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# Mobile-Based Health Care System Using Wireless Sensor Network

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***Abstract*** — The aim of this work is to investigate main techniques and technologies enabling user's mobility in wearable health monitoring systems. For this, design requirements for key enabling mechanisms are pointed out, and a number of conceptual and technological recommendations are presented. The whole is schematized and presented into the form of a design framework covering design layers and taking in consideration patient context constraints. This work aspires to bring a further contribution for the conception and possibly the evaluation of health monitoring systems with full support of mobility offering freedom to users while enhancing their life quality.

***Keywords — Health monitoring, wearable devices, wireless body area network (WBAN), e-Health, m-health, ageing, mobility.***

## I. Introduction

Continuous health monitoring especially for elderly and impotent patients becomes more and more necessay. The ageing of the world population added to the increase of health costs have been the principal motivations for the design of such monitoring systems [1]. The development of a special type of wireless sensor Networks (WSNs) called Wireless Body Area Network (WBAN), was directly triggered by the unsuitability of WSN for monitoring human body [2, 3]. Such systems called wearable health monitoring systems (WHMS) based on wearable sensors, in addition to allow the decrease of health costs, are also made in order to enhance quality of life of patients becoming more independent. For this, it seems important that HMS need to support non restricted mobility for monitored users as well as health professionals which enables an anywhere and anytime monitoring, allowing an instant detection of abnormal health cases, predicting and preventing serious and critical health problems such as falls and thus enabling immediate reaction towards the patient[4,5].

However, user's mobility implying contextual information changes such as available resources and location, needs specific requirements to be fulfill, and leads to various issues and challenges such as intermittent connectivity or wireless technologies interferences. These combining multiple research areas related to WHMS' design, require a certain number of techniques and technologies for a seamless mobility support [5,8,9].

Examining the literature, a number of research studies and proposals addressing or including mobility support in HMS exist. In [44], authors proposing a framework for comparison of health monitoring systems, considered mobility of patientsthrough wireless communications aspects since mobility is said to be maximally supported through wireless communication technologie. Authors in [11], within a survey of requirements for health monitoring systems, considered mobility support through techniques to adapt to broken routes and fluctuating transmission link quality. In [45], authors supported mobility within their proposed data collection system through cost effective communication by switching between available networks according to current region and using buffering with postponed transmissions in order tohandle intermittent connectivity. Other studies and research works addressed and focused on some of the key mechanisms for mobility support such as handover [9,12], coexistence handling [13,14,15], intermittent connectivity handling [20] or localization [16]. However, to the best of our knowledge, none of these studies addressed mobility support from a perspective describing its design requirements and their correlation with user's context. Addressing mobility support from suchperspective, aims to give a clear view of requirements and challenges, and techniques and technologies around the subject, which possibly contribute in the conception of efficient WHMS.

This work therefore highlights key means enabling full mobility support in WHMS. For this, main aspects around mobility support from techniques and technologies to surrounding contexts of the user are reviewed, discussed and correlated within our framework proposal. This, aspire to be astarting point for the conception of WHMS with full support of mobility while also attempts to provide an assessment platform helping to evaluate mobility support of monitoring systems and projects.

## II.FOREWORD

WHMS are generally designed on the basis of the typical three-tiers architecture composed from intra, inter and beyondBAN levels and whose the core idea is the use of any existingICT-based wireless communication to achieve cooperationbetween these three components [2]. It is reported that using athree-tiers representation considered as a complete model is areasonable choice for remote HMS [2]. For this, three-tiers representation will be the starting architectural point for this work.

Besides, supporting non-restricted user mobility implies different locations around which a patient can roam such as home, hospital or public parks. Besides, systems supporting delimited area mobility, exploit specific location advantages; such advantages can also be exploited in case of non-restricted mobility. Therefore, a HMS supporting a non-restricted mobility, allowing the user to move anywhere, would ideally take at the same time advantages of different locations the patient could meet. Within this outlook, this work further addresses in-home indoor environment and its specificities, as a special location for patient, in order to take advantage of, as this specific environment can be considered as a major typical and totally customizable location. A. Multi-layers architecture A HMS is typically built of three building blocks namely sensing, communication and data analysis, considered as the three main functionalities enabling HMS to operate [6].

