.065402  213.115.115.187 80.221.38.163    SIP       Status: 200 OK
 1471 367.098352  80.221.38.163   213.115.115.187  SIP/XML   Request: PUBLISH sip:Darwin.Valderas1@imsinnovation.com:3506
 1477 368.573298  213.115.115.187 80.221.38.163    SIP       Status: 200 OK
 1525 373.608118  80.221.38.163   213.115.115.187  SIP/XML   Request: PUBLISH sip:Darwin.Valderas1@imsinnovation.com:3506
 1529 375.068051  213.115.115.187 80.221.38.163    SIP       Status: 200 OK
 1578 380.094034  80.221.38.163   213.115.115.187  SIP/XML   Request: PUBLISH sip:Darwin.Valderas1@imsinnovation.com:3506
 1584 381.579033  213.115.115.187 80.221.38.163    SIP       Status: 200 OK
 1633 386.611805  80.221.38.163   213.115.115.187  SIP/XML   Request: PUBLISH sip:Darwin.Valderas1@imsinnovation.com:3506
 1637 388.073059  213.115.115.187 80.221.38.163    SIP       Status: 200 OK
 1686 393.114501  80.221.38.163   213.115.115.187  SIP/XML   Request: PUBLISH sip:Darwin.Valderas1@imsinnovation.com:3506
 1691 394.595506  213.115.115.187 80.221.38.163    SIP       Status: 200 OK
 1760 399.686022  80.221.38.163   213.115.115.187  SIP/XML   Request: PUBLISH sip:Darwin.Valderas1@imsinnovation.com:3506
 1768 401.170022  213.115.115.187 80.221.38.163    SIP       Status: 200 OK
 1815 406.202760  80.221.38.163   213.115.115.187  SIP/XML   Request: PUBLISH sip:Darwin.Valderas1@imsinnovation.com:3506
 1821 407.675734  213.115.115.187 80.221.38.163    SIP       Status: 200 OK
 1869 412.708692  80.221.38.163   213.115.115.187  SIP/XML   Request: PUBLISH sip:Darwin.Valderas1@imsinnovation.com:3506
 1873 414.051982  213.115.115.187 80.221.38.163    SIP       Status: 200 OK
```

