Digital Cities of the Future: Extending @Home Assistive Technologies

Abstract
This paper presents the notion of home assistive technologies as they will be supported and deployed in the digital cities of the future. State of the art in intelligent pervasive healthcare applications and the corresponding enabling technologies are discussed. Special focus is raised on intelligent platforms such as agents, context-aware and location-based services, and classification systems that enable advanced monitoring and interpretation of patient status and environment optimizing the whole medical assessment procedure. A framework for extending assistive technologies is proposed that considers individuals belonging to special groups of interest and locations other than their home. Remaining challenges and issues for the successful deployment of assistive technologies in digital cities are also discussed.

1. Introduction

In this era of ubiquitous and mobile computing the vision in biomedical informatics is towards achieving two specific goals: the availability of software applications and medical information anywhere and anytime and the invisibility of computing [40]. Both aforementioned goals lead to the introduction of pervasive computing concepts and features in e-health applications. Applications and interfaces that will be able to automatically process data provided by medical devices and sensors, exchange knowledge and make intelligent decisions in a given context are strongly desirable. Natural user interactions with such applications are based on autonomy, avoiding the need for the user to control every action, and adaptivity, so that they are contextualized and personalized, delivering the right information and decision at the right moment [41]. All the above pervasive computing features add value in modern pervasive e-healthcare systems.

Providing at home health assistance through pervasive sensor network and other technologies remains a big challenge because of the heterogeneity of devices, network systems and health policies. Extending this work to providing human support to the outdoors, in an urban or other setting, presents even bigger challenges as the outside of the home environment is not predetermined, cannot be controlled or easily monitored. The technologies that can help are restricted to ways to monitor the individual, through mobile sensors, and through public transportation designs that anticipate different types of users interacting. These users might need assistance and others might not. Any technologies involved must be minimally intrusive to the first group and not affect the second group.

The issues are technical, social and legal. Our work on Assistive Cyberphysical Systems for @home and @work environments, has addressed some of the technical issues involved in the ability to recognize critical changes or “events” that would trigger an assistive response to the human in need. It addressed challenges of meshing together dynamic and diverse data streams, ranging from spatiotemporal information, to discrete events such as door opening, phone ringing, etc, in order to predict, for example, a fall, or prevent some risk in the indoor environment [42], [52].

In this paper, we focus on how to extend the support that a user receives to stay as long as possible alone at home, to the outdoors environment. We assume a user who can navigate her/him-self through physical spaces using assistive aides (wheelchair, rollator, cane) and possibly with the support of a caregiver. We ask: What is the most critical support that such a user needs from a digital city environment to ensure safe navigation in an open outdoors environment and safe return to home environment with minimal cost and maximum efficiency.

In ancient times, the notion of ramps, elevators, rolling sidewalks, did not exist. Now, they serve all of us, even if we do not absolutely need them. How would digital cities of the future look for us when we grow old and will need such assistance and even much more?

Although there has been a significant improvement towards removing structural barriers encountered by people using wheelchairs the progress in assisting people with other types of disabilities such as vision problems and cognitive deficiencies, or older people has not been proportional. The notion of digital cities ([50], [53]) together with the blooming ubiquitous computing applications [57] comes to cover this gap by introducing new potentials in the area of pervasive assistive technologies. Such technologies can be of benefit not only to people with special needs but also to non-impaired people may who visit a new town and have problems in navigation and/or communication, or even to local residents to make their live easier.

2. Related Work

Recent work on the design digital city frameworks discuss issues such as how to create technologically-supported environments that provide assistance to the elderly or persons in need of public access support. Discussions also center around technologies that lead to "intelligent" cities, with a pool of strategies, the ability to collect and transform collected information and knowledge into decision making, privacy-preserving virtual health clusters, social networks of e-communities, and the seamless integration of physical and virtual spaces (cyberphysical systems) [50], [53]. One type of support is through using personal digital assistants (PDAs) to monitor patients and test results [61], [62]. Social support projects include projects such as in [60]. This European Union-funded project, called PlayMancer, uses 3D networked games to improve people's health. How can such interactive games be used to prepare and train patients and healthcare givers for a digital city infrastructure and especially warn about risks and precautions to take?

In another project in England, [59], a sensing system is used to help persons with dementia with monitoring technologies [Engineering and Physical Sciences Research Council's Pioneers 09 showcase event in London] that monitor a person's movements, provide voice prompts, actively take part in managing appliances and thus enable people with dementia to live on their own. Extending such a system to an urban environment would be extremely challenging.