From another hand, user mobility, being part of the patient context, could not be isolated; instead, techniques and technologies used to support it are rather in close relation with this context. Communications are particularly impacted by user mobility, more especially transmission of patient's data. Therefore, any mean for supporting mobility might be dependant of patient's data profile whether it's in term of frequency, reliability or any other profile constraints as it will be described below. Moreover, patient's location is also an important parameter on which mobility support means might be dependant in term of available communication and sensing infrastructures for example or suitable techniques adapted to the environment.

## III. DESIGN FRAMEWORK FOR MOBILITY SUPPORT

In order to shape our design framework proposal (see Fig. 1): (1) we introduce a multi-layers architecture based on the typical three-tiers representation [2], aiming to cover major involved WHMS design aspects. This architecture will serve as a basis for our design framework; (2) we study some of the main relevant elements of the patient context i.e. data profile and patient location, and extract different context constraints impacting mobility support means; (3) major techniques andtechnologies for supporting user mobility in WHMS are defined in the form of conceptual recommendations and key mechanisms' design requirements; (4) techniques and technologies for mobility support are correlated with different defined constraints then overlaid on the multi-layers architecture forming the design framework proposal

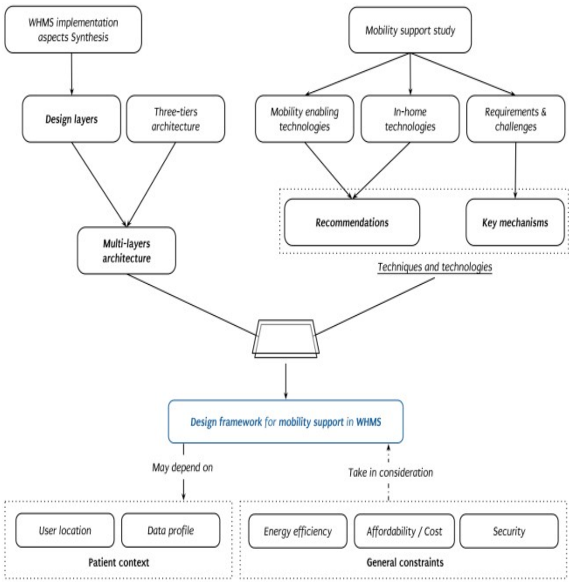


Fig. 1. System Architecture

### *A. Multi-layers architecture:*

A HMS is typically built of three building blocks namely sensing, communication and data analysis, considered as the three main functionalities enabling HMS to operate [6].

### *B. Patient context: design requirements:*

As user mobility is a part of the patient context, techniques and technologies for its support could not be disassociated from this context's constraints but are rather in close relation. In fact, since communications are subject to be impacted by mobility, supporting techniques and technologies might be dependent from the profile of transmitted data such as their frequency or reliability requirement. Besides, location of the patient is also an important factor on which these techniquesand technologies might be dependent such as availablecommunication networks or sensing infrastructures. Therefore, three major aspects and their impact are interesting for our design framework, (1) the mobility of the patient which is the basis for constraints defining design requirements and mechanisms, and (2) the patient location, as well as (3) the profile of data to be monitored, both representing the selection indicator for customization.

### C. Recommendations:

Data profile requirements are associated with recommendations illustrating their impact on these latter's parameters or squarely their need.

### D. Key mechanisms:

One of the main concerns when supporting mobility in HMS is maintaining connectivity and quality of service (QoS) at a sufficient level meeting application requirements [12,21]. Furthermore, WHMS relying on wireless technologies, energy as well as cost are important criteria to be considered, where from one hand, the more energy consumption is optimized the more the monitoring sustainability and convenience of the user increase, while from another hand, cost-effectiveness allows such systems to be more affordable and accessible [12]. Besides, because of surrounding environment changing of a mobile user such as in term of network coverage, context awareness should be considered. In order to cope with these concerns, a number of means supporting context awareness should be designed and implemented within WHMS. A set of key mechanisms for supporting mobility are briefly described and presented below in the form of design requirements, along with associated data profile requirements. It is noted that basically different algorithms used in following mechanisms should be designed and implemented to be energy efficient and not constitute or leads to any kind of security vulnerabilities.