```
⊟ Session Initiation Protocol
  ⊞ Request-Line: PUBLISH sip:Darwin.Valderas1@imsinnovation.com:35060 SIP/2.0
  ⊞ Message Header
  ⊟ Message Body
    ⊟ eXtensible Markup Language
      ⊞ <?xml
      ⊟ <presence
          xmlns="urn:ietf:params:xml:ns:pidf"
          xmlns:op="urn:oma:xml:prs:pidf:oma-pres"
          xmlns:pdm="urn:ietf:params:xml:ns:pidf:data-model"
          entity="sip:Darwin.Valderas1@imsinnovation.com">
```

Publish requests sent by the PUA

Figure 55: PUA publishing HRM information.

Note: *by the presented evaluation tests we can conclude that our system is totally functional, and fulfils the requirements of the SIP Presence service framework.*

5.2 Performance tests

In this subsection we will introduce the performance tests that were held over the system and their results. The executed tests were the following:

i. The SPU's response time for HRM queries.
ii. End-to-end delay measurements.
iii. Time between consecutive received messages in the AS.

When executing each of these tests we are always handling real heart rate data (this implies that a person must be wearing the heart rate monitoring belt in each of the tests, otherwise the sensor does not respond, as it is in sleeping mode)

The measurements specified in *ii* and *iii* were performed over real production environments (wide area cellular network, IMS network, and Internet where our AS is publically available). The clocks used for taking the timestamps were synchronized to *time.nist.gov's* Internet time server.

5.2.1 The SPU's response time for HRM queries

These tests were performed over the two exiting SPUs' (the mobile alternative that was introduced in section 4.2 (figure 25) and the fixed solution showed in section 4.3). The test procedure was to generate a *Request Sensor Data* query from the application and wait for a valid response. A timestamp was taken before executing the query and when getting the response.

From figure 56 we can view the result that was obtained when measuring the response time of the *mobile SPU* for HRM queries.

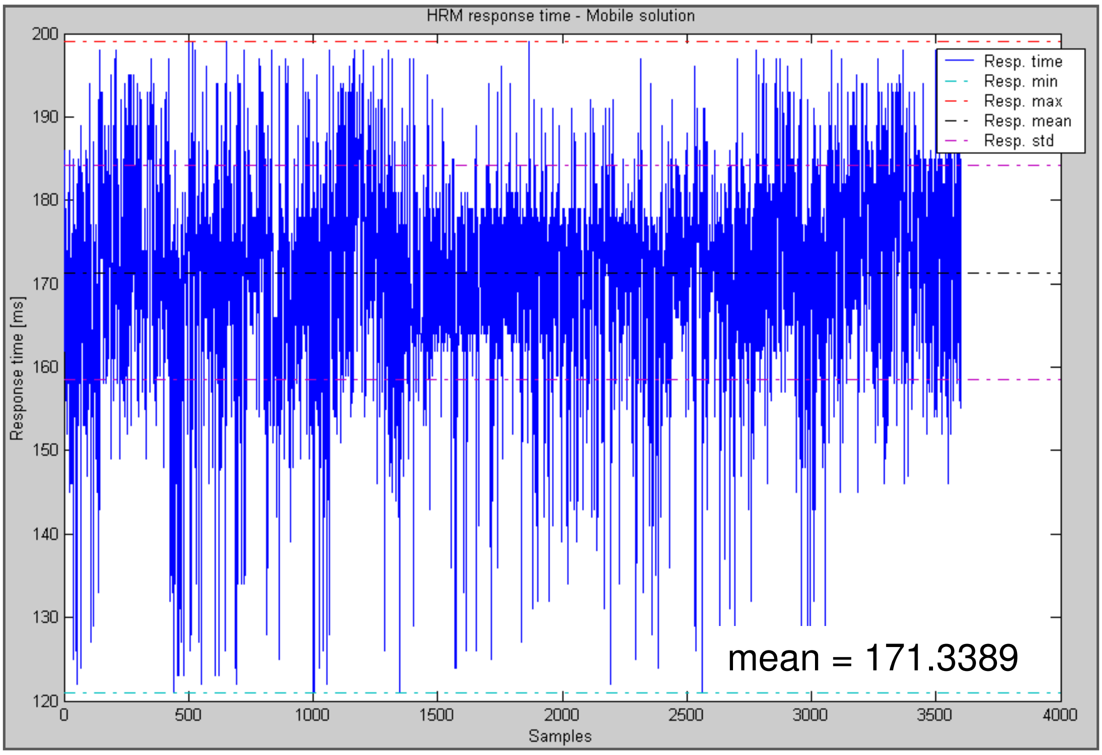


Figure 56: the SPU's response time for HRM queries – *Mobile solution*.

The resulting **mean** was 171,3389 milliseconds, this is 71,3389 milliseconds above the value of 100 milliseconds replied from the sensor node (in section 2.11.2, figure 19), this means that the All-in-one module is adding an extra delay of 71,3389 milliseconds in average to the maximum expected HRM response time.

Figure 57 shows the result of the measurements taken from the *fixed SPU* for HRM queries.

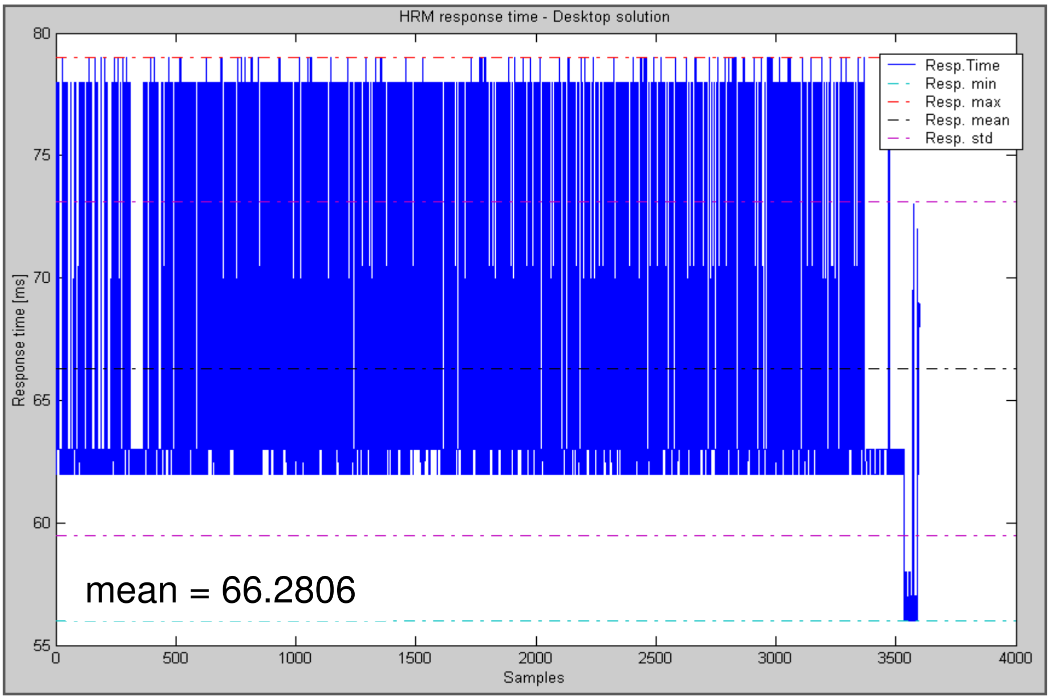


Figure 57: the SPU's response time for HRM queries – *Fixed solution*.

What we can notice immediately from this figure is that the average and maximum are below the *Delay* value obtained in section 2.11.2, figure 19. This can mean that the chipset vendors have put an offset to assure the system developers that the sensor chipset will work and is able to respond to a sample (processing) rate higher than 100 milliseconds.

5.2.2 End-to-end delay measurements

By measuring the end-to.end delay we can estimate the period of time that it will take for the collected sensor data to be available for the end user.

The measurement process consisted in taking two timestamps, one right before acquiring the sensor data (heartbeat rate) and the second when the message was received by the application, resident in the AS. The period is obtained through a simple subtraction operation between the two timestamps.

Figure 58 illustrates the end-to-end delay obtained for the *mobile solution* and figure 59 the measured time for the *fixed solution*.

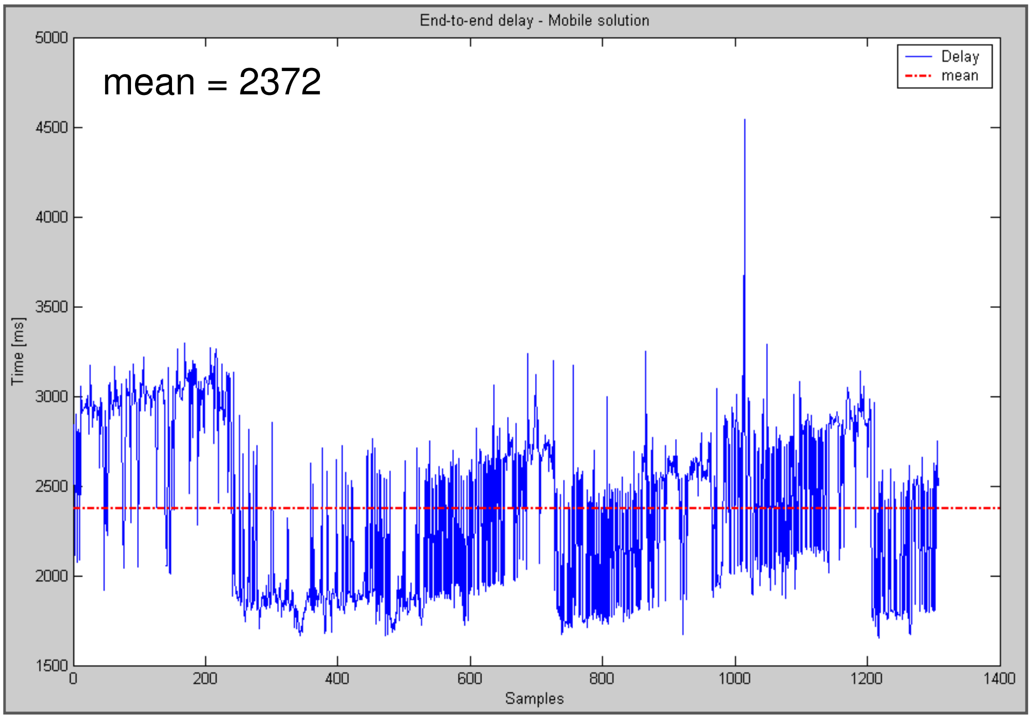


Figure 58: end-to-end delay – *Mobile solution*.

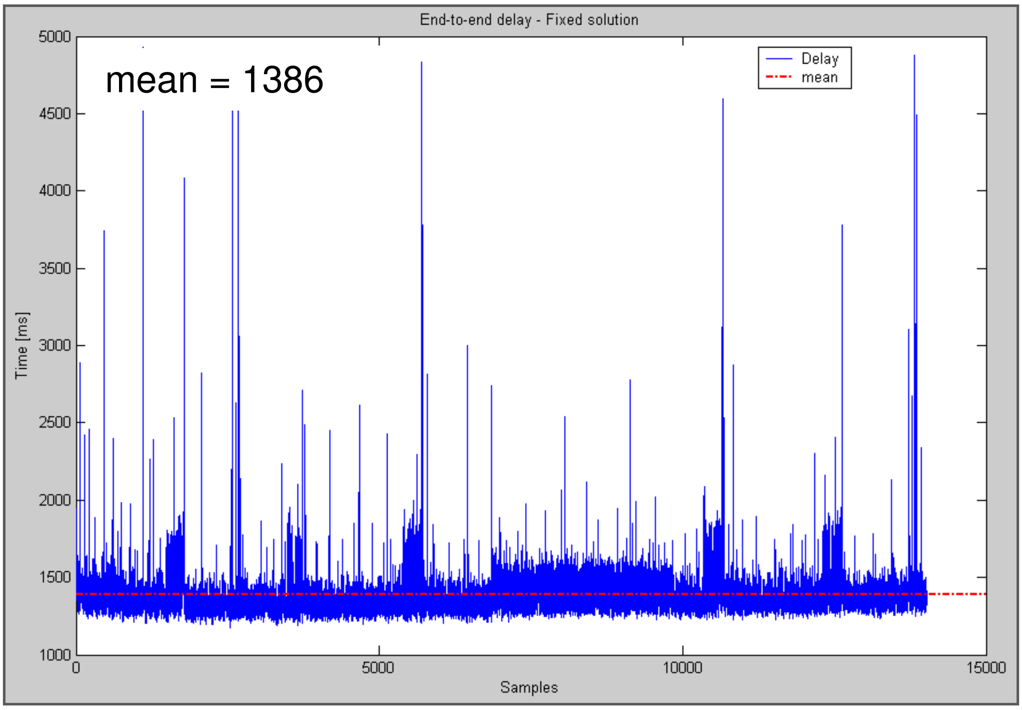


Figure 59: end-to-end delay – *Fixed solution*.

The **mean** value for these two measurements is beyond the expected (a mean bellow of 500 ms would be suitable for this system, that doesn't have a high frequency rate), but on the other hand this is the first time any performance testing has been done to the system. This can be seen as a starting point for performance tuning.

This project is still at an early stage and many improvements can be done, and this is definitively a good moment for evaluating the prototype and review goals, to see how to go ahead. Discuss if a real-time solution is this is still one the goals the final goals, if so other protocols (as those mentioned section 2.7) should been considered as a valid option to follow, due to the fact that the Presence service framework is not optimized yet, for handling real-time communication.

5.2.3 Time period between consecutive messages received by the AS

This process consisted in taking the time difference between two consecutive messages received by the application running in the AS. These measurements will give us an idea on how the users (of the watcher application) perception can be. This data will also give us an additional input to improve the performance of our solution.

Figure 60 illustrates the time computed for the *mobile solution* and figure 61 shows the time calculated for the *fixed solution*.

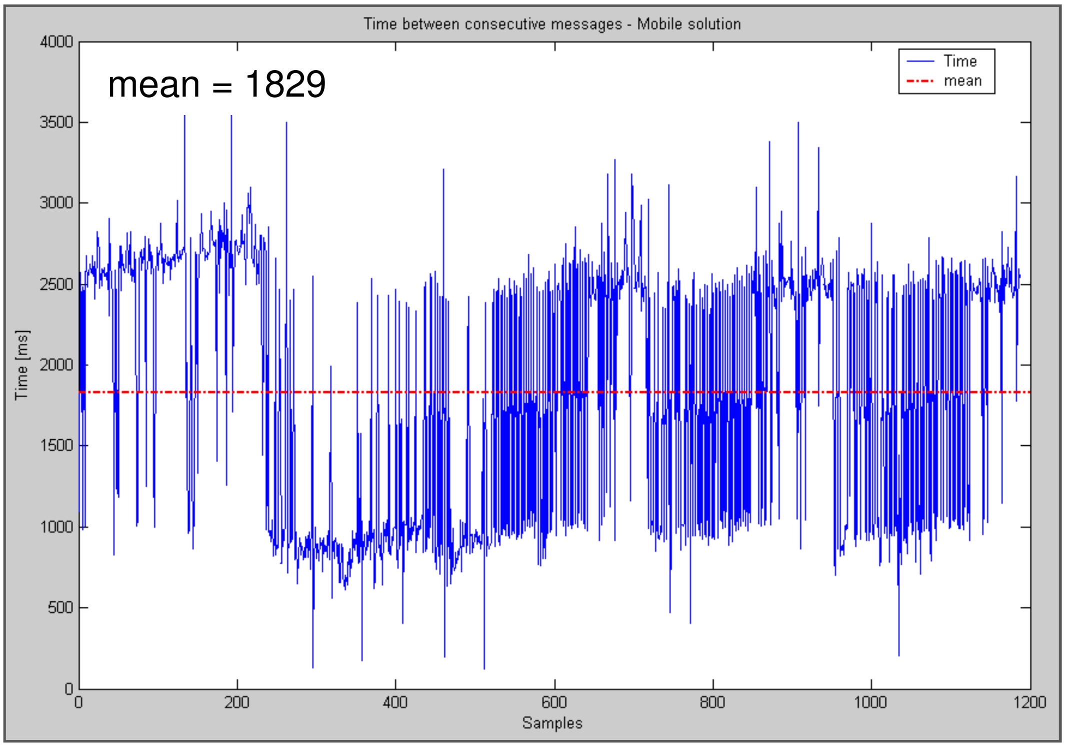


Figure 60: time between two consecutive messages received in the AS – *Mobile solution*.

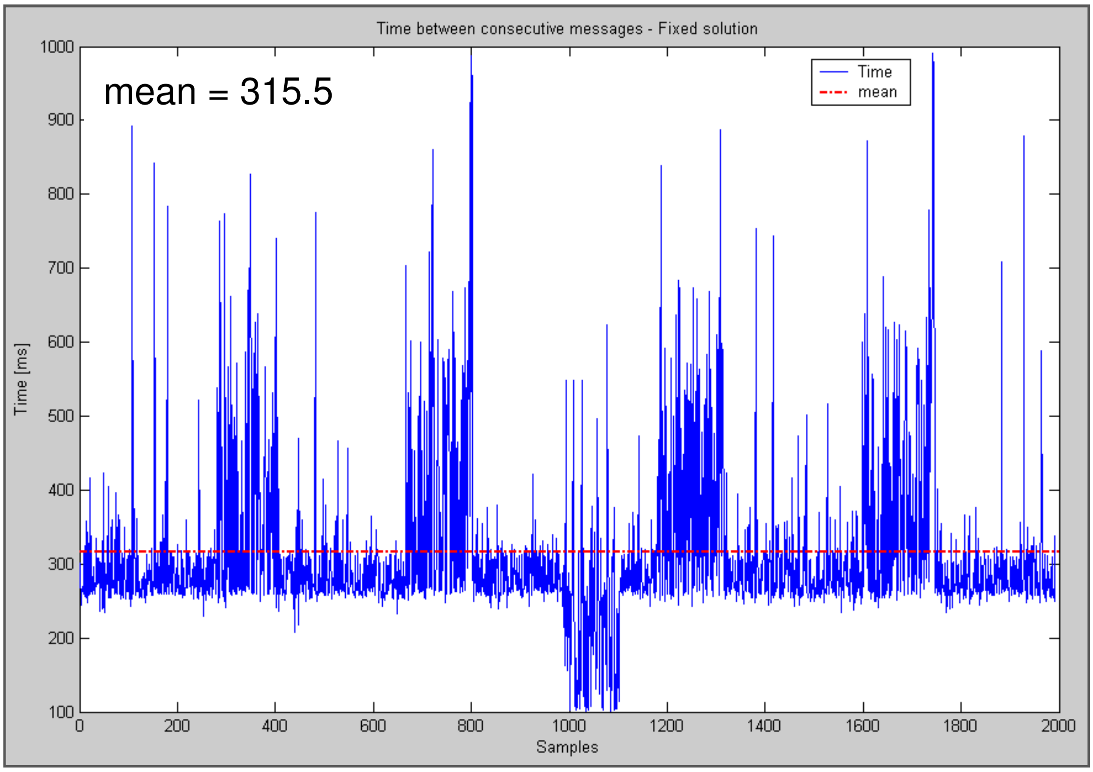


Figure 61: time between two consecutive messages received in the AS – *Fixed solution*.

By comparing the results of the two solutions, we can see that the *fixed alternative* is much faster. The **fixed solution's** measured time between consecutives messages is totally acceptable. The only delay that the user might perceive, is the one caused by the initial message (end-to-end delay, mean=1386 [ms]), but after that, the messages will only be space in time by ~315 [ms], this is almost real-time for the heart rate frequency, as far as it doesn't exceed a pace of 180 [beats/min]. The **mobile solution** is as we expect slower than the *fixed solution*. Much of this delay has to do with the way cellular networks [87] handles IP packets, because once the packets accesses the fixed IP network the path is more or less the same, and here there shouldn't be a visible difference in delay between both of the solutions.

Conclusions and future work

6.1 Conclusions

In this thesis project we have developed two end-to-end systems (described in chapter 4) that are able to interact with a sensor unit (heart rate monitor), and publish the information collected from it to a Presence server (PGM), who redistributes this information to different watchers that are subscribed to it.

6.1.1 General advantages and disadvantages

Advantages: the general solution offers data sharing, and almost real-time communication (see section 5.2) between the sensor network and the end users. The system is built on top of the IMS infrastructure, which has the potential to support a very large variety of devices and a large number of services giving. This gives the system interesting interaction possibilities. Another interesting feature is that the system uses the SIP Presence service, so it should be fairly easy to incorporate it to other communication services or to add new functionalities.

Disadvantages: the mayor problem with this solution is related to one of its strengthen points, this is the use of the Presence service frame work which is not optimize for handling truly real-time traffic, although in the fixed solution this delays are not critical and they are most of the time unperceivable, but in the mobile solution the delay is much bigger and perceivable if we are expecting a real-time service.

Note: *For a more accurate real-time solution the usage of other protocols is needed (as analyzed in section 2.7), but this means a more complex solution.*

6.1.2 Mobile solution

Advantages: the mayor advantage of this solution is the mobility and flexibility offer by its platform. As the mobile application is programmed over Java ME it is portable to any Java ME enabled phone with Bluetooth, today a large number of phones has these features.

Disadvantage: the mobile solution’s user terminal has limited processing power, low bandwidth Internet connectivity, and higher delays (as showed in section 5.2) in the interaction between the SPU and the HRM due to the All-in-one module.

6.1.3 Fixed solution

Advantages: the fixed solution offers almost real-time communication. The user terminal can be plugged to a high speed Internet access, a USB ANT transceiver is used to interact directly with the HRM. The application is run over a much more powerful platform. This system compared to the mobile solution improves considerably the sensor network response time and the end-to-end delay (PUA-watcher).

Disadvantages: its principal weakness is its lack of mobility, but on the other hand this was its purpose.

6.1.4 Watcher application

Advantages: it possible to have access to numerous presentities presence information in almost real-time, administer presentities, and store information related to each of them.

Disadvantages: the watcher application can be a bit processor demanding for both the client host and the server, if the data pulling is configured for a too short period of time (less than a second).

6.2 Future work

The future work for this project has already started, as we are integrating more sensors to the system. We are adding an additional feature to the application so it can interact with a speed sensor for runners (known as a foot POD [86]), and at a later stage we will make the fixed solution capable of interacting with several heart rate monitors at foot-pods at the same time. A location (cell or GPS based) module for the mobile application has also been brought up, as well as adding push-to-talk functionalities, but this last alternative has only been mentioned in informal meetings. Besides these new features, that we pretend to add to the system, there is still much to optimize, as the system is at a very immature state, many things can be improved, such as the design, performance, and hardware components (e.g. All-in-one module). The watcher application should also provide richer information, handle more data, and it should also offer a communication channel for interacting with the athlete, e.g. SMS or push-to-talk. The community concept implemented in Runner+ [8] has also very interesting features that are worth a thought.

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Appendix A: Functional testing logs

A.1 - A PUA’s registration, subscription, and publishing process

A.1.1 - *Registration process*