At the Heracleia Human Centered Computing Lab, researchers are developing monitoring tools that take as input a plethora of heterogeneous data in both discrete and continuous format and produce "events" that summarize or evaluate the situation about a person living at home. This event-driven environment predicts cases of risk that my come up as it learns from the persons usual behavior. It uses advanced computation methods to fuse information and combine it with domain expertise as to what is important to look out for. It is an environment that also allows the communication among different types of sensors in a wireless environment [45]. Among the tools being developed are ways to have robots assist through voice recognition, interfaces that provide customized notices and training, and ability to detect pain or depression from facial expressions. The Heracleia apartment resides within the laboratory and includes team projects such as the *Smart Drawer RFID project* [47] designed to track whether the correct medication is taken at the right time, and its impact on behavior afterwards.

Ambient Assisted Living (AAL) technologies aim at enabling independence in the old age with the support of advanced technologies. In AAL, accessibility, usability and learning play a major role in the emerging digital cities area to enable citizens with specific demands, e.g. handicapped, chronic patients or elderly, to live in congenial environments longer [46]. Ambient home care systems (AHCS) are specially designed for this purpose; they aim at minimizing the potential risks that living alone may suppose for an elder, relying on their capability of gathering user related data, inferring information about their activity and state, and taking decisions on the user potential demands.

There are several initiatives, especially in Europe and Japan, for the creation of digital representation of physical cities/towns [50], [53]. These representations can act as public information spaces that can support our everyday life. Telematics tools such as Geographical Information Systems (GIS) can facilitate urban planning and can remove geographical and physical boundaries by enhancing the user experience in transportation, tele-shopping, etc.

In order to enjoy the benefits of a digital city, the users will have to continuously connect to publicly available wireless network access point and exchange data. This raises the issue of personal privacy and security. However, similar problem exist even in more local settings such as the interior of a building, and so methods for preserving anonymity, privacy and security have already been examined and successfully solved [58], [55]. Their application to the broader setting of a city can be feasible with minor extensions.

3. Pervasive HealthCare Enabling Technologies

Applications that conform to the pervasive computing paradigm are continuously running and always available. Pervasive applications are characterized by adaptation of their functionality subject to their current environment. Such environment may refer to the physical location, orientation or a user profile. In a mobile and wireless environment, changes of location and orientation are frequent. Apart from collecting patient-related data, sensing the user’s identity, environment characteristics and location in e-health applications is quite important for adapting the provided to the physician or patient, services in an intelligent manner.

3.1. Signal and Data Collection

A broad definition of a signal is a ‘measurable indication or representation of an actual phenomenon’, which in the field of biosignals, refers to observable facts or stimuli of biological systems or life forms. In order to extract and document the meaning or the cause of a signal, a physician may utilize simple examination procedures, such as measuring the temperature of a human body or have to resort to highly specialized and sometimes intrusive equipment, such as an endoscope. Following signal acquisition, physicians go on to a second step, that of interpreting its meaning, usually after some kind of signal enhancement or ‘pre-processing’, that separates the captured information from noise and prepares it for specialized processing, classification and decision support algorithms.

Biosignals require a digitization step in order to be converted into a digital form. This process begins with acquiring the raw signal in its analog form, which is then fed into an analog-to-digital (A/D) converter. Since computers cannot handle or store continuous data, the first step of the conversion procedure is to produce a discrete-time series from the analog form of the raw signal. This step is known as ‘sampling’ and is meant to create a sequence of values sampled from the original analog signals at predefined intervals, which can faithfully reconstruct the initial signal waveform. The second step of the digitization process is quantization, which works on the temporally sampled values of the initial signal and produces a signal, which is both temporally and quantitatively discrete; this means that the initial values are converted and encoded according to properties such as bit allocation and value range. Essentially, quantization maps the sampled signal into a range of values that is both compact and efficient for algorithms to work with. The most popular biosignals utilized in pervasive health applications ([1], [3], [4], [10], [11], [18], [19], [23], [24], [30]) are summarized in the table below.

Table 1. Broadly used biosignals with corresponding metric ranges, number of sensors required and information rate.

Biomedical Measurements (Broadly Used Biosignals)	Voltage range (V)	Number of sensors	Information rate (b/s)
ECG	0.5-4 m	5-9	15000
Heart sound	Extremely small	2-4	120000
Heart rate	0.5-4 m	2	600
EEG	2-200 μ	20	4200
EMG	0.1-5 m	2+	600000
Respiratory rate	Small	1	800
Temperature of body	0-100 m	1+	80

In addition to the aforementioned biosignals, patient physiological data (e,g., body movement information based on accelerometer values), and context-aware data (e.g., location, environment and age group information) have also been used by pervasive health applications ([1], [2], [3][4], [6], [13], [14], [15], [22], [24], [26], [31]). The utilization of the latter information is discussed in the following sections.