#### 1) Handover.

Context-awareness decisional mechanism dealing with network coverage change by switching between points of attachment (PA). Handovers allow to maintain connectivity, maximize throughput and support QoS [12]. We talk about micro/macro mobility handovers whether the switching is between the same network domain PAs (keeping same IP address) or through different network domains Pas ; Horizontal/vertical handovers from another hand distinguish between transitions through homogeneous or heterogeneous network technologies. Handover decisions are performed on the basis of a number of parameters such as RSSI (Received Signal Strength Indication) [12]. Power consumption and cost are important parameters to be taken in consideration by handover decision algorithms and a tradeoff between quality of the connections and others parameters such as cost might be considered. Handover decision algorithm should be designed to perform handovers in a seamless manner, avoiding unnecessary handovers while being energy efficient. Mechanisms for data buffering should also be designed in order to locally store temporary data in case for example of a slow handover. Required handover time of performing is highly related to the data profile real-time and frequency requirements. In some cases, a handover can be not necessary, even if the current connection is lost such as in case of very small data collection frequency like one measurement per day, or in case of delay tolerance like in applications where collected data are transmitted to remote side after a number of days. However, these cases are not emergencies aware since the connectivity is not maintained as much as possible.

#### 2) Intermittent connectivity handling.

Handling intermittent connectivity is typically performed through switching to DTN (Delay-Tolerant Networking) communication mode that handles temporary ruptures of connectivity [20] which might be more necessary in rural environments. DTN "Store and forward" algorithms require local storage capability as well as possibly local computing ability and a minimum of processing algorithms for real-time analysis and continuous emergencies detection. Moreover, because of the connectivity ruptures and delayed transmissions, remote-side algorithms for processing-out received data are needed including ordering and synchronization [18]. DTN communication mode features are closely related to data profile real-time requirement defining for example if local processing is needed or not, data prioritization requirement is also important to differentiate between data that could support delay and those that don't whether it is for processing or uploading, as well as prioritizing data handling on reconnection. Lastly, data frequency requirement could determine whether DTN mode should be used or not. From another hand, intermittent connectivity might be mitigated through wireless coverage extension by increasing network connectivity if node cooperation with its neighboring is possible .

#### 3) Coexisting of Networks.

A monitored user can besurrounded by different wireless technologies. Its body network therefore coexists with this environment whether it comes to other surrounding body networks, called homogeneous coexistence, or other wireless networks around within the same range called heterogeneous coexistence [13]. Obviously, this coexistence causes interferences resulting in the loss of monitored user's health data and other traffic; thus, coexistence handling requirement is closely dependent from reliability needs, knowing that many applications require high reliability particularly in emergency situations [21]. It is reported that up to now, current standards haven't yet properly address coexistence problem between WBAN and other same- band surrounding networks [21]. Mechanisms to detect as well as to mitigate coexistence interferences impact are therefore necessary.

***4) Localization and tracking.***

Mechanisms for localization are of high importance, as a user being mobile especially elderly should