```
   1. PUA -----------------------------> S-CSCF
REGISTER sip:imsinnovation.com:35060;transport=tcp SIP/2.0
Call-ID: 4477de9c83a5627248a78a821c963f08@80.221.38.163
CSeq: 1 REGISTER
Via: SIP/2.0/TCP 80.221.38.163:58786;branch=z9hG4bK2d14495563e5231a8877abc7389e3710
Max-Forwards: 70
From: <sip:Darwin.Valderas1@imsinnovation.com>;tag=1583898140
Contact: <sip:80.221.38.163:58786;transport=tcp>
Accept-Contact2: *;g.3gpp.app_ref=urn%3Aurn-xxx%3Anull
To: <sip:Darwin.Valderas1@imsinnovation.com>;transport=tcp
Expires: 3600
P-Application-Identity: desktop_client
Content-Length: 0
```

```
   2. PUA <----------------------------- S-CSCF
SIP/2.0 401 Unauthorized
Via: SIP/2.0/TCP
80.221.38.163:58786;received=213.115.115.187;branch=z9hG4bK2d14495563e5231a8877abc7
389e3710
To:
<sip:Darwin.Valderas1@imsinnovation.com>;tag=h7g4Esbg_9e87a6fa069136089afa0904210ae
;transport=tcp
From: <sip:Darwin.Valderas1@imsinnovation.com>;tag=1583898140
Call-ID: 4477de9c83a5627248a78a821c963f08@80.221.38.163
CSeq: 1 REGISTER
P-Charging-Function-Addresses:
ecf="aaa://mmfe.imsinnovation.com:3867;transport=tcp";ccf="aaa://mmfe.imsinnovation
.com:3867;transport=tcp"
P-Charging-Vector: icid-value=9e87a6fa069136089afa0903ab1ec
WWW-Authenticate: Digest
qop="auth",stale=false,domain="sip:hss@imsinnovation.com",realm="imsinnovation.com"
,nonce="32f8ec1cec31610a7871b7c6b10e4cec",algorithm=MD5
Content-Length: 0
```

```
   3. PUA -----------------------------> S-CSCF
REGISTER sip:imsinnovation.com:35060;transport=tcp SIP/2.0
Call-ID: 4477de9c83a5627248a78a821c963f08@80.221.38.163
CSeq: 2 REGISTER
Via: SIP/2.0/TCP 80.221.38.163:58786;branch=z9hG4bKcb0fd189f827e94310de5fe741ed440d
Max-Forwards: 70
From: <sip:Darwin.Valderas1@imsinnovation.com>;tag=1583898140
Contact: <sip:80.221.38.163:58786;transport=tcp>
Accept-Contact2: *;g.3gpp.app_ref=urn%3Aurn-xxx%3Anull
To: <sip:Darwin.Valderas1@imsinnovation.com>;transport=tcp
Expires: 3600
P-Application-Identity: desktop_client
Authorization: Digest
qop="auth",uri="sip:imsinnovation.com:35060;transport=tcp",response="5cf60bf8298c75
2fa6816b9d216a4f75",username="Darwin.Valderas1@imsinnovation.com",nc=00000001,realm
="imsinnovation.com",nonce="32f8ec1cec31610a7871b7c6b10e4cec",algorithm=MD5,cnonce=
"9505d1b642028354e63d38734e592dc0"
Content-Length: 0
```

```
   4. PUA <----------------------------- S-CSCF
SIP/2.0 200 OK
Via: SIP/2.0/TCP
80.221.38.163:58786;received=213.115.115.187;branch=z9hG4bKcb0fd189f827e94310de5fe7
41ed440d
To:
<sip:Darwin.Valderas1@imsinnovation.com>;tag=h7g4Esbg_9e87a6fa06914f089afa090be23ff
;transport=tcp
From: <sip:Darwin.Valderas1@imsinnovation.com>;tag=1583898140
Call-ID: 4477de9c83a5627248a78a821c963f08@80.221.38.163
CSeq: 2 REGISTER
Contact: <sip:80.221.38.163:58786;transport=tcp>;expires=1890
P-Associated-URI: <sip:Darwin.Valderas1@imsinnovation.com>
P-Charging-Function-Addresses:
ecf="aaa://mmfe.imsinnovation.com:3867;transport=tcp";ccf="aaa://mmfe.imsinnovation
.com:3867;transport=tcp"
P-Charging-Vector: icid-value=9e87a6fa06914f089afa090b9388b
Authentication-Info:
cnonce="9505d1b642028354e63d38734e592dc0",qop=auth,nextnonce="32f8ec1cec31610a7871b
7c6b10e4cec",rspauth="0e1fdff3cc7765cc0c49d069514600ab",nc=00000001
Service-Route: <sip:213.115.115.187:35060;lr;transport=tcp>
Content-Length: 0
```

A.1.2 - *Subscription process*

```
   1. PUA -----------------------------> PGM
SUBSCRIBE sip:Darwin.Valderas1@imsinnovation.com;transport=tcp SIP/2.0
Call-ID: 7e522758a19a199781a431317c986adc@80.221.38.163
CSeq: 1 SUBSCRIBE
To: <sip:Darwin.Valderas1@imsinnovation.com:5060;transport=tcp>
Via: SIP/2.0/TCP 80.221.38.163:58786;branch=z9hG4bKb3cb9dae6961f7d1c2bac3f481b4b8ab
Max-Forwards: 70
From: <sip:Darwin.Valderas1@imsinnovation.com>;tag=1433761786
Contact: <sip:80.221.38.163:58786;transport=tcp>
Route: <sip:213.115.115.187:35060;lr;transport=tcp>
P-Application-Identity: desktop_client
Accept-Contact2: *;g.3gpp.app_ref=urn%3Aurn-xxx%3Anull
Event: presence.winfo
Expires: 3600
Content-Length: 0
```

```
   2. PUA <----------------------------- PGM
SIP/2.0 200 OK
Via: SIP/2.0/TCP
80.221.38.163:58786;received=213.115.115.187;branch=z9hG4bKb3cb9dae6961f7d1c2bac3f4
81b4b8ab
To:
<sip:Darwin.Valderas1@imsinnovation.com:5060;transport=tcp>;tag=h7g4Esbg_flm2qfum-
xyq
From: <sip:Darwin.Valderas1@imsinnovation.com>;tag=1433761786
Call-ID: 7e522758a19a199781a431317c986adc@80.221.38.163
CSeq: 1 SUBSCRIBE
Contact: <sip:sgc_c@193.180.168.44:35060;transport=tcp>
Record-Route: <sip:213.115.115.187:35060;lr;transport=tcp>
Expires: 3600
P-Charging-Vector: icid-value=d137184b069148089afa0a4444bd6
Server: PGM4.1_PS
Content-Length: 0
```

```
   3. PUA <----------------------------- PGM
NOTIFY sip:80.221.38.163:58786;transport=tcp SIP/2.0
Max-Forwards: 67
Via: SIP/2.0/TCP 193.180.168.44:35060;branch=z9hG4bKihc9gloxjjqhndvtirrwz7hrm
To: <sip:Darwin.Valderas1@imsinnovation.com>;tag=1433761786
From:
<sip:Darwin.Valderas1@imsinnovation.com:5060;transport=tcp>;tag=h7g4Esbg_flm2qfum-
xyq
Call-ID: 7e522758a19a199781a431317c986adc@80.221.38.163
CSeq: 2 NOTIFY
Contact: <sip:sgc_c@193.180.168.44:35060;transport=tcp>
Record-Route: <sip:213.115.115.187:35060;lr;transport=tcp>
Event: presence.winfo
Subscription-State: active;expires=3599
Content-Type: application/watcherinfo+xml
Content-Length: 234

<?xml version="1.0" encoding="UTF-8"?>
<urn:watcherinfo version="0" state="full"
xmlns:urn="urn:ietf:params:xml:ns:watcherinfo"><urn:watcher-list
resource="sip:Darwin.Valderas1@imsinnovation.com"
package="presence"/></urn:watcherinfo>


