PAMAP

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System Specification

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Table of Contents

Table of Figures

EXECUTIVE SUMMARY

PAMAP project aims at developing a system that enables the accurate monitoring of the physical activities of aging people. This deliverable provides the reader with information related to the first iteration of the PAMAP System Specifications.

Chapter 1 summarizes the PAMAP System concept and architecture, which are presented in detail in deliverable *D.2.2 Architecture Design*.

In Chapter 2 we present in detail the specifications of the hardware components that constitute the PAMAP System architecture: the subject's Personal Area Network, the subject's home stationary infrastructure and the backbone infrastructure.

Finally, in Chapter 3 we particularize the applications that provide end users with the necessary functionality in accordance with *D.2.1 User Requirements Report*.

1. PAMAP SYSTEM CONCEPT & ARCHITECTURE

The objective of this project is to develop the **PAMAP system**, an unobtrusive and fully mobile system that enables the accurate monitoring of the physical activities of aging people. This system will be based on a Patient Personal Area Network, consisting of a set of tiny **Sensor Units**, a **Control Unit** and corresponding **software** for professional and private use. It will rely on a sound **biomechanical model** of the human body, and it will accurately measure the motion and efforts of the upper and lower limbs, thanks to appropriate parameterization. Of significant importance are the PAMAP **User Interfaces** that will enable reviewing and sharing of the recorded activity measurements among physicians and monitored persons, and also a **videoconference application** that will enable their communication. The physical activity information will be stored in an **Electronic Health Record (EHR)**, **the content of which will be presented in a web and TV interface**.

Among the targeted features of the PAMAP system, the following are the most essential:

- **Scalability** and **extendibility** of the Patient Personal Area Network (PAN): for the monitoring of the motion and efforts of the upper and lower limbs a minimum set of sensors will be used; however the PAMAP System architecture will enable the future integration of additional sensors, and thus an extended set of vital signs (e.g. temperature, EMG) to be taken into account for the monitoring. The Control Unit (CU) will automatically adapt its computation process to the available data.
- **Diverse User Interfaces**: TV is a device that people are familiar with. It is therefore essential to exploit this device as much as possible as a means for the monitored person to interact with the PAMAP System and make use of its potency. A simple TV User Interface, easily activated with the well-known standard remote control will provide information about the activity of the monitored person. It will also enable her to get access to educational material that is selected by the physician. The navigation will be based upon the use of the well-known standard remote control. A web based User Interface will enable the physicians to monitor the physical activity of their patients and view/edit their Electronic Health Record.

A rough approach of the PAMAP concept is depicted in the following Figure 1, where three major physical areas for the system deployment are identified:

1. The environment of living of the monitored individual;
2. The working environment of the rehabilitation professional; and
3. The PAMAP Service provision center.

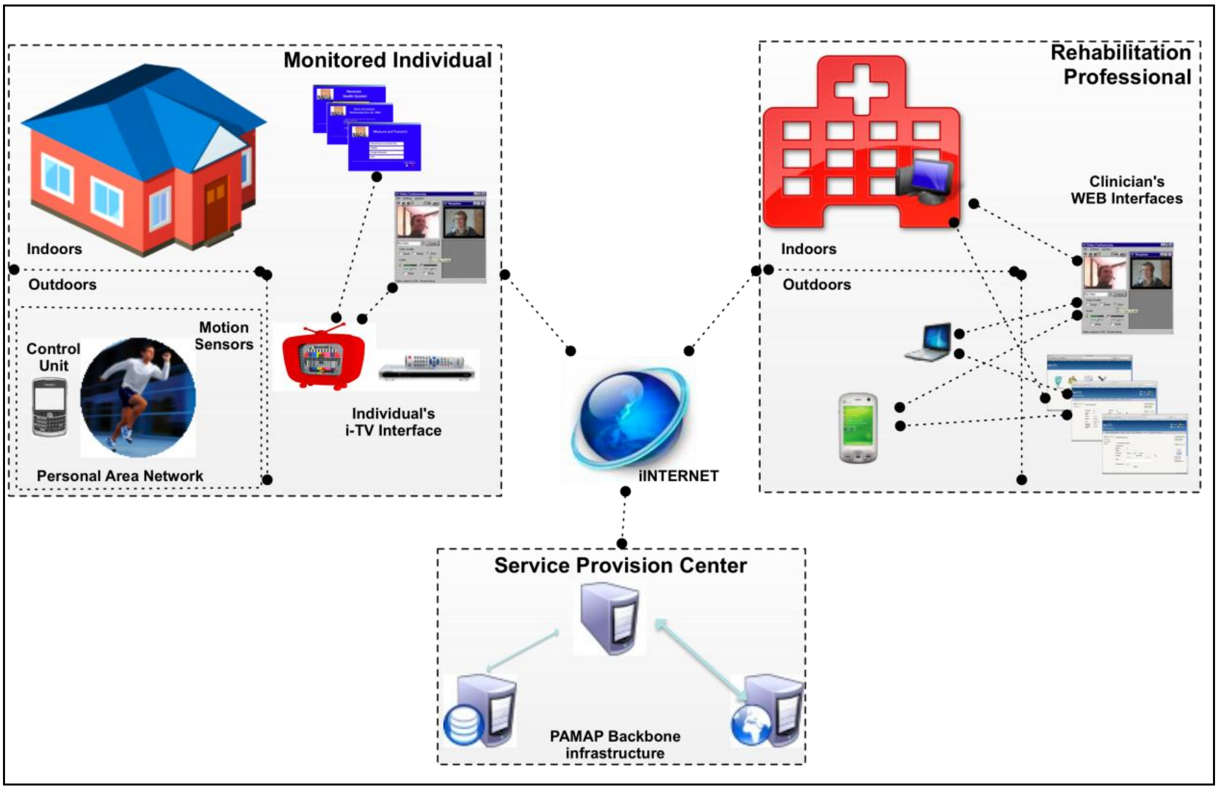


Figure 1: Basic Units in PAMAP concept

The major system components involved into the collection, processing, storage and visualization of activity data are shown in Figure 2:

- The **Personal Area Network** consists of the sensor network and the **Control Unit** worn by the monitored individual in order to collect data to deduce different types of physical activity. The PAN hardware is detailed in Section 2.1. The software is specified in Section 3.7.
- The preprocessed activity data in the Control Unit (particularly the inertial motion data) requires further processing before sending it to the PAMAP server, where it is stored in the database. This advanced processing requires considerable processing power and will therefore run on a PC, i.e. the local processing unit in the individual's home environment. The application to do this is the **Measurements Advanced Processing Application (MAPA)**, which is further specified in Section 3.3. This application also communicates with the Control Unit on the one hand and the **Personal Health Record** application on the other hand.
- The **Measurements Visualization Application** provides proper visualizations for all types of measurements extracted by the Measurements (Advanced) Processing Application. This application is further specified in Section 3.4. If feasible, this application will be a web application.

Both, the Measurements Advanced Processing and the Measurements Visualization Application interact with the Personal Health Record application that is responsible for communicating with the PAMAP server and web applications. There is no direct link to either the server or the web applications. This assures a minimal interface between the software components provided by the different partners.

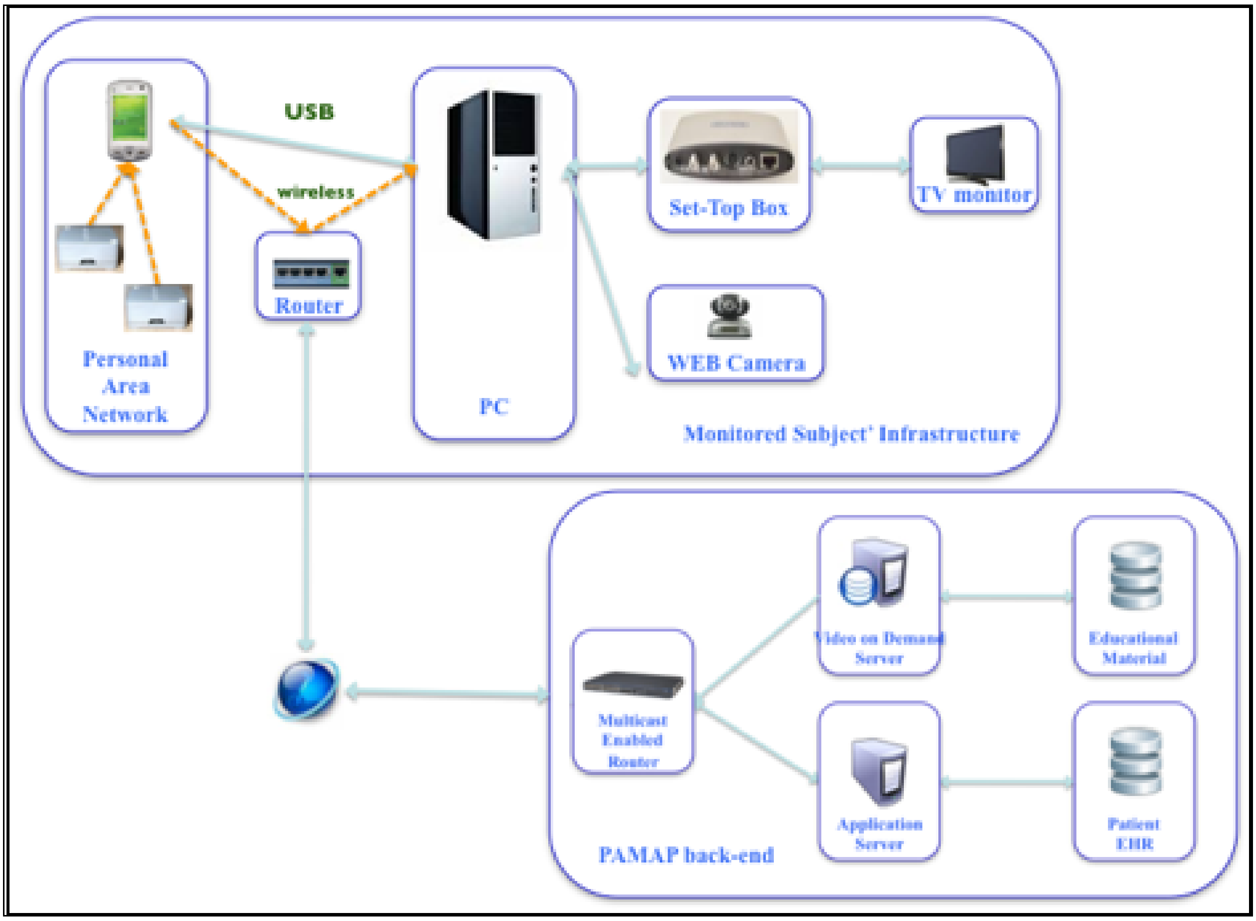


Figure 2: PAMAP Measurement Component Interaction Diagram

2.1. Personal Area Network infrastructure

The Personal Area Network as outlined in Figure 3 consists of the Control Unit (with support for different I/O devices) and the different sensors used for measuring physical activity. For the first prototype, tiny inertial motion sensors, a heart rate monitor and GPS are used. The different components are specified below.