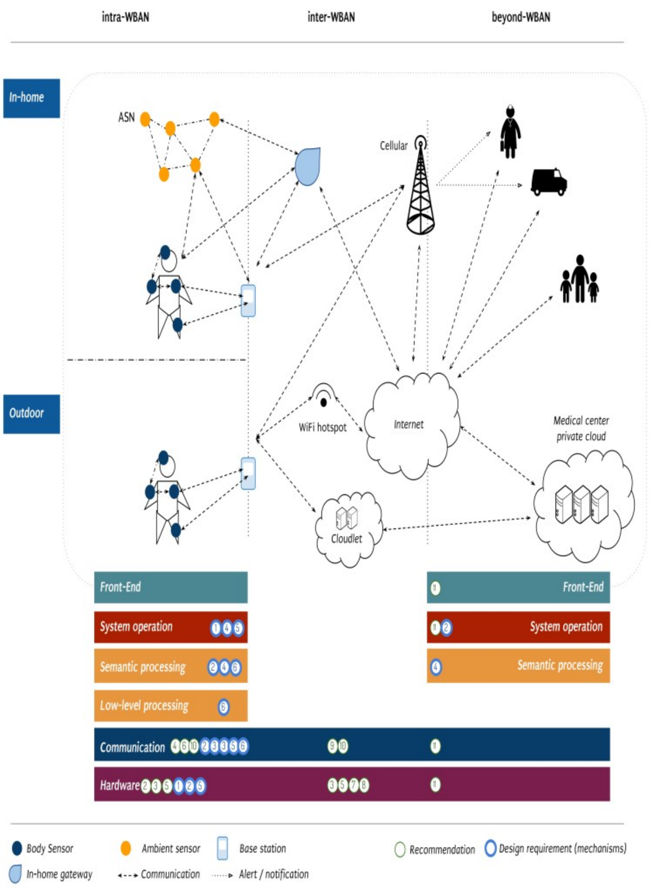


Fig. 2 Illustration of design framework for mobility support in WHMS

always be trackable in real-time so that if an emergency is detected, the user can be immediately located and found. Since a mobile user roams between indoor and outdoor environments where mechanisms for localization should be location-context aware and thus differs, algorithms to differentiate between in-home and outdoor should be used which might further allow to take advantage of the user's location. In in-home environment, localization algorithms could rely on different fixed home wireless infrastructures such as the ASN if available; Depending on target application requirements, Wireless Multimedia Sensor Networks (WMSN) might also be used as they are reported to provide more information than classical WSN but need however energy-aware algorithms. Regarding outdoor, mobile platforms used as base station especially Smartphones are typically equipped with GPS sensor on which localization algorithms can easily rely; information provided by cellular networks through Location Area Identity (LAI) can also be used in order to calculate user position.

*5) Cost - effective and energy-saving Transmission schemes.*

For a system that supports mobility, saving energy and mitigating communication costs are important; for this, scheme of transmission used should be context aware and flexible so that it can adapt to different situations on the basis of application requirements. If for example, in a given application, some of the data historization at remote side is not used while their processing is not complex, this latter can be performed at the base station and only emergency data or alerts are transmitted such as in [2], whereas for the rest of data, a periodic transmission can still be performed. Another examples are to proceed to the transmission only if values changed, or also to differentiate between in-home and outdoor communications in the way that in in-home where remote connectivity can be costless, all data can be transmitted periodically while in outdoor where transmission's cost is more important, thresholds can be for example used and only data exceeding this latter are sent; or, only data that might need a remote processing for computing power needs for example are transmitted. Appropriate transmission scheme would therefore depend on data processing, prioritization and real-time requirements. Algorithms for managing the schema of transmission are therefore also needed. These are typically based on a given criteria such as threshold, data classification into emergency/routine or network infrastructure used, and might require local storage and computing capabilities. The overall mechanism algorithms should be able to classify given criteria information such as differentiating between routine and emergency data and messages, then take relevant decision on the basis of this classification.

## IV. CONCLUSION AND FUTURE WORK

In this paper, we proposed a design framework taking in consideration patient context constraints with the aim to serve as a starting point for the conception and possibly the evaluation of health monitoring systems with mobility support. The framework was schematized by double projecting pointed out design requirements for key mechanisms, and a number of conceptual recommendations, on the three-tiers representation, as well as the introduced design layers. From the design layers of the framework, it was noted that communication and physical aspects were the most involved aspects for mobility support; this can explained by the fact that mobility essentially affects transmissions between patients sensors and remote center which require appropriate communication protocols, standards and so on, while the mobility freedom of the patient requires equipments with specific characteristics as it was described in this work. For future perspectives, presented design framework should be practically validated through simulations and experimentations where mechanisms should be designed and implemented within targeted application and context, as well as different conceptual recommendations where available technologies could be compared in order to validate their suitability.

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