   4. PUA <----------------------------- PGM
NOTIFY sip:80.221.38.163:58786;transport=tcp SIP/2.0
Max-Forwards: 67
Via: SIP/2.0/TCP 193.180.168.44:35060;branch=z9hG4bKihc9gloxjjqhndvtirrwz7hrm
To: <sip:Darwin.Valderas1@imsinnovation.com>;tag=1433761786
From:
<sip:Darwin.Valderas1@imsinnovation.com:5060;transport=tcp>;tag=h7g4Esbg_flm2qfum-
xyq
Call-ID: 7e522758a19a199781a431317c986adc@80.221.38.163
CSeq: 2 NOTIFY
Contact: <sip:sgc_c@193.180.168.44:35060;transport=tcp>
Record-Route: <sip:213.115.115.187:35060;lr;transport=tcp>
Event: presence.winfo
Subscription-State: active;expires=3599
Content-Type: application/watcherinfo+xml
Content-Length: 234

<?xml version="1.0" encoding="UTF-8"?>
<urn:watcherinfo version="0" state="full"
xmlns:urn="urn:ietf:params:xml:ns:watcherinfo"><urn:watcher-list
resource="sip:Darwin.Valderas1@imsinnovation.com"
package="presence"/></urn:watcherinfo>


   5. PUA -----------------------------> PGM
SIP/2.0 200 OK
Via: SIP/2.0/TCP 193.180.168.44:35060;branch=z9hG4bKihc9gloxjjqhndvtirrwz7hrm
To: <sip:Darwin.Valderas1@imsinnovation.com>;tag=1433761786
From:
<sip:Darwin.Valderas1@imsinnovation.com:5060;transport=tcp>;tag=h7g4Esbg_flm2qfum-
xyq
Call-ID: 7e522758a19a199781a431317c986adc@80.221.38.163
CSeq: 2 NOTIFY
Record-Route: <sip:213.115.115.187:35060;lr;transport=tcp>
Contact: <sip:80.221.38.163:58786;transport=TCP>
Content-Length: 0
```

```
   6. PUA -----------------------------> PGM
SIP/2.0 200 OK
Via: SIP/2.0/TCP 193.180.168.44:35060;branch=z9hG4bKihc9gloxjjqhndvtirrwz7hrm
To: <sip:Darwin.Valderas1@imsinnovation.com>;tag=1433761786
From:
<sip:Darwin.Valderas1@imsinnovation.com:5060;transport=tcp>;tag=h7g4Esbg_flm2qfum-
xyq
Call-ID: 7e522758a19a199781a431317c986adc@80.221.38.163
CSeq: 2 NOTIFY
Record-Route: <sip:213.115.115.187:35060;lr;transport=tcp>
Contact: <sip:80.221.38.163:58786;transport=TCP>
Content-Length: 0
```

A.1.3 - *Publishing process*

```
   1. PUA -----------------------------> PGM
PUBLISH sip:Darwin.Valderas1@imsinnovation.com SIP/2.0
Call-ID: 1577a6145985967ec84a62f6f909c7c9@80.221.38.163
CSeq: 1 PUBLISH
To: <sip:Darwin.Valderas1@imsinnovation.com:5060;transport=tcp>
Via: SIP/2.0/TCP 80.221.38.163:58786;branch=z9hG4bKa58673877b5f92ac893fa44dac2ebd0e
Max-Forwards: 70
From: <sip:Darwin.Valderas1@imsinnovation.com>;tag=1573040888
Contact: <sip:80.221.38.163:58786;transport=tcp>
Route: <sip:213.115.115.187:35060;lr;transport=tcp>
P-Application-Identity: desktop_client
Accept-Contact2: *;g.3gpp.app_ref=urn%3Aurn-xxx%3Anull
Event: presence
Expires: 3600
Content-Type: application/pidf+xml
Content-Length: 903
<?xml version="1.0" encoding="UTF-8"?>
<presence xmlns:rpid="urn:ietf:params:xml:ns:pidf:rpid"
xmlns:pdm="urn:ietf:params:xml:ns:pidf:data-model"
xmlns:op="urn:oma:xml:prs:pidf:oma-pres" xmlns="urn:ietf:params:xml:ns:pidf"
entity="sip:Darwin.Valderas1@imsinnovation.com">
<tuple id="INQYul39">
<status>
<basic>open</basic></status>
<op:service-description>
<op:service-id>desktop_client</op:service-id>
<op:version>1.0</op:version></op:service-description>
<timestamp>2008-09-27T01:33:31.218Z</timestamp></tuple>
<pdm:person id="p1">
<pdm:note>67;67;67;00:00:00</pdm:note>
<pdm:timestamp>2008-09-27T01:33:31.218Z</pdm:timestamp>
</pdm:person>
</presence>
```

```
   2. PGM <----------------------------- PGM
SIP/2.0 200 OK
Via: SIP/2.0/TCP
80.221.38.163:58786;received=213.115.115.187;branch=z9hG4bKa58673877b5f92ac893fa44d
ac2ebd0e
To:
<sip:Darwin.Valderas1@imsinnovation.com:5060;transport=tcp>;tag=h7g4Esbg_flm2qiem-
xyr
From: <sip:Darwin.Valderas1@imsinnovation.com>;tag=1573040888
Call-ID: 1577a6145985967ec84a62f6f909c7c9@80.221.38.163
CSeq: 1 PUBLISH
Expires: 3600
P-Charging-Vector: icid-value=5d465baf0b2de1089afa2474f3c1a
SIP-ETag: 3
Server: PGM4.1_PS
Content-Length: 0
```

A.2 - A watcher subscribing to a presentity's presence information

```
   1. Watcher -------------------------> PGM
SUBSCRIBE sip:Darwin.Valderas2@imsinnovation.com;list=MiPropiaLista_darwin SIP/2.0
P-Asserted-Identity: sip:Darwin.Valderas2@imsinnovation.com
From: <sip:Darwin.Valderas2@imsinnovation.com>;tag=fllxchxn-3
To: <sip:Darwin.Valderas2@imsinnovation.com;list=MiPropiaLista_darwin>
Via: SIP/2.0/UDP
213.115.115.188:5060;branch=z9hG4bKdaac4351a7fbf6ca4a3dbead0a01ee8b53e0
Accept: application/pidf+xml, application/rlmi+xml, multipart/related,
application/cpim-pidf+xml
Content-Length: 0
Max-Forwards: 69
Expires: 3600
Cseq: 1 SUBSCRIBE
Contact: <sip:213.115.115.188:5060;fid=server_1>
Route: <sip:172.23.214.27:5063;lr>
Supported: eventlist
Event: presence
Call-Id: 213.115.115.188_3_2478652265596970642


   2. Watcher <----------------------------- PGM
SIP/2.0 200 OK
To:
<sip:Darwin.Valderas2@imsinnovation.com;list=MiPropiaLista_darwin>;tag=fllxbafp-9dq
From: <sip:Darwin.Valderas2@imsinnovation.com>;tag=fllxchxn-3
Call-ID: 213.115.115.188_3_2478652265596970642
CSeq: 1 SUBSCRIBE
Content-Length: 0
Via: SIP/2.0/UDP
213.115.115.188:5060;branch=z9hG4bKdaac4351a7fbf6ca4a3dbead0a01ee8b53e0
Record-Route:
<sip:3Zqkv7%0BaGqjGaaaacqsip%3ADarwin.Valderas2%40imsinnovation.com@scscf.imsinnova
tion.com:5062;maddr=172.23.214.27;lr>
Record-Route: <sip:3Zqkv7%0BaHasaaaaad4sip%3ADarwin.Valderas2%40imsinnovation.com-
uac-
be43537904c3a7089af1509e36a38@scscf.imsinnovation.com:5063;maddr=172.23.214.27;lr>
Contact: <sip:172.23.214.171:22021;transport=tcp>
Require: eventlist
Expires: 3600
Server: PGM4.1_RLS
P-Charging-Vector: icid-value=be43537904c3a7089af1509e3d49c;orig-ioi=1;term-ioi=1
```

```
   3. Watcher <------------------------------ PGM
NOTIFY sip:213.115.115.188:5060;fid=server_1 SIP/2.0
To: <sip:Darwin.Valderas2@imsinnovation.com>;tag=fllxchxn-3
From:
<sip:Darwin.Valderas2@imsinnovation.com;list=MiPropiaLista_darwin>;tag=fllxbafp-9dq
Call-ID: 213.115.115.188_3_2478652265596970642
CSeq: 2 NOTIFY
Max-Forwards: 67
Content-Length: 912
Via: SIP/2.0/TCP
172.23.214.27:5063;branch=z9hG4bKf065ad5136fe26822b4d5bca79a6eaa9jaaaaaaiaaaaaabukx
kya3Zqkv7v4injxsnabwnsa
Via: SIP/2.0/TCP
172.23.214.27:5060;branch=z9hG4bKe4fd8d5dcc14d6c8fa8390b6ce09e024jaaaaaaiaaaaaapxui
cla3Zqkv7f4injxtr0qdn4a
Via: SIP/2.0/TCP 172.23.214.171:22021;branch=z9hG4bK1213218k3baaaa
Record-Route:
<sip:3Zqkv7%0BaGqjOaaaaeOsip%3ADarwin.Valderas2%40imsinnovation.com@scscf.imsinnova
tion.com:5062;maddr=172.23.214.27;lr>
Contact: <sip:172.23.214.171:22021;transport=tcp>
Content-Type:
multipart/related;type="application/rlmi+xml";start="<sip:Darwin.Valderas2@imsinnov
ation.com;list=MiPropiaLista_darwin>"; boundary="----
=_Part_18818_32210634.1222500634629"
Require: eventlist
Subscription-State: active;expires=3599
Event: presence
------=_Part_18818_32210634.1222500634629
Content-Type: application/rlmi+xml;charset="UTF-8"
Content-Transfer-Encoding: binary
Content-ID: <sip:Darwin.Valderas2@imsinnovation.com;list=MiPropiaLista_darwin>

<?xml version="1.0" encoding="UTF-8"?>
<list uri="sip:Darwin.Valderas2@imsinnovation.com;list=MiPropiaLista_darwin"
version="0" fullState="true" xmlns="urn:ietf:params:xml:ns:rlmi"><resource
uri="sip:Darwin.Valderas1@imsinnovation.com"><instance id="1" state="active"
cid="sip:Darwin.Valderas1@imsinnovation.com"/></resource></list>
------=_Part_18818_32210634.1222500634629
Content-Type: application/pidf+xml;charset="UTF-8"
Content-Transfer-Encoding: binary
Content-ID: <sip:Darwin.Valderas1@imsinnovation.com>

<?xml version="1.0" encoding="UTF-8"?><presence xmlns="urn:ietf:params:xml:ns:pidf"
entity="sip:Darwin.Valderas1@imsinnovation.com"/>
------=_Part_18818_32210634.1222500634629—


   4. Watcher -------------------------> PGM
SIP/2.0 200 OK
Record-Route:
<sip:3Zqkv7%0BaGqjOaaaaeOsip%3ADarwin.Valderas2%40imsinnovation.com@scscf.imsinnova
tion.com:5062;maddr=172.23.214.27;lr>
Content-Length: 0
From:
<sip:Darwin.Valderas2@imsinnovation.com;list=MiPropiaLista_darwin>;tag=fllxbafp-9dq
Cseq: 2 NOTIFY
Contact: <sip:213.115.115.188:5060;fid=server_1>
To: <sip:Darwin.Valderas2@imsinnovation.com>;tag=fllxchxn-3
Server: Glassfish_SIP_1.0.0
Via: SIP/2.0/TCP
172.23.214.27:5063;branch=z9hG4bKf065ad5136fe26822b4d5bca79a6eaa9jaaaaaaiaaaaaabukx
kya3Zqkv7v4injxsnabwnsa
Via: SIP/2.0/TCP
172.23.214.27:5060;branch=z9hG4bKe4fd8d5dcc14d6c8fa8390b6ce09e024jaaaaaaiaaaaaapxui
cla3Zqkv7f4injxtr0qdn4a
Via: SIP/2.0/TCP 172.23.214.171:22021;branch=z9hG4bK1213218k3baaaa
```