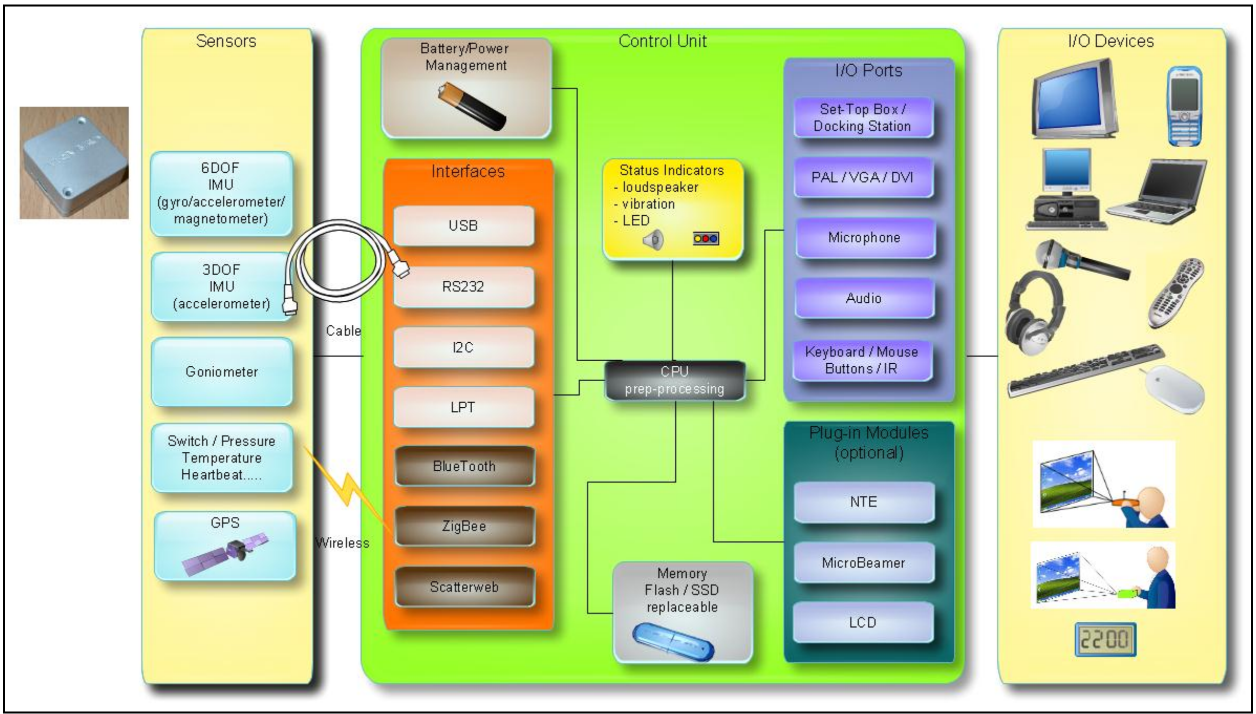


Figure 3: PAMAP Sensors Network

2.1.1. Control Unit

The control unit is planned as wearable belt worn unit. It will contain the interfaces connecting to the wired and wireless motion sensors as well as the heart rate monitor and GPS. It will also allow simple interaction with the user and provide alarm functions. Furthermore, the device will act as a data logger.

For building the control unit, off-the-shelve components, such as embedded processing hardware (mainboard, LCD touch panels, buttons and battery packs), will be integrated into a self-designed case. The individual components are specified in Table 1. The Sony Vaio P-series, suggested by DFKI, served as performance reference and will be used as fall back solution in case of technical problems or delays. A detailed description of the different components and design process will be given in deliverable D3.2 Sensor Platform Report and Documentation, which is due in Month 14.

Dimensions	165mm x 115mm x 35mm (preliminary)
Weight	550g (preliminary)
CPU	Intel Atom™ Z530
RAM	1GB
HDD	64 GB, Read up to 110 MB/s

Memory extension	microSD
Network	Gigabit Ethernet, RJ45
WiFi	802.11n (150Mbps)
USB	2x USB 2.0, connector A (free for keyboard, mouse + accessories)
LCD (touch) screen	3.5", 640x480, resistive touch
GPS	integrated
Sound/Audio	integrated loudspeaker
Operating System	Microsoft Windows (XP) or Linux
Heart Rate Monitor	(external connected via BlueTooth)
Battery	Li-Ion 28Wh, replaceable, rechargeable
Operating time	5 hours (preliminary)

Table 1: Indicatice Control Unit specifications

2.1.2. Sensors Network

2.1.2.1. Wired Motion Sensors

The development of the wired motion sensors was done in an iterative process. Table 2 compares the specifications of the three prototypes of the wired motion sensor "Colibri".

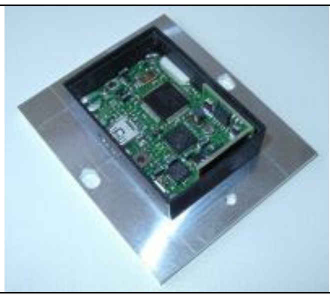
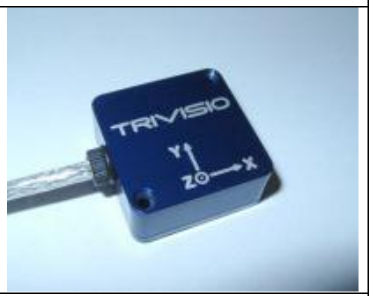
	1st Generation	2nd Generation	3rd Generation
			