In the context of pervasive healthcare applications, the acquisition of biomedical signals is performed through special devices (i.e. sensors) attached on the patients body (see **Fig. 1**) or special wearable devices (see **Fig. 2**). The transmission of the collected signals to the monitoring unit is performed through appropriate wireless technologies discussed in Section 2.2. Regarding the contextual information, most applications are based on data collected from video cameras, microphones, movement and vibration sensors.

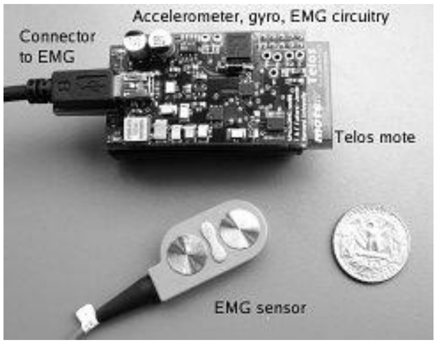

Fig. 1. Accelerometer, gyroscope, and electromyogram (EMG) sensor for stroke patient monitoring [**9**].

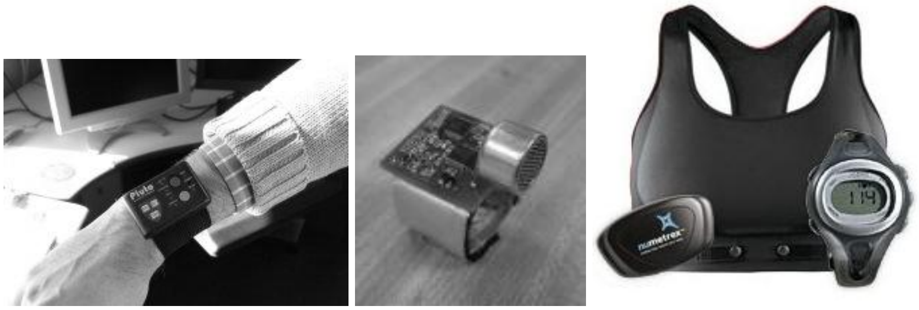
(a) (b) (c)

Fig. 2. Wearable medical sensor devices: (a) A 3-axis accelerometer on a wrist device enabling the acquisition of patient movement data [**9**], (b) A ring sensor for monitoring of blood oxygen saturation [**21**], (c) Wearable heart rate monitoring system by Numetrex [63].

3.2. Communication Issues

Regarding communication, there are two main enabling technologies according to their topology: on-body (wearable) and off-body networks. Recent technological advances have made possible a new generation of small, powerful, mobile computing devices. A wearable computer must be small and light enough to fit inside clothing. Occasionally, it is attached to a belt or other accessory, or is worn directly like a watch or glasses. An important factor in wearable computing systems is how the various independent devices interconnect and share data. An off-body network connects to other systems that the user does not wear or carry and it is based on a Wireless Local Area Network (WLAN) infrastructure, while an on-body or Wireless Personal Area Network (WPAN) connects the devices themselves; the computers, peripherals, sensors, and other subsystems and runs at ad hoc mode. Table 2 presents the characteristics of wireless connectivity and mobile networking technologies correspondingly, which are related to off-body and on-body networks. WPANs are defined within the IEEE 802.15 standard. The most relevant protocols for pervasive e-health systems are Bluetooth and ZigBee (IEEE 802.15.4 standard []). Bluetooth technology was originally proposed by Ericsson in 1994, as an alternative to cables that linked mobile phone accessories. It is a wireless technology that enables any electrical device to communicate in the 2.5-GHz ISM (license free) frequency band. It allows devices such as mobile phones, headsets, PDAs and portable computers to communicate and send data to each other without the need for wires or cables to link the devices together. It has been specifically designed as a low-cost, low-size, and low-power radio technology, which is particularly suited to the short range of a

Personal Area Network (PAN). The main features of Bluetooth are: a) Real-time data transfer usually possible between 10–15m, b) Support of point-to-point wireless connections without cables, as well as point-to-multipoint connections to enable ad hoc local wireless networks, c) data speed of 400 kb/s symmetrically or 700–150 kb/s of data asymmetrically. On the other hand, ZigBee (IEEE 802.15.4 standard) has been developed as a low data rate solution with multi-month to multiyear battery life and very low complexity. It is intended to operate in an unlicensed international frequency band. The maximum data rates for each band are 250, 40, and 20 kbps, respectively. The 2.4 GHz band operates worldwide while the sub-1-GHz band operates in North America, Europe, and Australia.