```
Call-Id: 213.115.115.188_3_2478652265596970642
   5. Watcher <----------------------------- PGM
NOTIFY sip:213.115.115.188:5060;fid=server_1 SIP/2.0
To: <sip:Darwin.Valderas2@imsinnovation.com>;tag=fllxchxn-3
From:
<sip:Darwin.Valderas2@imsinnovation.com;list=MiPropiaLista_darwin>;tag=fllxbafp-9dq
Call-ID: 213.115.115.188_3_2478652265596970642
CSeq: 3 NOTIFY
Max-Forwards: 67
Content-Length: 1668
Via: SIP/2.0/TCP
172.23.214.27:5063;branch=z9hG4bK0b22504430b02b033fbf0a0b1dcfa76ajaaaaaaiaaaaaa5kxf
ceq3Zqkv7v4injxsvaptkta
Via: SIP/2.0/TCP
172.23.214.27:5060;branch=z9hG4bKa0f14bbd4b4c55033dc119d66b96a15djaaaaaaiaaaaaatbm1
ccq3Zqkv7f4injxsx0tsega
Via: SIP/2.0/TCP 172.23.214.171:22021;branch=z9hG4bK1213219k3baaaa
Record-Route:
<sip:3Zqkv7%0BaGqjOaaaagOsip%3ADarwin.Valderas2%40imsinnovation.com@scscf.imsinnova
tion.com:5062;maddr=172.23.214.27;lr>
Contact: <sip:172.23.214.171:22021;transport=tcp>
Content-Type:
multipart/related;type="application/rlmi+xml";start="<sip:Darwin.Valderas2@imsinnov
ation.com;list=MiPropiaLista_darwin>"; boundary="----
=_Part_18819_32230965.1222501045379"
Require: eventlist
Subscription-State: active;expires=3188
Event: presence

------=_Part_18819_32230965.1222501045379
Content-Type: application/rlmi+xml;charset="UTF-8"
Content-Transfer-Encoding: binary
Content-ID: <sip:Darwin.Valderas2@imsinnovation.com;list=MiPropiaLista_darwin>

<?xml version="1.0" encoding="UTF-8"?>
<list uri="sip:Darwin.Valderas2@imsinnovation.com;list=MiPropiaLista_darwin"
version="1" fullState="true" xmlns="urn:ietf:params:xml:ns:rlmi"><resource
uri="sip:Darwin.Valderas1@imsinnovation.com"><instance id="1" state="active"
cid="sip:Darwin.Valderas1@imsinnovation.com"/></resource></list>
------=_Part_18819_32230965.1222501045379
Content-Type: application/pidf+xml;charset="UTF-8"
Content-Transfer-Encoding: binary
Content-ID: <sip:Darwin.Valderas1@imsinnovation.com>

<?xml version="1.0" encoding="UTF-8"?>
<presence entity="sip:Darwin.Valderas1@imsinnovation.com"
xmlns:pt="urn:ietf:params:xml:ns:location-type" xmlns="urn:ietf:params:xml:ns:pidf"
xmlns:gml="urn:opengis:specification:gml:schema-xsd:feature:v3.0"
xmlns:pdm="urn:ietf:params:xml:ns:pidf:data-model" xmlns:other="urn:other"
xmlns:gp="urn:ietf:params:xml:ns:pidf:geopriv10"
xmlns:op="urn:oma:xml:prs:pidf:oma-pres"
xmlns:rpid="urn:ietf:params:xml:ns:pidf:rpid"
xmlns:cl="urn:ietf:params:xml:ns:pidf:geopriv10:civicLoc">
<tuple id="NYGzG0dO">
<status>
<basic>open</basic></status>
<op:service-description>
<op:service-id>mobile_client</op:service-id>
<op:version>1.0</op:version></op:service-description>
<timestamp>2008-09-27T07:37:24.157Z</timestamp></tuple>
<pdm:person id="p1">
<pdm:note>0;0;0;00:00:00</pdm:note>
<pdm:timestamp>2008-09-27T07:37:24.157Z</pdm:timestamp></pdm:person></presence>
------=_Part_18819_32230965.1222501045379—
```

```
   6. Watcher -------------------------> PGM
SIP/2.0 200 OK
Record-Route:
<sip:3Zqkv7%0BaGqjOaaaagOsip%3ADarwin.Valderas2%40imsinnovation.com@scscf.imsinnova
tion.com:5062;maddr=172.23.214.27;lr>
Content-Length: 0
From:
<sip:Darwin.Valderas2@imsinnovation.com;list=MiPropiaLista_darwin>;tag=fllxbafp-9dq
Cseq: 3 NOTIFY
Contact: <sip:213.115.115.188:5060;fid=server_1>
To: <sip:Darwin.Valderas2@imsinnovation.com>;tag=fllxchxn-3
Server: Glassfish_SIP_1.0.0
Via: SIP/2.0/TCP
172.23.214.27:5063;branch=z9hG4bK0b22504430b02b033fbf0a0b1dcfa76ajaaaaaaiaaaaaa5kxf
ceq3Zqkv7v4injxsvaptkta
Via: SIP/2.0/TCP
172.23.214.27:5060;branch=z9hG4bKa0f14bbd4b4c55033dc119d66b96a15djaaaaaaiaaaaaatbm1
ccq3Zqkv7f4injxsx0tsega
Via: SIP/2.0/TCP 172.23.214.171:22021;branch=z9hG4bK1213219k3baaaa
Call-Id: 213.115.115.188_3_2478652265596970642
```

A.3 - Adding a new watcher

A.3.1 – *Subscription process (showing the pending state)*

```
   1. Watcher -------------------------> PGM
SUBSCRIBE sip:Oscar.Novo1@imsinnovation.com;list=MiPropiaLista_oscar1 SIP/2.0
P-Asserted-Identity: sip:Oscar.Novo1@imsinnovation.com
From: <sip:Oscar.Novo1@imsinnovation.com>;tag=flmgzumc-6
To: <sip:Oscar.Novo1@imsinnovation.com;list=MiPropiaLista_oscar1>
Via: SIP/2.0/UDP
213.115.115.188:5060;branch=z9hG4bKdaac7d9067722c794a0d8738d09b44d85242
Accept: application/pidf+xml, application/rlmi+xml, multipart/related,
application/cpim-pidf+xml
Content-Length: 0
Max-Forwards: 69
Expires: 3600
Cseq: 1 SUBSCRIBE
Contact: <sip:213.115.115.188:5060;fid=server_1>
Route: <sip:172.23.214.27:5063;lr>
Supported: eventlist
Event: presence
Call-Id: 213.115.115.188_6_7715831493867887540
```

```
   2. Watcher <------------------------- PGM
SIP/2.0 200 OK
To: <sip:Oscar.Novo1@imsinnovation.com;list=MiPropiaLista_oscar1>;tag=flmgyn11-xzl
From: <sip:Oscar.Novo1@imsinnovation.com>;tag=flmgzumc-6
Call-ID: 213.115.115.188_6_7715831493867887540
CSeq: 1 SUBSCRIBE
Content-Length: 0
Via: SIP/2.0/UDP
213.115.115.188:5060;branch=z9hG4bKdaac7d9067722c794a0d8738d09b44d85242
Record-Route:
<sip:3Zqkv7%0BaGqiqaaaacqsip%3AOscar.Novo1%40imsinnovation.com@scscf.imsinnovation.
com:5062;maddr=172.23.214.27;lr>
Record-Route: <sip:3Zqkv7%0BaHaqWaaaad4sip%3AOscar.Novo1%40imsinnovation.com-uac-
4cb495100b35dd089b10ed744d31c@scscf.imsinnovation.com:5063;maddr=172.23.214.27;lr>
Contact: <sip:172.23.214.171:22023;transport=tcp>
Require: eventlist
Expires: 3600
```

```
Server: PGM4.1_RLS
P-Charging-Vector: icid-value=4cb495100b35dd089b10ed7453e37;orig-ioi=1;term-ioi=1


   3. Watcher <------------------------- PGM
NOTIFY sip:213.115.115.188:5060;fid=server_1 SIP/2.0
To: <sip:Oscar.Novo1@imsinnovation.com>;tag=flmgzumc-6
From: <sip:Oscar.Novo1@imsinnovation.com;list=MiPropiaLista_oscar1>;tag=flmgyn11-
xzl
Call-ID: 213.115.115.188_6_7715831493867887540
CSeq: 2 NOTIFY
Max-Forwards: 67
Content-Length: 535
Via: SIP/2.0/TCP
172.23.214.27:5063;branch=z9hG4bKaba850b039b28448528877626c41e832jaaaaaaiaaaaaa1ymb
e1a3Zqkv7smwskrakzxzwaa
Via: SIP/2.0/TCP
172.23.214.27:5060;branch=z9hG4bK057030d3dec92affdaa9358c25a5baf1jaaaaaaiaaaaaadgtv
rsa3Zqkv7cmwskrbyxgnfha
Via: SIP/2.0/TCP 172.23.214.171:22023;branch=z9hG4bK1583232doeaaaa
Record-Route:
<sip:3Zqkv7%0BaGqiyaaaaeOsip%3AOscar.Novo1%40imsinnovation.com@scscf.imsinnovation.
com:5062;maddr=172.23.214.27;lr>
Contact: <sip:172.23.214.171:22023;transport=tcp>
Content-Type:
multipart/related;type="application/rlmi+xml";start="<sip:Oscar.Novo1@imsinnovation
.com;list=MiPropiaLista_oscar1>"; boundary="----=_Part_21879_5214906.1222533636417"
Require: eventlist
Subscription-State: active;expires=3599
Event: presence

------=_Part_21879_5214906.1222533636417
Content-Type: application/rlmi+xml;charset="UTF-8"
Content-Transfer-Encoding: binary
Content-ID: <sip:Oscar.Novo1@imsinnovation.com;list=MiPropiaLista_oscar1>

<?xml version="1.0" encoding="UTF-8"?>
<list uri="sip:Oscar.Novo1@imsinnovation.com;list=MiPropiaLista_oscar1" version="0"
fullState="true" xmlns="urn:ietf:params:xml:ns:rlmi"><resource
uri="sip:Darwin.Valderas1@imsinnovation.com"><instance id="1"
state="pending"/></resource></list>
------=_Part_21879_5214906.1222533636417--