Accelerometer (3 axis)	±16g10bit	±16g13-bit	±16g13-bit
Gyroscope (3 axis)	±300°/s10-bit	±300°/s10-bit	±1500°/s10-bit
Magnetic Sensor (3 axis)	±1100µT0.0263µT (37Hz) to 3.3681µT (4700Hz)	±1100µT0.0263µT (37Hz) to 3.3681µT (4700Hz)	±1100µT0.0263µT (37Hz) to 3.3681µT (4700Hz)
Temp-Sensor	/	/	±0.5°C0°C to +70°C
Orientation accuracy		Pitch/roll: 0.5 ° Yaw: 1 °	Pitch/roll: 0.5 ° Yaw: 1 °
Frequency	100Hz	100Hz	100Hz
Power consumption			0.2W
Dimensions	50mm x 34mm x 20mm	30mm x 30mm x 14mm	30mm x 30mm x 13mm
Weight		18g	22g
Comment	First test platform	USB cable detachable	USB cable fix, water resistant

Table 2: Indicative "Colibri" specifications

The third generation Colibri sensor has been used by DFKI for the early demonstrator. Here, the IMUs have been synchronized by timestamp in software. The same IMUs will also be used for the first integrated PAMAP prototype, however, with the option of a hardware synchronization as shown in Figure 4.

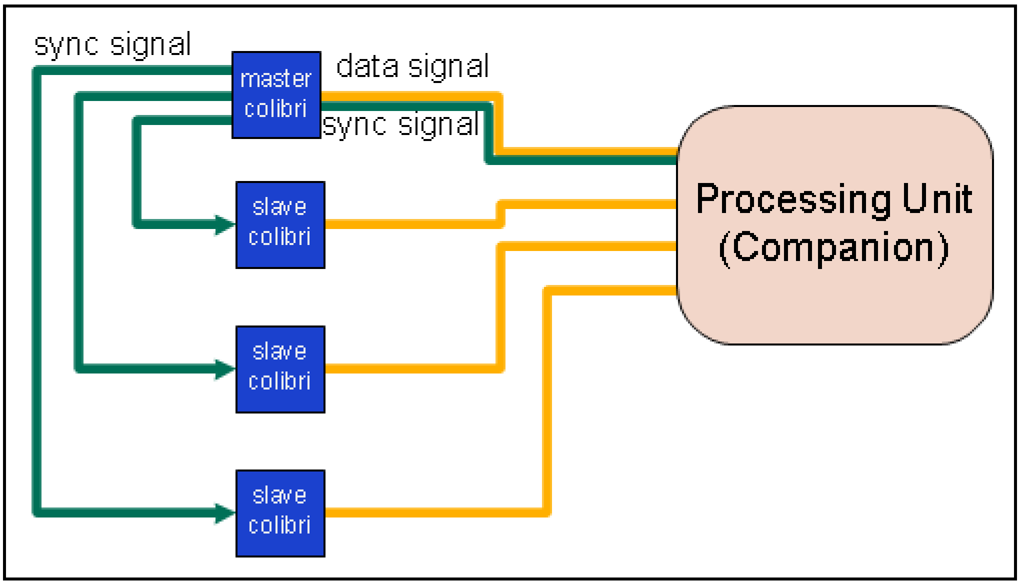


Figure 4: Wired IMUs with wired sync possibility.

2.1.2.2. *Wireless Motion Sensors*

The specification of the wireless IMUs is tentative at the moment. A maximum number of 15 trackers is planned to enable full-body motion tracking. The synchronization between the sensors will be wireless as shown in Figure 5. Currently, a first breadboard setup is assembled at Trivisio for tests. Dimensions, weight, range and operation time of the wireless sensors will be estimated at a later stage of development.

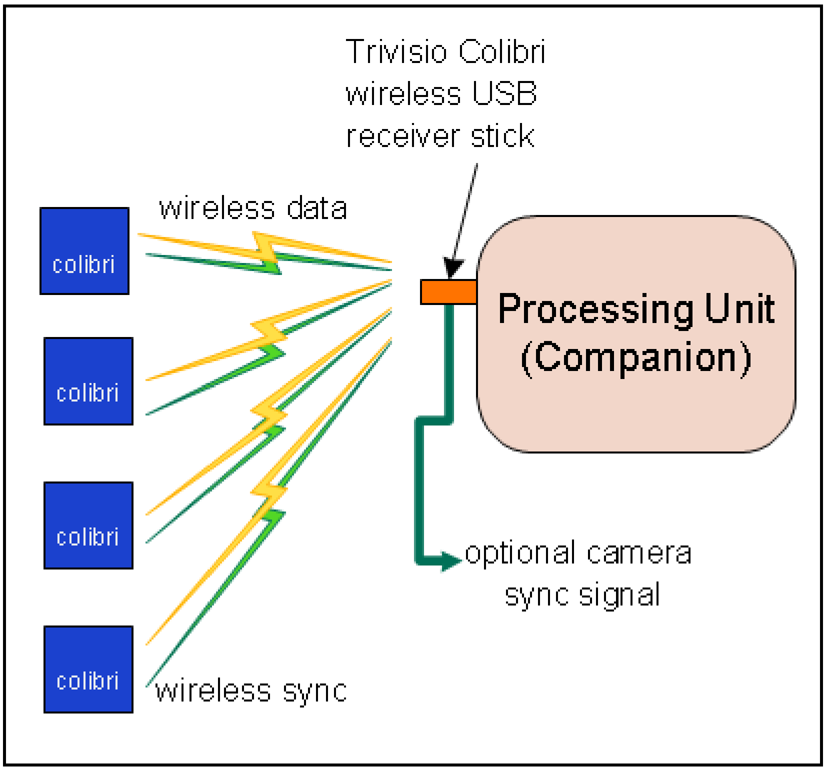


Figure 5: Wireless IMU sensors sync

2.1.2.3. *Heart Rate Monitor*

There are several commercial wireless heart rate monitors available on the market, all connected via Bluetooth. Figure 6 through Figure 8 show a preselected set of devices that are considered for usage in PAMAP. Table 3 compares their specifications. A final decision will be taken during the development process of the Contol Unit.