Table 2. Wireless connection technologies for pervasive health systems.

Technology	Data rate	Range	Frequency
IEEE 802.11a	54 Mbps	150 m	5 GHz
IEEE 802.11b	11 Mbps	150 m	2.4 GHz ISM
Bluetooth (IEEE 802.15.1)	721 Kbps	10 m - 150 m	2.4 GHz ISM
HiperLAN2	54 Mbps	150 m	5 GHz
HomeRF (Shared Wireless Access Protocol, SWAP)	1.6 Mbps (10 Mbps for Ver.2)	50 m	2.4GHz ISM
DECT	32 kbps	100 m	1880-1900 MHz
PWT	32 kbps	100 m	1920-1930 MHz
IEEE 802.15.3 (high data rate wireless personal area network)	11-55 Mbps	1 m - 50 m	2.4GHz ISM
IEEE 802.16 (Local and Metropolitan Area Networks)	120 Mbps	City limits	2-66 GHz
IEEE 802.15.4 (low data rate wireless personal area network), Zigbee	250 kbps, 20 kbps, 40 kbps	100 m - 300 m	2.4 GHz ISM, 868 MHz, 915MHz ISM
IrDA	4Mbps (IrDA-1.1)	2 m	IR (0.90 micro-meter)

Pervasive healthcare systems set high demanding requirements regarding energy, size, cost, mobility, connectivity and coverage. Varying size and cost constraints directly result in corresponding varying limits on the energy available, as well as on computing, storage and communication resources. Low power requirements are necessary also from safety considerations since such systems run near or inside the body.

Mobility is another major issue for pervasive e-health applications because of the nature of users and applications and the easiness of the connectivity to other available wireless networks. Both off-body and personal area networks must not have line-of-sight (LoS) requirements. The various communication modalities can be used in different ways to construct an actual communication network. Two common forms are infrastructure-based networks and ad hoc networks. Mobile ad hoc networks represent complex systems that consist of wireless mobile nodes, which can freely and dynamically self-organize into arbitrary and temporary, ”ad hoc” network topologies, allowing devices to seamlessly inter-network in areas with no pre-existing communication infrastructure or centralized administration. The effective range of the sensors attached to a sensor node defines the coverage area of a sensor node. With sparse coverage, only parts of the area of interest are covered by the sensor nodes. With dense coverage, the area of interest is completely (or almost completely) covered by sensors. The degree of coverage also influences information processing algorithms. High coverage is a key to robust systems and may be exploited to extend the network lifetime by switching redundant nodes to power-saving sleep mode.

3.3. Location Based Technologies

Positioning of individuals provides healthcare applications with the ability to offer services like supervision of elderly patients or those with mental illnesses who are ambulatory but restricted to a certain area. In addition, assisted care facilities can use network sensors and radiofrequency ID badges to alert staff members when patients leave a designated safety zone. Network or satellite positioning technology also can be used to quickly and accurately locate wireless subscribers in an emergency and communicate information about their location. Proximity information services can direct mobile users to a nearby healthcare facility. Location-based health information services can help find people with matching blood types, organ donors, and so on. A more extensive list of location-based health services can be found in [33].

Positioning techniques can be implemented in two ways: Self-positioning and remote positioning. In the first approach, equipment that the user uses (e.g., a mobile terminal, or a tagging device) uses signals, transmitted by the gateways/antennas (which can be either terrestrial or satellite) to calculate its own position. More specifically, the positioning receiver makes the appropriate signal measurements from geographically distributed transmitters and uses these measurements. Technologies that can be used are satellite based (e.g., the Global Positioning System (GPS) and assisted-GPS), or terrestrial infrastructure-based (e.g., using the cell id of a subscribed mobile terminal).

The second technique is called remote positioning. In this case the individual can be located by measuring the signals traveling to and from a set of receivers. More specifically, the receivers, which can be installed at one or more locations, measure a signal originating from, or reflecting off, the object to be positioned. These signal measurements are used to determine the length and/or direction of the individual radio paths, and then the mobile terminal position is computed from geometric relationships; basically, a single measurement produces a straight-line locus from the remote receiver to the mobile phone. Another Angle Of Arrival (AOA) measurement will yield a second straight line, the intersection of the two lines giving the position fix for this system. Time delay can also be utilized: Since electromagnetic waves travel at a constant speed (speed of light) in free space, the distance between two points can be easily estimated by measuring the time delay of a radio wave transmitted between them. This method is well suited for satellite systems and is used universally by them. Popular applications that are based on the latter technique for tracking provision are the Ekahau Positioning Engine [34], MS RADAR [35] and Nibble [36]. More information regarding positioning techniques and systems can be found in [32].