   4. Watcher -------------------------> PGM
SIP/2.0 200 OK
Record-Route:
<sip:3Zqkv7%0BaGqiyaaaaeOsip%3AOscar.Novo1%40imsinnovation.com@scscf.imsinnovation.
com:5062;maddr=172.23.214.27;lr>
Content-Length: 0
From: <sip:Oscar.Novo1@imsinnovation.com;list=MiPropiaLista_oscar1>;tag=flmgyn11-
xzl
Cseq: 2 NOTIFY
Contact: <sip:213.115.115.188:5060;fid=server_1>
To: <sip:Oscar.Novo1@imsinnovation.com>;tag=flmgzumc-6
Server: Glassfish_SIP_1.0.0
Via: SIP/2.0/TCP
172.23.214.27:5063;branch=z9hG4bKaba850b039b28448528877626c41e832jaaaaaaiaaaaaa1ymb
e1a3Zqkv7smwskrakzxzwaa
Via: SIP/2.0/TCP
172.23.214.27:5060;branch=z9hG4bK057030d3dec92affdaa9358c25a5baf1jaaaaaaiaaaaaadgtv
rsa3Zqkv7cmwskrbyxgnfha
Via: SIP/2.0/TCP 172.23.214.171:22023;branch=z9hG4bK1583232doeaaaa
Call-Id: 213.115.115.188_6_7715831493867887540
```

A.3.2 – *Watcher list notification - watcher allowed to view presence*

```
   1. PUA <------------------------- PGM
NOTIFY sip:80.221.38.163:54346;transport=tcp SIP/2.0
Max-Forwards: 67
Via: SIP/2.0/TCP 193.180.168.44:35060;branch=z9hG4bKuxn4758ru4nc5qy7qgqfih8nk
To: <sip:Darwin.Valderas1@imsinnovation.com>;tag=1234107759
From:
<sip:Darwin.Valderas1@imsinnovation.com:5060;transport=tcp>;tag=h7g4Esbg_flmgwtdd-
xzi
Call-ID: 7c93de23b60fe2dcf622d51a2b43fe1f@80.221.38.163
CSeq: 3 NOTIFY
Contact: <sip:sgc_c@193.180.168.44:35060;transport=tcp>
Record-Route: <sip:213.115.115.187:35060;lr;transport=tcp>
Event: presence.winfo
Subscription-State: active;expires=3514
Content-Type: application/watcherinfo+xml
Content-Length: 391

<?xml version="1.0" encoding="UTF-8"?>
<urn:watcherinfo version="1" state="partial"
xmlns:urn="urn:ietf:params:xml:ns:watcherinfo"><urn:watcher-list
resource="sip:Darwin.Valderas1@imsinnovation.com" package="presence"><urn:watcher
display-name="" status="pending" event="subscribe" expiration="3599"
id="0">sip:Oscar.Novo1@imsinnovation.com</urn:watcher></urn:watcher-
list></urn:watcherinfo>
```

```
   2. PUA -------------------------> PGM
SIP/2.0 200 OK
Via: SIP/2.0/TCP 193.180.168.44:35060;branch=z9hG4bKuxn4758ru4nc5qy7qgqfih8nk
To: <sip:Darwin.Valderas1@imsinnovation.com>;tag=1234107759
From:
<sip:Darwin.Valderas1@imsinnovation.com:5060;transport=tcp>;tag=h7g4Esbg_flmgwtdd-
xzi
Call-ID: 7c93de23b60fe2dcf622d51a2b43fe1f@80.221.38.163
CSeq: 3 NOTIFY
Record-Route: <sip:213.115.115.187:35060;lr;transport=tcp>
Contact: <sip:80.221.38.163:54346;transport=TCP>
Content-Length: 0
```

```
   3. Watcher <------------------------- PGM
NOTIFY sip:213.115.115.188:5060;fid=server_1 SIP/2.0
To: <sip:Oscar.Novo1@imsinnovation.com>;tag=flmgzumc-6
From: <sip:Oscar.Novo1@imsinnovation.com;list=MiPropiaLista_oscar1>;tag=flmgyn11-
xzl
Call-ID: 213.115.115.188_6_7715831493867887540
CSeq: 3 NOTIFY
Max-Forwards: 67
Content-Length: 1673
Via: SIP/2.0/TCP
172.23.214.27:5063;branch=z9hG4bK2f7314cade30d75f100e122e705e9708jaaaaaaiaaaaaat52p
ecq3Zqkv7smwskraobxxtha
Via: SIP/2.0/TCP
172.23.214.27:5060;branch=z9hG4bK8c53f1741d3ae0efb74fd3c647684c38jaaaaaaiaaaaaaewei
qka3Zqkv7cmwskrazrgouoa
Via: SIP/2.0/TCP 172.23.214.171:22023;branch=z9hG4bK1583235doeaaaa
Record-Route:
<sip:3Zqkv7%0BaGqiyaaaagOsip%3AOscar.Novo1%40imsinnovation.com@scscf.imsinnovation.
com:5062;maddr=172.23.214.27;lr>
Contact: <sip:172.23.214.171:22023;transport=tcp>
Content-Type:
multipart/related;type="application/rlmi+xml";start="<sip:Oscar.Novo1@imsinnovation
.com;list=MiPropiaLista_oscar1>"; boundary="----
=_Part_21880_10456047.1222533636799"
```

```
Require: eventlist
Subscription-State: active;expires=3599
Event: presence

------=_Part_21880_10456047.1222533636799
Content-Type: application/rlmi+xml;charset="UTF-8"
Content-Transfer-Encoding: binary
Content-ID: <sip:Oscar.Novo1@imsinnovation.com;list=MiPropiaLista_oscar1>

<?xml version="1.0" encoding="UTF-8"?>
<list uri="sip:Oscar.Novo1@imsinnovation.com;list=MiPropiaLista_oscar1" version="1"
fullState="true" xmlns="urn:ietf:params:xml:ns:rlmi"><resource
uri="sip:Darwin.Valderas1@imsinnovation.com"><instance id="1" state="active"
cid="sip:Darwin.Valderas1@imsinnovation.com"/></resource></list>
------=_Part_21880_10456047.1222533636799
Content-Type: application/pidf+xml;charset="UTF-8"
Content-Transfer-Encoding: binary
Content-ID: <sip:Darwin.Valderas1@imsinnovation.com>

<?xml version="1.0" encoding="UTF-8"?>
<presence entity="sip:Darwin.Valderas1@imsinnovation.com"
xmlns:pdm="urn:ietf:params:xml:ns:pidf:data-model"
xmlns:op="urn:oma:xml:prs:pidf:oma-pres" xmlns="urn:ietf:params:xml:ns:pidf">
<tuple id="iLJIQyKG">
<status>
<basic>open</basic></status>
<op:service-description>
<op:service-id>pichula</op:service-id>
<op:version>1.0</op:version></op:service-description>
<timestamp>2008-09-27T16:39:14.404Z</timestamp></tuple>
<pdm:person id="p1">
<pdm:note>80;57;86;00:10:09</pdm:note>
<pdm:timestamp>2008-09-27T16:39:14.404Z</pdm:timestamp></pdm:person></presence>
------=_Part_21880_10456047.1222533636799--
```

4. Watcher -------------------------> PGM

```
SIP/2.0 200 OK
Record-Route:
<sip:3Zqkv7%0BaGqiyaaaagOsip%3AOscar.Novo1%40imsinnovation.com@scscf.imsinnovation.
com:5062;maddr=172.23.214.27;lr>
Content-Length: 0
From: <sip:Oscar.Novo1@imsinnovation.com;list=MiPropiaLista_oscar1>;tag=flmgyn11-
xzl
Cseq: 3 NOTIFY
Contact: <sip:213.115.115.188:5060;fid=server_1>
To: <sip:Oscar.Novo1@imsinnovation.com>;tag=flmgzumc-6
Server: Glassfish_SIP_1.0.0
Via: SIP/2.0/TCP
172.23.214.27:5063;branch=z9hG4bK2f7314cade30d75f100e122e705e9708jaaaaaaiaaaaaat52p
ecq3Zqkv7smwskraobxxtha
Via: SIP/2.0/TCP
172.23.214.27:5060;branch=z9hG4bK8c53f1741d3ae0efb74fd3c647684c38jaaaaaaiaaaaaaewei
qka3Zqkv7cmwskrazrgouoa
Via: SIP/2.0/TCP 172.23.214.171:22023;branch=z9hG4bK1583235doeaaaa
Call-Id: 213.115.115.188_6_7715831493867887540
```

A.4 - Two watchers subscribing to the same HRM user’s presence information

A.4.1 – *Watchers subscription process*

```
   1. Watcher1 -------------------------> PGM
SUBSCRIBE sip:Darwin.Valderas2@imsinnovation.com;list=MiPropiaLista_darwin SIP/2.0
P-Asserted-Identity: sip:Darwin.Valderas2@imsinnovation.com
From: <sip:Darwin.Valderas2@imsinnovation.com>;tag=fllyndae-4
To: <sip:Darwin.Valderas2@imsinnovation.com;list=MiPropiaLista_darwin>
Via: SIP/2.0/UDP
213.115.115.188:5060;branch=z9hG4bKdaac73df4083bf16499fb23af89e7e32934e
Accept: application/pidf+xml, application/rlmi+xml, multipart/related,
application/cpim-pidf+xml
Content-Length: 0
Max-Forwards: 69
Expires: 3600
Cseq: 1 SUBSCRIBE
Contact: <sip:213.115.115.188:5060;fid=server_1>
Route: <sip:172.23.214.27:5063;lr>
Supported: eventlist
Event: presence
Call-Id: 213.115.115.188_4_4938965627018318151


   2. Watcher1 <------------------------- PGM
SIP/2.0 200 OK
To:
<sip:Darwin.Valderas2@imsinnovation.com;list=MiPropiaLista_darwin>;tag=fllym5sh-9dt
From: <sip:Darwin.Valderas2@imsinnovation.com>;tag=fllyndae-4
Call-ID: 213.115.115.188_4_4938965627018318151
CSeq: 1 SUBSCRIBE
Content-Length: 0
Via: SIP/2.0/UDP
213.115.115.188:5060;branch=z9hG4bKdaac73df4083bf16499fb23af89e7e32934e
Record-Route:
<sip:3Zqkv7%0BaGqjGaaaacqsip%3ADarwin.Valderas2%40imsinnovation.com@scscf.imsinnova
tion.com:5062;maddr=172.23.214.27;lr>
Record-Route: <sip:3Zqkv7%0BaHasaaaaad4sip%3ADarwin.Valderas2%40imsinnovation.com-
uac-
a69d47c104c462089af36670fc826@scscf.imsinnovation.com:5063;maddr=172.23.214.27;lr>
Contact: <sip:172.23.214.171:22021;transport=tcp>
Require: eventlist
Expires: 3600
Server: PGM4.1_RLS
P-Charging-Vector: icid-value=a69d47c104c462089af36670fd425;orig-ioi=1;term-ioi=1


   3. Watcher1 <------------------------- PGM
NOTIFY sip:213.115.115.188:5060;fid=server_1 SIP/2.0
To: <sip:Darwin.Valderas2@imsinnovation.com>;tag=fllyndae-4
From:
<sip:Darwin.Valderas2@imsinnovation.com;list=MiPropiaLista_darwin>;tag=fllym5sh-9dt
Call-ID: 213.115.115.188_4_4938965627018318151
CSeq: 2 NOTIFY
Max-Forwards: 67
Content-Length: 912
Via: SIP/2.0/TCP
172.23.214.27:5063;branch=z9hG4bK5bd3044f3cbe5101ecaa03142a40a35ajaaaaaaiaaaaaapkmq
lhq3Zqkv7vgtvd2dv1wjkla
```