	Zephyr™ HxM	mobimotion Spurty	Alive Heart Monitor
Type	Heart rate	Heart rate variability	Heart rate +ECG
Resolution	1 bpm		
Other	3-axis accelerometer	GPS optional	3-axis accelerometer
Operation time	26 h	14 h	
Link	www.zephyr-technology.com	www.mobimotion.com	www.alivetec.com
Weight		80g	
Price	100 EUR	125 EUR	

Table 3: Indicative Heart Rate Monitor specifications

Figure 6: Zephyr™ Heart Rate Chest Strap

Figure 7: mobimotion Spurty Chest Strap

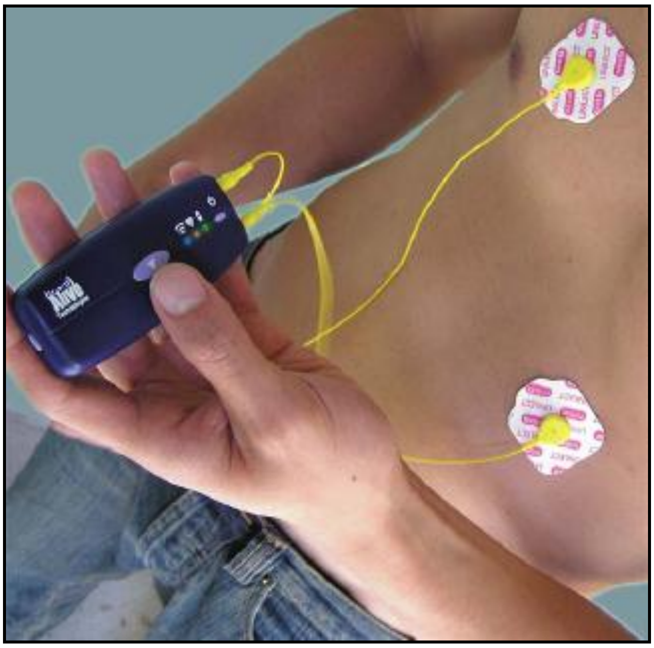


Figure 8: Alive Heart Monitor

2.2. *Subject's stationary infrastructure*

The stationary infrastructure in the subject's home includes the already existing TV monitor, a PC where applications like the measurements' advanced processing or Personal Health Record will be running (cf. Section 3), a set-top-box for streaming video material, a web camera to be used in videoconference, and a router.

Detailing the above, the PC will have an Ubuntu 10.04 OS; the STB will be an Amino A130[1] supporting MPEG4 streaming, and the router will be an off-the shelf component supporting wireless connectivity,

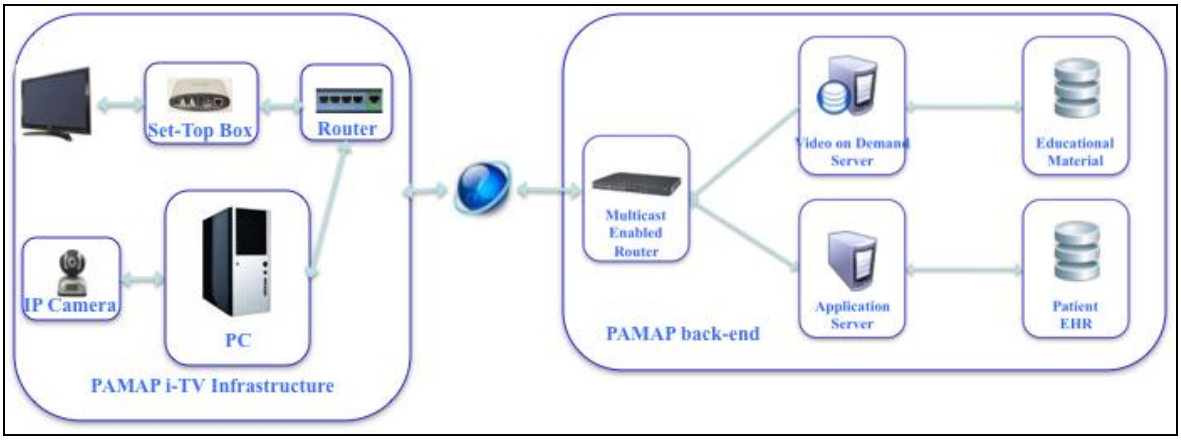


Figure 9: PAMAP i-TV Infrastructure

2.3. *Backbone infrastructure*

The major building blocks of the PAMAP back-end infrastructure are the application server, the video-on-demand server and the repositories (or the electronic health record of the monitored individuals and the educational material (cf. Figure 10).

