Monitoring, Tracking, and Recording Pancreas-Related Health Issues in Real Time

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Abstract. The monitoring of pancreas-related health issues in real-time and outside the medical room is a challenge in the wide e-health domain. This paper introduces WHEAMO, a novel e-health platform which employs medical implants (biosensors), which function as antennas, planted in the pancreas. WHEAMO uses wireless in-body propagation to track, monitor, and record critical parameters, such as glucose. The signal reaches the skin and then it is propagated in an indoor environment (e.g., medical room) over to a terminal equipped with adaptive, user-configurable, and intelligent mechanisms which provide personalized recommendations to varying WHEAMO users (e.g., medical personnel, health care workers, patients). The personalized nature of the provided recommendations is based on patients unique characteristics via a sophisticated knowledge-base. The fundamentals of in-body and on-body wireless propagation and channel characterization have been studied in a series of published works. Researchers have tested both electric-field (dipole) and magnetic-field (patch, loop) antennas. Another important aspect concerns the frequency band in which the signal propagation will occur. Among the frequencies that have gathered scientific and academic interest are the Medical Implant Communication Service (MICS) band at 402-405 MHz, the 900 MHz channel and the industrial, scientific and medical (ISM) radio band at 2.45 GHz.

1. Introduction
Recent advances in wireless communication and ICT domains provide the fertile ground for a growth of new applications, providing innovative solutions in varying fields such as energy-saving, green development, and e-health. One of the most fast-growing domains is the e-health, where researchers of interdisciplinary fields attempt to provide solutions to long-lasting and emerged health-related issues. A challenging part of the recent research endeavours in e-health domain is the diagnosis of pancreas-related health issues, mainly because of the nature of the human pancreas. In this paper, we introduce WHEAMO, a novel e-health platform which employs medical implants to monitor, track, and record pancreas-related health issues in real time.

2. WHEAMO platform
WHEAMO platform is an innovative medical healthcare platform that could provide an early and in real-time diagnosis for the pancreas, whose diseases cause a large number of casualties each year. WHEAMO is based on a knowledge-based model which retrieves, stores, and

distributes the information provided by the in-body medical implant through the pancreas-to-skin propagation channel and a complementary skin-to-terminal propagation scenario, aiming to create a customizable and personalized end-user profile, which could be monitored by medical personnel and assistant health workers. WHEAMO platform was presented in the *Falling Walls Greek Lab 2016*, held in Thessaloniki (Greece) in June 2016, wining the first prize and entering the *Finals of the Falling Walls Lab* held in Berlin (Germany) in November 2016. In the meantime, our research focused on the channel modelling and path loss characterization for in-body propagation, and small-scale fading for pancreas-to-skin in-body propagation. The results of these two studies are briefly presented next.

2.1. Channel modelling and path loss characterization for in-body propagation
In Chrysikos et al. [1], we established a set of empirical data concerning an in-body channel with the transmitter planted as deep in the human body as the pancreas. Two human phantoms were implemented (one for a male and one for a female adult). Gain patterns provided an azimuth-angle dependent pattern for the far-field, whereas the near-field presents phenomena require separate and more detailed investigation due to reactive fields. A half-wave dipole was employed, allowing for sufficient signal propagation up to the skin surface. SAR values were recorded and their maximum instance was found to be well below the limits [4, 5]. The study results revealed that the Medical Implant Communication Service (MICS) band is more suitable for applications concerning the pancreas, which, in the case of glucose monitoring, are of critical importance for e-health and telemetry in medical science and practice. Gender-related differences were observed, but, in all cases, the logarithmic values of local mean power followed the Gaussian distribution, validating the log-normal large-scale fading model.

*2.2. Small-scale fading for pancreas-to-skin in-body propagation*
Our second study [2] featured the characterization of small scale fluctuations of signal strength (electric field) and power density due to multipath fading for the pancreas-to-skin in-body channel, for the 402.5 MHz and 2.45 GHz bands. For the MICS band at 402.5 MHz, the normal distribution, known also in [3] to describe the small-scale fades for in-body scenarios, was confirmed for the specific channel as well, whose depth and length provides a unique scenario for propagation and attenuation. The received power density instances follow the exponential distribution. The 2.45 GHz (ISM) band provides more versatility for the electric field strength variations. The normal distribution, the logistic and the extreme value distributions are employed to describe the fade instances for the male phantom, whereas for the female phantom scenario the exponential distribution is also employed. For the power density fluctuations, the exponential distributions remain the best fitting tool for the small-scale fades.

3. System Architecture
Following common-practice [6], the WHEAMO information system has been built using an open-layered architecture. The platform consists of five horizontal layers and one vertical layer (Figure 1). Each horizontal layer provides functionality to the higher horizontal layers. The vertical layer provides mechanisms to the horizontal layers to interact with each other.

3.1. Horizontal layers
3.1.1. Data Sources and harmonization layer The data sources provide information which is required from the platform. However, the data may be represented in varying formats. A wrapper class is used by each data provider to connect to the platform. Using this class, the data provider describes the data, the manipulation functions, and the data-management procedures. Meta-data are also included, which provide information about the security of the transferred data.