```
Via: SIP/2.0/TCP
172.23.214.27:5060;branch=z9hG4bK81c4258b2265add7dd15cf7add9bb7dcjaaaaaaiaaaaaaax1y
jeq3Zqkv7fgtvd2cmeuzrca
Via: SIP/2.0/TCP 172.23.214.171:22021;branch=z9hG4bK121321km3baaaa
Record-Route:
<sip:3Zqkv7%0BaGqjOaaaagOsip%3ADarwin.Valderas2%40imsinnovation.com@scscf.imsinnova
tion.com:5062;maddr=172.23.214.27;lr>
Contact: <sip:172.23.214.171:22021;transport=tcp>
Content-Type:
multipart/related;type="application/rlmi+xml";start="<sip:Darwin.Valderas2@imsinnov
ation.com;list=MiPropiaLista_darwin>"; boundary="----
=_Part_18848_22625167.1222502935826"
Require: eventlist
Subscription-State: active;expires=3599
Event: presence

------=_Part_18848_22625167.1222502935826
Content-Type: application/rlmi+xml;charset="UTF-8"
Content-Transfer-Encoding: binary
Content-ID: <sip:Darwin.Valderas2@imsinnovation.com;list=MiPropiaLista_darwin>

<?xml version="1.0" encoding="UTF-8"?>
<list uri="sip:Darwin.Valderas2@imsinnovation.com;list=MiPropiaLista_darwin"
version="1" fullState="true" xmlns="urn:ietf:params:xml:ns:rlmi"><resource
uri="sip:Darwin.Valderas1@imsinnovation.com"><instance id="1" state="active"
cid="sip:Darwin.Valderas1@imsinnovation.com"/></resource></list>
------=_Part_18848_22625167.1222502935826
Content-Type: application/pidf+xml;charset="UTF-8"
Content-Transfer-Encoding: binary
Content-ID: <sip:Darwin.Valderas1@imsinnovation.com>

<?xml version="1.0" encoding="UTF-8"?><presence xmlns="urn:ietf:params:xml:ns:pidf"
entity="sip:Darwin.Valderas1@imsinnovation.com"/>
------=_Part_18848_22625167.1222502935826—
```

4. Watcher1 -------------------------> PGM

```
SIP/2.0 200 OK
Record-Route:
<sip:3Zqkv7%0BaGqjOaaaagOsip%3ADarwin.Valderas2%40imsinnovation.com@scscf.imsinnova
tion.com:5062;maddr=172.23.214.27;lr>
Content-Length: 0
From:
<sip:Darwin.Valderas2@imsinnovation.com;list=MiPropiaLista_darwin>;tag=fllym5sh-9dt
Cseq: 2 NOTIFY
Contact: <sip:213.115.115.188:5060;fid=server_1>
To: <sip:Darwin.Valderas2@imsinnovation.com>;tag=fllyndae-4
Server: Glassfish_SIP_1.0.0
Via: SIP/2.0/TCP
172.23.214.27:5063;branch=z9hG4bK5bd3044f3cbe5101ecaa03142a40a35ajaaaaaaiaaaaaapkmq
lhq3Zqkv7vgtvd2dv1wjkla
Via: SIP/2.0/TCP
172.23.214.27:5060;branch=z9hG4bK81c4258b2265add7dd15cf7add9bb7dcjaaaaaaiaaaaaaax1y
jeq3Zqkv7fgtvd2cmeuzrca
Via: SIP/2.0/TCP 172.23.214.171:22021;branch=z9hG4bK121321km3baaaa
Call-Id: 213.115.115.188_4_4938965627018318151
```

5. Watcher2 -------------------------> PGM

```
SUBSCRIBE sip:Oscar.Novo2@imsinnovation.com;list=MiPropiaLista_oscar SIP/2.0
P-Asserted-Identity: sip:Oscar.Novo2@imsinnovation.com
From: <sip:Oscar.Novo2@imsinnovation.com>;tag=fllyoyam-5
To: <sip:Oscar.Novo2@imsinnovation.com;list=MiPropiaLista_oscar>
Via: SIP/2.0/UDP
213.115.115.188:5060;branch=z9hG4bKdaac8be4761ebe134f769335705b8e4cdf4f
Accept: application/pidf+xml, application/rlmi+xml, multipart/related,
application/cpim-pidf+xml
```

```
Content-Length: 0
Max-Forwards: 69
Expires: 3600
Cseq: 1 SUBSCRIBE
Contact: <sip:213.115.115.188:5060;fid=server_1>
Route: <sip:172.23.214.27:5063;lr>
Supported: eventlist
Event: presence
Call-Id: 213.115.115.188_5_7687429797697315274


   6. Watcher2 <------------------------- PGM
SIP/2.0 200 OK
To: <sip:Oscar.Novo2@imsinnovation.com;list=MiPropiaLista_oscar>;tag=fllynqs0-xv6
From: <sip:Oscar.Novo2@imsinnovation.com>;tag=fllyoyam-5
Call-ID: 213.115.115.188_5_7687429797697315274
CSeq: 1 SUBSCRIBE
Content-Length: 0
Via: SIP/2.0/UDP
213.115.115.188:5060;branch=z9hG4bKdaac8be4761ebe134f769335705b8e4cdf4f
Record-Route:
<sip:3Zqkv7%0BaGqiqaaaacqsip%3AOscar.Novo2%40imsinnovation.com@scscf.imsinnovation.
com:5062;maddr=172.23.214.27;lr>
Record-Route: <sip:3Zqkv7%0BaHaqWaaaad4sip%3AOscar.Novo2%40imsinnovation.com-uac-
5541de44068e15089af3837d29a7e@scscf.imsinnovation.com:5063;maddr=172.23.214.27;lr>
Contact: <sip:172.23.214.171:22023;transport=tcp>
Require: eventlist
Expires: 3600
Server: PGM4.1_RLS
P-Charging-Vector: icid-value=5541de44068e15089af3837d2a69e;orig-ioi=1;term-ioi=1


   7. Watcher2 <------------------------- PGM
NOTIFY sip:213.115.115.188:5060;fid=server_1 SIP/2.0
To: <sip:Oscar.Novo2@imsinnovation.com>;tag=fllyoyam-5
From: <sip:Oscar.Novo2@imsinnovation.com;list=MiPropiaLista_oscar>;tag=fllynqs0-xv6
Call-ID: 213.115.115.188_5_7687429797697315274
CSeq: 2 NOTIFY
Max-Forwards: 67
Content-Length: 900
Via: SIP/2.0/TCP
172.23.214.27:5063;branch=z9hG4bKb59c195e4966e5d9cce3f7c12a0c9b76jaaaaaaiaaaaaabjbx
eaa3Zqkv7svihpei1oyezea
Via: SIP/2.0/TCP
172.23.214.27:5060;branch=z9hG4bKb52c3253e0486c890ace096e307b3885jaaaaaaiaaaaaa4aq0
4ma3Zqkv7cvihpei0mxuqqa
Via: SIP/2.0/TCP 172.23.214.171:22023;branch=z9hG4bK158323knneaaaa
Record-Route:
<sip:3Zqkv7%0BaGqiyaaaagOsip%3AOscar.Novo2%40imsinnovation.com@scscf.imsinnovation.
com:5062;maddr=172.23.214.27;lr>
Contact: <sip:172.23.214.171:22023;transport=tcp>
Content-Type:
multipart/related;type="application/rlmi+xml";start="<sip:Oscar.Novo2@imsinnovation
.com;list=MiPropiaLista_oscar>"; boundary="----=_Part_21761_17314934.1222502935837"
Require: eventlist
Subscription-State: active;expires=3599
Event: presence

------=_Part_21761_17314934.1222502935837
Content-Type: application/rlmi+xml;charset="UTF-8"
Content-Transfer-Encoding: binary
Content-ID: <sip:Oscar.Novo2@imsinnovation.com;list=MiPropiaLista_oscar>

<?xml version="1.0" encoding="UTF-8"?>
<list uri="sip:Oscar.Novo2@imsinnovation.com;list=MiPropiaLista_oscar" version="1"
fullState="true" xmlns="urn:ietf:params:xml:ns:rlmi"><resource
```

```
uri="sip:Darwin.Valderas1@imsinnovation.com"><instance id="1" state="active"
cid="sip:Darwin.Valderas1@imsinnovation.com"/></resource></list>
------=_Part_21761_17314934.1222502935837
Content-Type: application/pidf+xml;charset="UTF-8"
Content-Transfer-Encoding: binary
Content-ID: <sip:Darwin.Valderas1@imsinnovation.com>

<?xml version="1.0" encoding="UTF-8"?><presence xmlns="urn:ietf:params:xml:ns:pidf"
entity="sip:Darwin.Valderas1@imsinnovation.com"/>
------=_Part_21761_17314934.1222502935837--
   8. Watcher2 --------------------------> PGM
SIP/2.0 200 OK
Record-Route:
<sip:3Zqkv7%0BaGqiyaaaagOsip%3AOscar.Novo2%40imsinnovation.com@scscf.imsinnovation.
com:5062;maddr=172.23.214.27;lr>
Content-Length: 0
From: <sip:Oscar.Novo2@imsinnovation.com;list=MiPropiaLista_oscar>;tag=fllynqs0-xv6
Cseq: 2 NOTIFY
Contact: <sip:213.115.115.188:5060;fid=server_1>
To: <sip:Oscar.Novo2@imsinnovation.com>;tag=fllyoyam-5
Server: Glassfish_SIP_1.0.0
Via: SIP/2.0/TCP
172.23.214.27:5063;branch=z9hG4bKb59c195e4966e5d9cce3f7c12a0c9b76jaaaaaaiaaaaaabjbx
eaa3Zqkv7svihpei1oyezea
Via: SIP/2.0/TCP
172.23.214.27:5060;branch=z9hG4bKb52c3253e0486c890ace096e307b3885jaaaaaaiaaaaaa4aq0
4ma3Zqkv7cvihpei0mxuqqa
Via: SIP/2.0/TCP 172.23.214.171:22023;branch=z9hG4bK158323knneaaaa
Call-Id: 213.115.115.188_5_7687429797697315274
```

A.4.2 – *A PUA publishing and watchers receiving notifications*

```
   1. PUA --------------------------> PGM
PUBLISH sip:Darwin.Valderas1@imsinnovation.com:35060 SIP/2.0
Call-ID: 73f44ffd539d380739ffbc9923bb4ab5@80.221.38.163
CSeq: 1 PUBLISH
From: <sip:Darwin.Valderas1@imsinnovation.com:35060>;tag=5983
To: <sip:Darwin.Valderas1@imsinnovation.com:35060>
Via: SIP/2.0/TCP 80.221.38.163:3245;branch=z9hG4bKca99b352946d859b281a9e6b8fb5919d
Max-Forwards: 69
Allow: INVITE,ACK,CANCEL,OPTIONS,BYE,REFER,NOTIFY,MESSAGE,SUBSCRIBE,INFO
Event: presence
Contact: <sip:Darwin.Valderas1@80.221.38.163:3245>
Expires: 3600
Content-Type: application/pidf+xml
Content-Length: 643