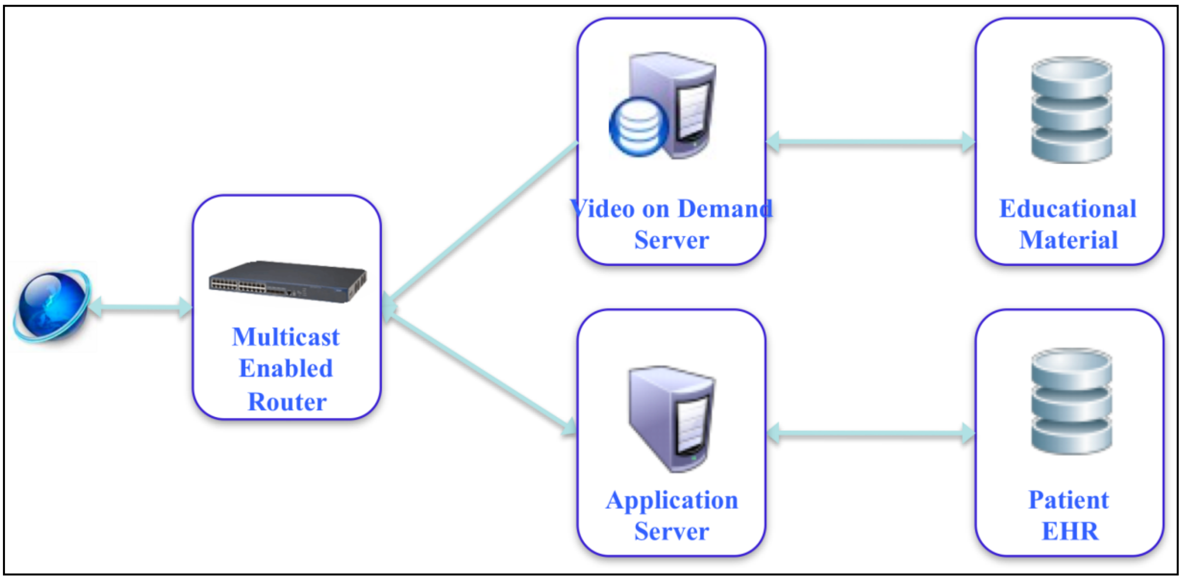


Figure 10: PAMAP Back-End Infrastructure Architecture

- **Application Server**; the application server to be used in PAMAP is GlashFish v2. GlassFish is an application server project by Sun Microsystems for the Java Enterprise Edition (Java EE) platform. The application server is based on the commercial version of the Sun Application Server 9.x. An alternative application server for intLife is the JBoss

[1] http://www.aminocom.com/index.asp?PageID=2145848492

Application Server (or JBoss AS), which is a free software/open source Java EE-based application server. It supports similar features with the GlassFish application server such as Clustering, Load balancing, Enterprise Java Beans version 3 support, J2EE-Web Services like JAX-RPC (Java API for XML for Remote Procedure Call), JSP/Servlets etc.

- **Video-on-Demand Server;** this server will be streaming content through the set–top-box of the subject. The server to be used in PAMAP is VLC open source multimedia framework, player and server. VLC server can stream in unicast or multicast the content of a video or a web source in MPEG-2, MPEG-4, H.264, DivX, MPEG-1, mp3, ogg formats. VLC server will be run in parallel with the application server. The application server will send the appropriate commands, in order to start streaming specific video sources. The management of the content to be streamed and the related with it persons, will be made in specific application modules, using dedicated for this reason, database schema.
- **Database**; intLIFE EHR database is an Oracle 10g R2 database and will be deployed on a Windows Server 2003. Oracle Database 10g R2 offers Transparent Database Encryption, which makes easier the encryption of sensitive personal information. Transparent Data Encryption eliminates the need to embed encryption routines in existing applications and dramatically lowers the cost and complexity of encryption. With a few simple commands, sensitive application data can be encrypted.

3.1. PAMAP System Administration

A PAMAP Administrator Web Interface enables the PAMAP System administrator to have access to a set of administrative tools. Specifically, it enables the administrator to perform the following processes:

- ***Login***; the login process authenticates the administrator. If the authentication is successful, the necessary user interface functionalities are activated and access to the PAMAP system database is granted. If the authentication fails, access to the PAMAP administrative environment is denied and the user is not able to use the administrative tools.
- ***PAMAP Users Administration***; this process activates the necessary web user interface controls that enable the administrator to manage the PAMAP users. The administrator is able to add (register), update and deactivate or reactivate PAMAP System users.
- ***PAMAP Equipment Administration;*** This process activates the necessary web interface controls that enable the administrator to manage PAMAP equipment, i.e. it is a device manager that associates medical devices, STBs and other terminal equipment to physical or logical entities (patients/healthcare professionals or network nodes, respectively).

3.2. Electronic Health Record application

The PAMAP EHR application enables clinicians and paramedical personnel to edit/review health related information of the monitored subjects. More specifically, the following information fields will be available for editing:

- ***General Health Profile of the Monitored Subject***; family health history, habits & social history (e.g. smoking, alcohol consumption), allergies, vaccinations
- ***Visits;*** organ system findings, manual entry of symptoms & measurements
- ***Medical Tests;*** test orders, manual entry of test results, test results overview and graphic representation
- ***Diagnosis Management;*** insert new diagnoses, using the ICD-10 nomenclature, search for past diagnoses
- ***Treatment Management;*** surgeries, medication

In addition to the above, an ***Overview*** tab will provide the user with a quick and printable outline of selected information (e.g. diagnoses, medications, surgeries, specific measurements, related to the subject).

3.3. Measurements Advanced Processing application

The Measurements Advanced Processing Application (MAPA) provides advanced processing functionalities for the data measured by means of the Personal Area Network. Advanced processing algorithms are incorporated in the MAPA (particularly for the inertial motion measurements) in order to extract relevant and meaningful activity data. Advanced statistical filtering is required especially for the online functional rehabilitation support, where the body pose is estimated and compared to a reference movement. Moreover, improved activity classification and localization, as well as advanced MET estimation, etc. are part of the heavy-duty filtering. The results of this application are the activity measurements that are stored on the PAMAP server and are visualized by means of the Measurements Visualization Application.