3.4. Intelligent Data Processing and Context Awareness

Context awareness is the capability of the networking applications to be aware of the existence and characteristics of the user's activities and environments. In rapidly changing scenarios, such as the ones considered in the fields of mobile, pervasive, or ubiquitous computing, systems have to adapt their behavior based on the current conditions and the dynamicity of the environment they are immersed in ([37]). A system is context-aware if it can extract, interpret and use context information and adapt its functionality to the current context of use. The challenge for such systems lies in the complexity of capturing, representing and processing contextual data. To capture context information generally some additional sensors and/or programs are required [27].

The way context-aware applications make use of context can be categorized into the three following classes: presenting information and services, executing a service, and tagging captured data.

Presenting information and services refers to applications that either present context information to the user, or use context to propose appropriate selections of actions to the user.

Automatically executing a service describes applications that trigger a command, or reconfigure the system on behalf of the user according to context changes.

Attaching context information for later retrieval refers to applications that tag captured data with relevant context information.

Intelligent agents can be viewed as autonomous software (or hardware) constructs that are proactively involved in achieving a predetermined task and at the same time reacting to its environment. According to [38], agents are capable of:

- performing tasks (on behalf of users or other agents).
- interacting with users to receive instructions and give responses.
- operating autonomously without direct intervention by users, including monitoring the environment and acting upon the environment to bring about changes.
- showing intelligence – to interpret monitored events and make appropriate decisions.

Agents can be proactive, in terms of being able to exhibit goal-directed behavior, reactive; being able to respond to changes of the environment, including detecting and communicating to other agents, autonomous; making decisions and controlling their actions independent of others. Intelligent agents can be also considered as social entities where they can communicate with other agents using an agent-communication language in the process of carrying out their tasks.

In the context of pervasive healthcare, intelligent agents can contribute by analyzing patient and contextual information, distributing tasks to responsible individuals, inform users regarding special actions and circumstances.

Data classification is important problem in a variety of engineering and scientific disciplines such biology, psychology, medicine, marketing, computer vision, and artificial intelligence [39]. Its main object is to classify objects into a number of categories or classes. Depending on the application, these objects can be images or signal waveforms or any type of measurements that need to be classified. Given a specific data feature, its classification may consist of one of the following two tasks: a) supervised classification in which the input pattern is identified as a member of a predefined class; b) unsupervised classification in which the pattern is assigned to a hitherto unknown class.

In statistical data classification, input data are represented by a set of n features, or attributes, viewed as a n-dimensional feature vector. The classification system is operated in two modes: training and classification. Data preprocessing can be also performed in order to segment the pattern of interest from the background, remove noise, normalize the pattern, and any other operation which will contribute in defining a compact representation of the pattern. In the training mode, the feature extraction/selection module finds the appropriate features for representing the input patterns and the classifier is trained to partition the feature space. The feedback path allows a designer to optimize the preprocessing and feature extraction/selection strategies. In the classification mode, the trained classifier assigns the input pattern to one of the pattern classes under consideration based on the measured features.

There is a vast array of established classification techniques, ranging from classical statistical methods, such as linear and logistic regression, to neural network and tree-based techniques (e.g., feed-forward networks, which includes multilayer perception, Radial-Basis Function networks, Self-Organizing Map, or Kohonen-Networks), to the more recent Support Vector Machines. Other types of hybrid intelligent systems are neuro-fuzzy adaptive systems which can comprise of an adaptive fuzzy controller and a network-based predictor. More information regarding data classification techniques can be found in [39].

In the context of intelligent pervasive health systems, input classification data can be both biomedical signals, physiological and contextual data. Generated classification results can contain information concerning the status of a patient, suggested diagnosis, behavioral patterns, etc. In the following sections, pervasive healthcare systems that use such intelligent technologies are presented.

4. Framework to extend @home Assistive Environment

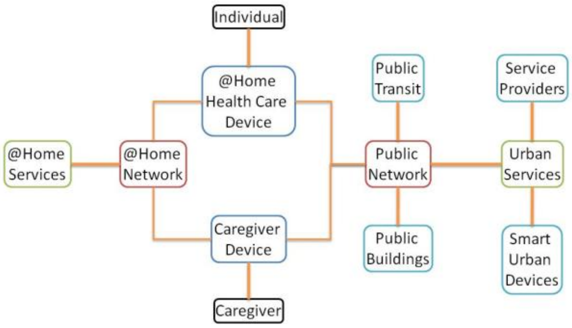

Figure 3 Connections between users, devices, and services in a digital city.