<?xml version="1.0" encoding="utf-8"?>
<presence xmlns="urn:ietf:params:xml:ns:pidf" xmlns:op="urn:oma:xml:prs:pidf:oma-
pres" xmlns:pdm="urn:ietf:params:xml:ns:pidf:data-model"
entity="sip:Darwin.Valderas1@imsinnovation.com">
<tuple id="zA6Dkacz">
<status>
<basic>open</basic>
</status>
<op:service-description>
<op:service-id>desktop_client</op:service-id>
<op:version>1.0</op:version>
</op:service-description>
<timestamp>2008-09-27T11:11:54.468Z</timestamp>
</tuple>
<pdm:person id="p1">
<pdm:note>86;86;86;00:00:00</pdm:note>
```

```
<pdm:timestamp>2008-09-27T11:11:54.468Z</pdm:timestamp>
</pdm:person>
</presence>


   2. PGM -------------------------> PUA
SIP/2.0 200 OK
Via: SIP/2.0/TCP
80.221.38.163:3245;received=213.115.115.187;branch=z9hG4bKca99b352946d859b281a9e6b8
fb5919d
To: <sip:Darwin.Valderas1@imsinnovation.com:35060>;tag=h7g4Esbg_fllyrbfc-xvb
From: <sip:Darwin.Valderas1@imsinnovation.com:35060>;tag=5983
Call-ID: 73f44ffd539d380739ffbc9923bb4ab5@80.221.38.163
CSeq: 1 PUBLISH
Expires: 3600
P-Charging-Vector: icid-value=cefe160804c483089af3a0d557a3d
SIP-ETag: 1
Server: PGM4.1_PS
Content-Length: 0


   3. PGM -------------------------> Watcher2
NOTIFY sip:213.115.115.188:5060;fid=server_1 SIP/2.0
To: <sip:Oscar.Novo2@imsinnovation.com>;tag=fllyoyam-5
From: <sip:Oscar.Novo2@imsinnovation.com;list=MiPropiaLista_oscar>;tag=fllynqs0-xv6
Call-ID: 213.115.115.188_5_7687429797697315274
CSeq: 4 NOTIFY
Max-Forwards: 67
Content-Length: 1392
Via: SIP/2.0/TCP
172.23.214.27:5063;branch=z9hG4bKe9980b6c365131ba1bf4d7de02485e6djaaaaaaiaaaaaau2xv
xyq3Zqkv7svihpeiahkpepa
Via: SIP/2.0/TCP
172.23.214.27:5060;branch=z9hG4bKe79ec709375d1d297c7a3446f1e744c9jaaaaaaiaaaaaaloeg
0ea3Zqkv7cvihpej2w1gp0a
Via: SIP/2.0/TCP 172.23.214.171:22023;branch=z9hG4bK158323unneaaaa
Record-Route:
<sip:3Zqkv7%0BaGqiyaaaaiOsip%3AOscar.Novo2%40imsinnovation.com@scscf.imsinnovation.
com:5062;maddr=172.23.214.27;lr>
Contact: <sip:172.23.214.171:22023;transport=tcp>
Content-Type:
multipart/related;type="application/rlmi+xml";start="<sip:Oscar.Novo2@imsinnovation
.com;list=MiPropiaLista_oscar>"; boundary="----=_Part_21762_30367093.1222503061673"
Require: eventlist
Subscription-State: active;expires=3433
Event: presence

------=_Part_21762_30367093.1222503061673
Content-Type: application/rlmi+xml;charset="UTF-8"
Content-Transfer-Encoding: binary
Content-ID: <sip:Oscar.Novo2@imsinnovation.com;list=MiPropiaLista_oscar>

<?xml version="1.0" encoding="UTF-8"?>
<list uri="sip:Oscar.Novo2@imsinnovation.com;list=MiPropiaLista_oscar" version="2"
fullState="true" xmlns="urn:ietf:params:xml:ns:rlmi"><resource
uri="sip:Darwin.Valderas1@imsinnovation.com"><instance id="1" state="active"
cid="sip:Darwin.Valderas1@imsinnovation.com"/></resource></list>
------=_Part_21762_30367093.1222503061673
Content-Type: application/pidf+xml;charset="UTF-8"
Content-Transfer-Encoding: binary
Content-ID: <sip:Darwin.Valderas1@imsinnovation.com>

<?xml version="1.0" encoding="UTF-8"?>
<presence entity="sip:Darwin.Valderas1@imsinnovation.com"
xmlns="urn:ietf:params:xml:ns:pidf" xmlns:op="urn:oma:xml:prs:pidf:oma-pres"
xmlns:pdm="urn:ietf:params:xml:ns:pidf:data-model">
<tuple id="zA6Dkacz">
```

```
<status>
<basic>open</basic>
</status>
<op:service-description>
<op:service-id>desktop_client</op:service-id>
<op:version>1.0</op:version>
</op:service-description>
<timestamp>2008-09-27T08:11:00.240Z</timestamp>
</tuple>
<pdm:person id="p1">
<pdm:note>86;86;86;00:00:00</pdm:note>
<pdm:timestamp>2008-09-27T08:11:00.240Z</pdm:timestamp>
</pdm:person>
</presence>
------=_Part_21762_30367093.1222503061673--
```

```
   4. Watcher2 -------------------------> PGM
SIP/2.0 200 OK
Record-Route:
<sip:3Zqkv7%0BaGqiyaaaaiOsip%3AOscar.Novo2%40imsinnovation.com@scscf.imsinnovation.
com:5062;maddr=172.23.214.27;lr>
Content-Length: 0
From: <sip:Oscar.Novo2@imsinnovation.com;list=MiPropiaLista_oscar>;tag=fllynqs0-xv6
Cseq: 4 NOTIFY
Contact: <sip:213.115.115.188:5060;fid=server_1>
To: <sip:Oscar.Novo2@imsinnovation.com>;tag=fllyoyam-5
Server: Glassfish_SIP_1.0.0
Via: SIP/2.0/TCP
172.23.214.27:5063;branch=z9hG4bKe9980b6c365131ba1bf4d7de02485e6djaaaaaaiaaaaaau2xv
xyq3Zqkv7svihpeiahkpepa
Via: SIP/2.0/TCP
172.23.214.27:5060;branch=z9hG4bKe79ec709375d1d297c7a3446f1e744c9jaaaaaaiaaaaaaloeg
0ea3Zqkv7cvihpej2w1gp0a
Via: SIP/2.0/TCP 172.23.214.171:22023;branch=z9hG4bK158323unneaaaa
Call-Id: 213.115.115.188_5_7687429797697315274
```

```
   5. PGM -------------------------> Watcher1
NOTIFY sip:213.115.115.188:5060;fid=server_1 SIP/2.0
To: <sip:Darwin.Valderas2@imsinnovation.com>;tag=fllyndae-4
From:
<sip:Darwin.Valderas2@imsinnovation.com;list=MiPropiaLista_darwin>;tag=fllym5sh-9dt
Call-ID: 213.115.115.188_4_4938965627018318151
CSeq: 4 NOTIFY
Max-Forwards: 67
Content-Length: 1404
Via: SIP/2.0/TCP
172.23.214.27:5063;branch=z9hG4bK3a2e55f030c5892da46ccd090b0bd141jaaaaaaiaaaaaamkni
dtq3Zqkv7vgtvd2c2j3ubna
Via: SIP/2.0/TCP
172.23.214.27:5060;branch=z9hG4bK9344085f534fe115db2c654316809a33jaaaaaaiaaaaaahvnx
5na3Zqkv7fgtvd2cwigg11a
Via: SIP/2.0/TCP 172.23.214.171:22021;branch=z9hG4bK121321lm3baaaa
Record-Route:
<sip:3Zqkv7%0BaGqjOaaaaiOsip%3ADarwin.Valderas2%40imsinnovation.com@scscf.imsinnova
tion.com:5062;maddr=172.23.214.27;lr>
Contact: <sip:172.23.214.171:22021;transport=tcp>
Content-Type:
multipart/related;type="application/rlmi+xml";start="<sip:Darwin.Valderas2@imsinnov
ation.com;list=MiPropiaLista_darwin>"; boundary="----
=_Part_18849_21592757.1222503061675"
Require: eventlist
Subscription-State: active;expires=3359
Event: presence

------=_Part_18849_21592757.1222503061675
```

```
Content-Type: application/rlmi+xml;charset="UTF-8"
Content-Transfer-Encoding: binary
Content-ID: <sip:Darwin.Valderas2@imsinnovation.com;list=MiPropiaLista_darwin>

<?xml version="1.0" encoding="UTF-8"?>
<list uri="sip:Darwin.Valderas2@imsinnovation.com;list=MiPropiaLista_darwin"
version="2" fullState="true" xmlns="urn:ietf:params:xml:ns:rlmi"><resource
uri="sip:Darwin.Valderas1@imsinnovation.com"><instance id="1" state="active"
cid="sip:Darwin.Valderas1@imsinnovation.com"/></resource></list>
------=_Part_18849_21592757.1222503061675
Content-Type: application/pidf+xml;charset="UTF-8"
Content-Transfer-Encoding: binary
Content-ID: <sip:Darwin.Valderas1@imsinnovation.com>

<?xml version="1.0" encoding="UTF-8"?>
<presence entity="sip:Darwin.Valderas1@imsinnovation.com"
xmlns="urn:ietf:params:xml:ns:pidf" xmlns:op="urn:oma:xml:prs:pidf:oma-pres"
xmlns:pdm="urn:ietf:params:xml:ns:pidf:data-model">
<tuple id="zA6Dkacz">
<status>
<basic>open</basic>
</status>
<op:service-description>
<op:service-id>desktop_client</op:service-id>
<op:version>1.0</op:version>
</op:service-description>
<timestamp>2008-09-27T08:11:00.240Z</timestamp>
</tuple>
<pdm:person id="p1">
<pdm:note>86;86;86;00:00:00</pdm:note>
<pdm:timestamp>2008-09-27T08:11:00.240Z</pdm:timestamp>
</pdm:person>
</presence>
------=_Part_18849_21592757.1222503061675--


   6. Watcher1 -------------------------> PGM
SIP/2.0 200 OK
Record-Route:
<sip:3Zqkv7%0BaGqjOaaaaiOsip%3ADarwin.Valderas2%40imsinnovation.com@scscf.imsinnova
tion.com:5062;maddr=172.23.214.27;lr>
Content-Length: 0
From:
<sip:Darwin.Valderas2@imsinnovation.com;list=MiPropiaLista_darwin>;tag=fllym5sh-9dt
Cseq: 4 NOTIFY
Contact: <sip:213.115.115.188:5060;fid=server_1>
To: <sip:Darwin.Valderas2@imsinnovation.com>;tag=fllyndae-4
Server: Glassfish_SIP_1.0.0
Via: SIP/2.0/TCP
172.23.214.27:5063;branch=z9hG4bK3a2e55f030c5892da46ccd090b0bd141jaaaaaaiaaaaaamkni
dtq3Zqkv7vgtvd2c2j3ubna
Via: SIP/2.0/TCP
172.23.214.27:5060;branch=z9hG4bK9344085f534fe115db2c654316809a33jaaaaaaiaaaaaahvnx
5na3Zqkv7fgtvd2cwigg11a
Via: SIP/2.0/TCP 172.23.214.171:22021;branch=z9hG4bK121321lm3baaaa
Call-Id: 213.115.115.188_4_4938965627018318151
```

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