Figure 1. WHEAMO platform architecture
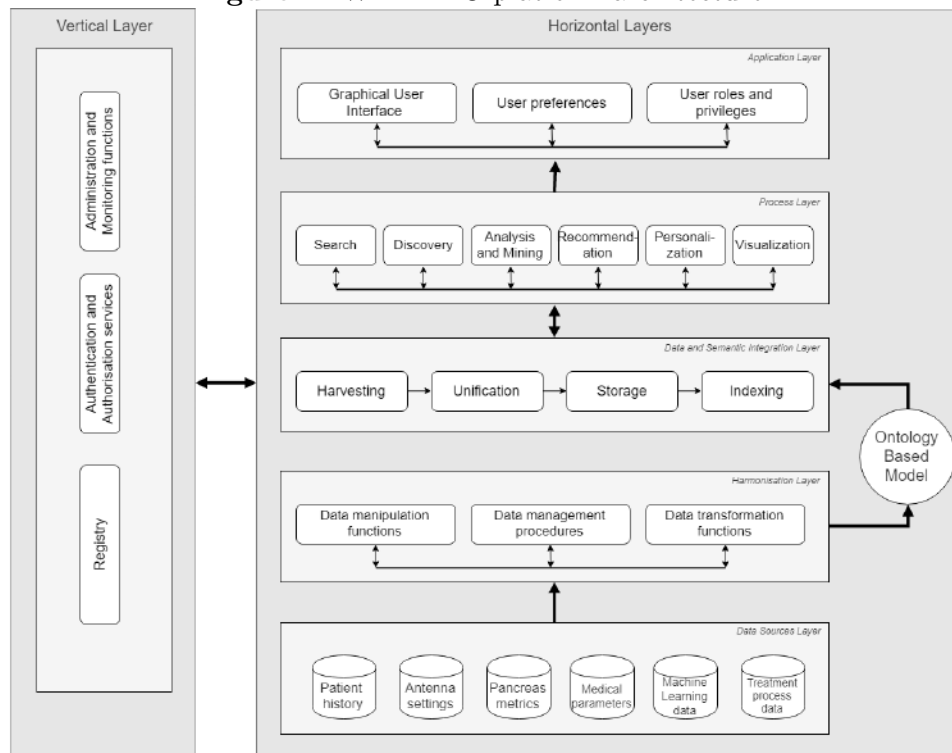
3.1.2. Data and semantic integration layer This layer includes the functionalities needed for the unification of the information which has been collected from the data providers and the creation of a rich and effective data storage which supports a number of functions:

- Harvesting: The harvesting process collects data from registered data providers periodically. The collected data is annotated with its source, and the date and time when it was collected.

- Unification: The unification process handles streams of data and transforms them into suitable formats, aiming to form an integrated and unified database.

- Storage: The storage process creates a local and permanent copy of the collected data. The stored copy is transformed in such a way to match the ontology model of the platform.

- Indexing: The indexing process creates special structures to support clustering and drilling functions.

3.1.3. Ontology-based data model The data is stored in an ontology-based schema, which enables the integration of the semantics and the boundaries of the semantics, and ensures the integrity and the coherence of the data. Schema understandability is a crucial point for the end-users, so they can navigate through the platform, drill-down, and set ad-hoc queries.

3.1.4. Process layer   Through this layer, the end-users can search and discover information; the retrieved information is analysed through mining techniques; personalized recommendations are made to the users; the information is visualized for improved perception.

- Search: This sub-layer allows the end-users to search and retrieve information. They use customized search engines to fetch meta-data which is stored in the data layer. Sophisticated queries with semantic criteria are used.

- Discovery: This sub-layer allows the end-users to discover information relevant to their search queries. The users are able to customize their queries which enables them to search and discover specific meta-data.

- Analysis and Mining: Through this sub-layer, the end-users analyse the provided data and search for varying patterns of interest.

- Recommendation and Personalization: This sub-layer provides the adaptive characteristics of the platform, and ensures that the end-users receive personalized recommendations based on their unique characteristics, needs and preferences.

- Visualization: This sub-layer provide tools which enable the end-users to monitor, track, and record pancreas-related health issues and their progress in real time.

3.1.5. Application layer   This layer provides the application which enables users to access the platform (e.g., medical staff, patients). Each end-user would need to create an account, and view and handle data based on his/her privileges and role.

3.2. Vertical layer
The vertical layer provides the following services:

- Administration and Monitoring: This service allows the management of the platform by users with appropriate privileges and roles (e.g., administrators and moderators). The actions performed and the resources used are monitored and managed through this service.

- Authentication and Authorization: This service ensures that only members of the system have access to specific sections of the platform, depending on their privileges and role.

- Registry: This service records the available resources to the system, including the data providers. More resources can be used on demand for demanding tasks, such as data-mining.

4. Conclusion

In this paper, we introduced WHEAMO, an innovative e-health platform aiming to monitor, track, and record pancreas-related critical parameters, in order to help medical staff diagnose pancreatic disorders on time. WHEAMO is based on a set of medical implants (biosensors) planted in the pancreas, and it supports an adaptive knowledge-based interactive system providing real-time personalized recommendations on patients and medical staff. In this paper, we outlined the system architecture. Our future step is to investigate further tools in order to describe the large-scale fading phenomena and the path loss contributed by distance-dependent attenuation and by specific losses attributed to specific organs along the pancreas-to-skin route.

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