Once it has been established that the disabled or elderly person would be wearing devices to monitor their medical status or their homes will be fitted with sensors to observe human activity, it is possible to extend this concept outwards into the urban environment. Firstly, we assume that each individual will be caring a type of @home health care device that will monitor their medical condition, and that it can connect either to their home network or into some public network out in the digital city. Should the individual have a caregiver living with them, say a nurse companion or even a spouse, they, too, would have some technological device to let them interface with both networks. While these devices on the home network would assist with the systems inside their living quarters, they would have additional features outside in the urban setting. A public network would be able to assist in more functions, connecting the devices to other urban services, including public transit and public buildings. Additionally, automatic devices and businesses connected in the digital city could provide benefits through a set of urban services. An overview of this setup can be seen in figure 3.

4.1 Disabled Persons Living Alone

A number of solutions have been suggested for @home assistance of people with disabilities the elderly. These solutions include automatic schedule reminders, dangerous situation alarms, body health monitors, accessible communication devices and other electronic devices. In order for these types of people to enjoy a fully independent life, however, such support should be also extended to the urban environment. In many cases, they need navigation support to reach their destination. Often their communication skills are limited and they find it difficult to take advantage of the public services which are mainly designed to fit the needs of the average healthy individual. In addition, these people usually need closer health monitoring and a good way to contact a caregiver in case of emergency.

Since it is not easy to always adapt the public infrastructures to meet the needs of impaired people, the most promising solution seems to be the use of special interaction devices the subjects carry with them. These health monitoring devices would track their activities and help them in their interaction and communication with the outside world. The interplay of this can be seen in figure 5.

With the current saturation of cell phones in the urban population, it is not unlikely for such an electronic package to be carried by an ordinary individual. The world is full of radio communication devices that can be taken advantage of by such a system. For navigation, the disabled person could receive updated directions for how to reach a destination. Other information about their health would be on standby in case of an emergency. Likewise, if their electronic widget included an identification beacon, automatic doors or wait staff could be alerted in advance that someone with special needs was about to enter their establishment. Perhaps even special parking meters would switch over from public use to handicap use when a disabled person arrived in that quarter of the city. In some cases, information could be supplied to the disabled person, and other times the information could be applied to either the city infrastructure or alert other citizens.

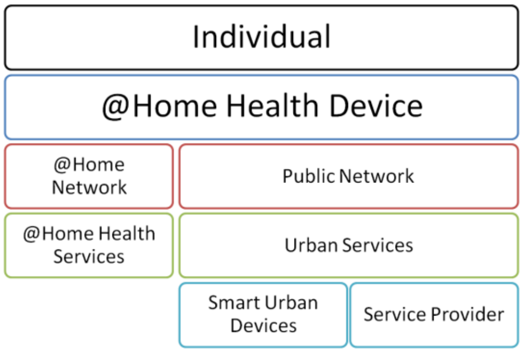

Figure 5. Framework for disabled person living alone. The individual works with their device to connect with the different networks, either @home or into the digital city.

4.2 Disabled Person Living With a Caregiver

Sometimes, a person has become disabled and requires the special attention of a caregiver. A caregiver living with a disabled person also would take advantage of the home health network, having their own interface to connect with the system. The use of the combined system would allow the caregiver and the disabled person to coordinate their schedules and activities. Other tools would be to keep logs of events for compliance and training exercises. Again, this system could be expanded for use in the urban environment. If both parties were meeting at a public place, the navigation would be a key tool. Other options could be private data sharing or remote monitoring using the public network. If the two were together, calculations could even be distributed between the two units.

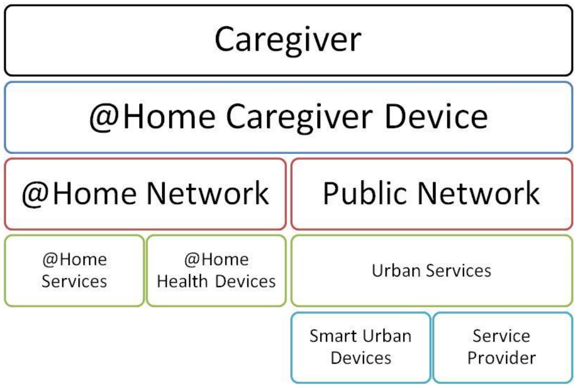

Figure 6. Framework for a cargeiver. The caregiver works with their device to connect with the different networks, either @home or into the digital city. Also, they would want to connect with the individual's device.