From a communications point of view we discriminate the following links:

Control Unit – PC communication link; In order for the MAPA to retrieve data from the CU, the subject attaches the latter to the USB port or network interface of the PC. The timestamped activity measurements are sent to the PC running the MAPA. The data will be uploaded in a batch (e.g. file-based), using a custom XML format with specific structures for the different types of vital information that are extracted.

PC client - PAMAP Server communication link; the uplink from the PC client to the PAMAP server is used to push the (pre)processed information to the EHR of the subject. The downlink is used to receive subject-related settings that are required for data (pre)processing, in the Control Unit, or advanced processing in the MAPA (e.g. min/max allowed heart rate, weight/age of the patient, etc.). Data is exchanged in batches using a custom XML format with specific structures for the different types of extracted vital information /subject-related settings.

Client-server communication will be performed via **https** and **Web Services**. Web services allow clients and servers to communicate using XML messages that follow the SOAP standard. The Web Services Security specification (WS-Security) provides a set of mechanisms to secure SOAP message exchanges. More specifically, WS-Security describes enhancements to the existing SOAP messaging to provide quality of protection through the application of message integrity, message confidentiality, and single message authentication to SOAP messages. These mechanisms can be combined to accommodate building a wide variety of security models using a variety of cryptographic technologies.

3.4. Measurements Visualization application

The Measurements Visualization Application provides the functionality to visualize the measurements generated by the Measurements Advanced Processing application (cf. Section 3.4) and the Measurements Preprocessing application (cf. Section 3.7). The visualization might be graphs showing the heart rate or a virtual avatar animated with the body poses of the patient during the rehabilitation exercises. The Measurements Visualization application receives the data to be visualized either directly from the MAPA (cf. Section 3.3), or from the PAMAP server, whereat the data to be visualized might be either real-time (i.e. currently streamed from the MAPA) or offline (i.e., a database record).

3.5. Personal Health Record application

The *Personal Health Record* application will provide an i-TV interface to the intLIFE EHR. Automatic login, will reveal only those EHR tabs that are relevant to the user (e.g. exclude visits, etc). Moreover, in addition to the typical EHR functionality described in Section 3.2 the PHR application supports personalized messages, personal reminders, personal rehabilitation plans and questionnaires.

3.5.1. *Personalized Messages*

The number of messages available for the logged user determines whether the screen following the login would be the messages screen. If there are available messages, the application software requests and receives the list of messages, and automatically switches to the messages screen. The list of messages containing the following information:

- User ID (to verify that the application has received the correct file)
- Message (multiple occurrences possible)
  - Date
  - Message Text

All messages will be erased from the PC memory when the user selects to log out. This means that when the user will log in again lately, he/she will not be able to see the previous list of messages. Hence only new (or zero) messages are available every time the user logs in. This is why the user is forced, prior to logging out to check his list of unread messages.

If there are no messages available, then the application software automatically switches to the main menu screen.

3.5.2. *Personal Reminders*

Personal Reminders is a single xml file, containing text that appears to the user when she logs out in order to remind him to perform several tasks while he is away from the TV screen. The application software is responsible for parsing this file and appropriately generating the information that is displayed when the viewer logs out (in the log out screen). Each reminder file should at least contain the following information:

- User ID
- Task (multiple occurrences)
- Description

3.5.3. *Personal Rehabilitation Plans*

We discriminate between the *Overall Rehabilitation Plan*, i.e. the list of activities that are prescribed by the Medical Doctor/Attending Nurse during the set up of the rehabilitation plan of a patient; and, the *Daily Rehabilitation Plan*, i.e. the list of activities that the patient should carry out each day, as derived from the Rehabilitation Plan.

Overall Rehabilitation Plan is a single xml file, containing information on what the user has to do during the rehabilitation period. The application software is responsible for parsing this file and appropriately generating the information that is required when the viewer switches to the Overall Rehabilitation Plan screen.

Each Overall Rehabilitation Plan should at least contain the following information:

- User ID
- Measurements (only one occurrence if at least one measurement to perform is required – otherwise omit)
  - Title
  - Measurement to perform (more than one possible)

    - Week day(s) (Mon, Tue, etc.)
    - Action (more than one possible)
      - Description
  - Educational Sessions (only one occurrence if at least one educational session to watch is available-otherwise omit)
    - Title
    - Educational Session to watch (more than one possible)
      - Description
      - Week day(s) (Mon, Tue, etc.) and time (more than one possible)
  - Hospital Visits (only one occurrence if at least one hospital visit to watch is required – otherwise omit)
    - Title
    - Hospital Visit to perform (more than one possible)
      - Date
      - Purpose of visit (more than one possible)
        - Description
  - Laboratory Tests (only one occurrence if at least one lab test is required – otherwise omit)
    - Title
    - Lab test to perform (more than one possible)
    - Date
    - Description of test (more than one possible)
      - Description

Daily Rehabilitation Plan is a single xml file, containing information on what the user has to do during the current day. The application software is responsible for parsing this file and appropriately generating the information that is required when the viewer switches to the Daily Rehabilitation Plan screen.

Each Daily Rehabilitation Plan should at least contain the following information:

- User ID
- Day (Monday, Tuesday, etc.)
- Date
- Time Tags (multiple occurrences possible)
  - Action description (zero, one or more than one possible for each action tag, describe everything for this particular action in a single line)

3.5.4. Questionnaires

Once the user answers a questionnaire, her answers are sent to the server:

- User ID
  - Answer

- Question ID
- Answer (1 to 5, for the Visual Analog Scale).