To that end, the devices would have to be able to interface with the home service system, the public service system, and even behave in an ad-hoc manner with each other as shown in figure 6. Additionally, a caregiver may have more than one patient in their charge, and would have to coordinate with multiple @home devices. At the same time, the caregiver should be able to use the public network in much the same way as the disabled person.

A caregiver could have to arrange to let their patient off at the door of a hospital or a clinic, and then need to find a way to navigate back to them afterwards. For public transportation, the fee for the transit or a subscription for a pass could be taken straight from the electronic device.

4.3 Public Buildings in a Digital City

In a new digital city, it is assumed that a public network is in place connecting the citizenry, infrastructure, and public buildings. Voice, touch-tone phone systems, and web pages currently give information about their operations, and extending this ability to connect to a portable electronic device like a smartphone is possible. And each building, depending on everything from a normal day, weekend, holiday, or emergency, can have a different schedule. These schedules can be updated throughout the day, and the information made available for the public network.

For example, a car license plate office tends to be busiest at the beginning of a month when a plate is due. This causes a slowdown in the building that could be identified. On a daily basis, sensors placed at the counters of the public buildings could generate a traffic report to give an estimate of how long each individual is waiting at a window, how many people have entered the building, and to figure out how long it would take for an average visit. This could help an individual keep an appointment. That slow-down then could be relayed to a central exchange so an individual could look up how busy the building is before leaving.

Likewise, schools and libraries can have different hours of operation depending on their location and for inclement weather. Currently, this information is broadcast to the general public on all media, and then each individual is responsible to keep track of closings. If this were automated, then flags and reminders about the public buildings could be tailored for the individual.

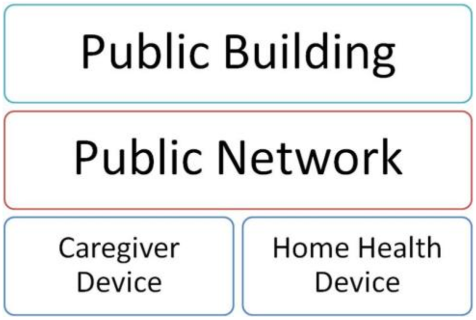

Figure 4.3 Information about public buildings would be put to a public network and accessed using one of the devices.

In each case, the public buildings would be able to generate status updates and other useful information and post them to a public network, that could then be accessed by either an individual or a caregiver using their device as in Figure 7.

4.4 Public Transit in a Digital City

Previous studies have showed that people with special needs find it very difficult to navigate in the setting of a modern city [48]. People with vision problem cannot read the navigation signs, and people with hearing problems cannot hear certain audio prompts. People using wheelchairs do not know if the route that they want to follow is accessible, and people with cognitive disabilities are not capable of navigating in the complex large-scale transportation systems of the modern society. People with these types of disabilities would greatly benefit by devices with interfaces that meet their special needs.

As Fischer [48] points out to use public transportation, one needs to deals with a number of "essential navigation artifacts". These artifacts include: maps, schedules, labels and signs, landmarks, and clocks. It is obvious that people with vision, memory or other cognitive problems would find it very challenging to successfully deal with these essential navigation artifacts.

For the special case of blind people for example, the current situation makes almost prohibitive the possibility of their navigation inside a city without companion. In that case a system that would specify the location of the person at each time and give them audio input for the status of their environment would make their live much easier. That way they would know exactly where they are, how far is the bus station, which bus is approaching etc. Similar situations and solutions apply to people with other types of disabilities. For instance, in the case of people with cognitive disabilities, the caregiver could design special schedules and itineraries that the subjects would follow to get to their destination.

In order for such systems to be operational there is a requirement for ubiquitous networking and digital representation of the physical setting of a city. Of course, that derives increased needs for information storage and management. Such systems could benefit not only people with special needs but also visitors who are unfamiliar with the regional specialties and cannot read the sings due to lack of knowledge of the local language. With the globalization of the market this problem could give extra motivations.