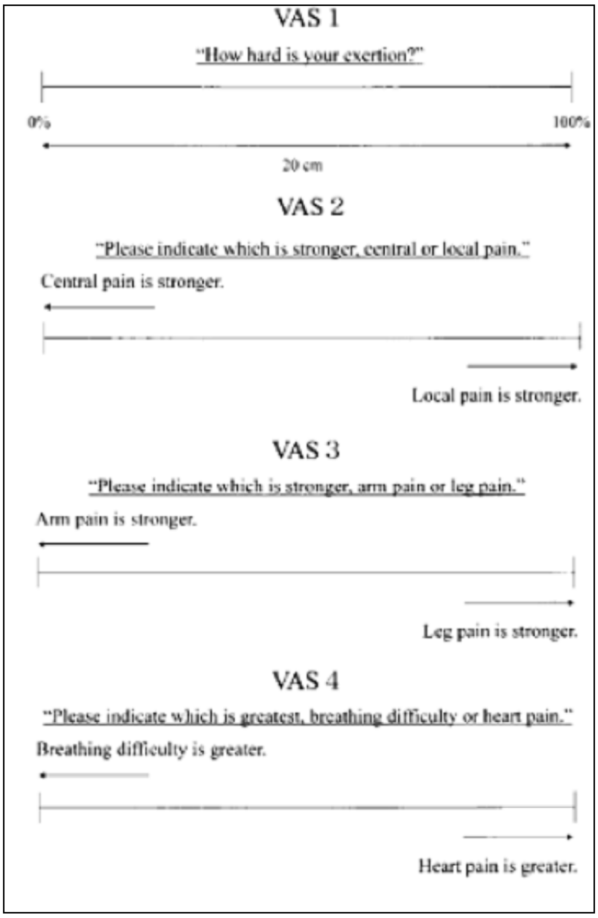


Figure 11: The Visual Analog Scale, reprinted from the Japan Society of Physiological Anthropology (Ueda et al. 2006).

3.5.5. Personal Trainer (Educational Material)

Once the user switches to the *Personal Trainer* screen, the application downloads the Personal Trainer xml file. Educational Session is a single xml file, containing information on the content of a scheduled educational session. The application software is responsible for parsing this file and appropriately generating the information that is displayed to the user. After filtering out from the total of the information, the application determines which are the appropriate, for the particular patient multimedia, text or image files to be downloaded and dynamically creates the graphics user interface of the Personal Trainer screen. Each Personal Trainer session file should at least contain the following information:

- Personal Trainer (only one possible – leave empty if there is no educational session for all patient groups)
  - Personal Trainer List (one for each patient group – omit or leave empty if no session occurs for a group)
    - Video Menu (zero, one or multiple possible)
      - Video Menu Title (only one)
      - Video (at least one or multiple)
        - Video Title

    - Filepath
- Image Menu (zero, one or multiple possible)
  - Image Menu Title (only one)
  - Image (at least one or multiple)
    - Image Title
    - Filepath
- Text Menu (zero, one or multiple possible)
  - Text Menu Title (only one)
  - Text (at least one or multiple)
    - Text Title
    - Filepath

If the user switches to the Personal Trainer screen and there is no session available, then an onscreen message informs the user that there is no personal training session available at the moment.

3.6. Videoconference application

The PAMAP videoconference application will be a web-based application that allows the communication between the subject and the clinician. This application will be sending commands to the VLC video server, in order to start streaming video sources. The relation between the subject, the clinician and the video source, will be managed using an appropriate database schema.

The videoconference application consists of the module offering the database manipulation, the GUI (a set of web pages) offering the appropriate functionality and the module offering the integration with the video server (Figure 12).

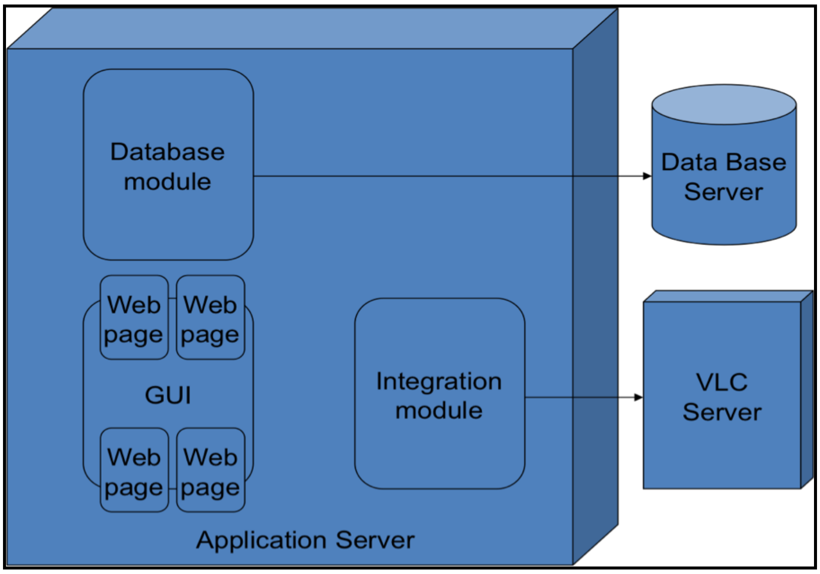


Figure 12: Videoconference application architecture

3.7. Control Unit applications

The Control Unit is worn by the monitored subject in order to collect and pre-process the data streams received from the Personal Area Network. For communicating with the PC, the CU is attached to either the USB port or a network interface of the PC.

The Control Unit receives patient-related settings that are required for data pre-processing (e.g. min/max allowed heart rate, weight/age of the patient, etc.).

Moreover, a Measurements Preprocessing Application will be running in the Control Unit; the purpose of it will be to synchronize the different data streams (inertial motion trackers, GPS, heart rate monitor) of the sensor network and to do the light-weight processing that is required for early warnings and real-time feedback.