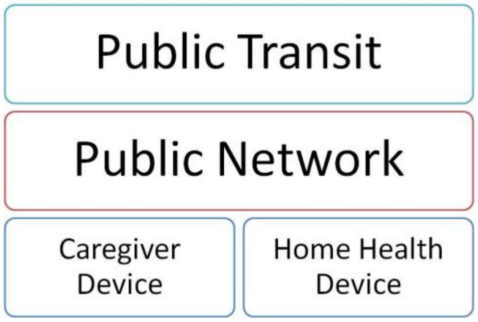

Figure 8. Public Transportation vehicles would also be fitted with devices to connect with the public network to update their status for user devices.

Another issue is the public vehicles that move through a digital city. Public transportation can be fitted with transponders to track their motion through the traffic, and to estimate the arrival time and departure time of each vehicle from each location. As a result, estimates of the public transit can be generated and posted. Given the increased intelligence of handheld devices, and an increasingly wireless networked cityscape, schedules and notices could be updated publicly. And individuals could even have their systems tailored to look for notices that affect their plans for the day.

As a result, the information about the public transit systems and street traffic can be recorded; decisions can be made, and then uploaded via a public network to support urban services as in figure 8.

4.5 Connection Public Buildings with Public Transit

Given that the building location and status can be found, and that the routes and schedule of the transpiration are known, it should be possible to connect the two. For example, a disabled individual has to cross town to visit the social security office for an appointment. The building status of the expected time of a visit and the hours of operation can be conjoined with the traffic information to create an estimated schedule for when the disabled person should leave their home in order to arrive at their destination on time to have an acceptable amount of waiting time at the public building. This could be the difference between telling a disabled person to leave between five minutes early to an hour early without missing the appointment. The goal would be to connect the temporal aspects of both public buildings and public transportation as well as constraining them by recognizing if they connect. A local bus would not be connected to a hospital on the far side of town, while an urban subway that connected all stations would figure into all the buildings. These kinds of constraints would have to be considered while connecting public buildings with public transportation.

With the idea that the city is connected by a public network, the information from public transportation and the schedules and status of public buildings would travel through the public network system to an urban services provider. Now, either the data can be compared or redirected to where it needs to go in order to be useful. Additionally the data could be routed between buildings and transit systems in a peer to peer fashion, or directed to a center for urban services for further processing and distribution as shown in figure 9.

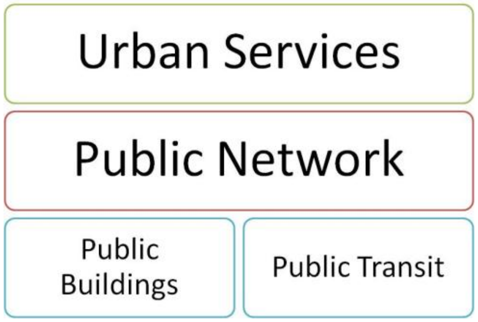

Figure 9. Public buildings and transit systems could connect either through a peer-to-peer network, or with some central urban services.

5. Remaining Issues and Challenges

The deployment of pervasive and smart health technologies in the digital cities of the future introduces several issues and challenges. The most important issues concern interoperability and communication issues between the different systems, security and privacy issues, usability and acceptance from both the patients and the caregivers.

5.1. Interoperability and collaboration

The integration of pervasive computing depends significantly on the ability to build, maintain and augment interoperable systems: different software and hardware components and systems that are required to interact to achieve the user’s overall goals. Most important interoperability issues concern:

Service and device integration: Pervasive systems often contain devices, which must operate in very different environments and connect together in different ways, e.g., over ad-hoc wireless connections to a variety of systems. Thus, communication of sensor devices from different vendors requires common protocols for data exchange or appropriate gateways for interconnection.

Information access: Assistive technologies require access to additional information regarding the patient and his/her environment. Such information (e.g., user profiles, medical records, etc.) is stored in various repositories requiring thus common ways of information annotation, interpretation and access.

Context semantic representation: In addition to the latter information access requirements, proper interpretation of user's contextual information is required, meaning that common ways of annotating collected data are required (e.g., through semantic languages, ontologies, etc.) [68].

Potential solutions that address the aforementioned issues, such as pervasive web services for either developing proper middleware software solutions or providing interoperable interfaces have been proposed [65].

5.2. **Usability and User Acceptance**

In order to prepare the elderly population to live longer and more independent lives with the help of information technology, the notion of pervasive health systems must be introduced into their lives. Awareness and acceptance can be fostered and increased by education and example. Industry must be cognizant of the fact that awareness training must go hand-in-hand with good design and that knowledge of the end users is as important as functionality, since without the end user's cooperation, functionality will be ineffective. Usability of pervasive healthcare systems and platforms can require that:

- The design needs to be adapted to the end user's physical impairments.
- The interfaces must offer a relative degree of familiarity to overcome any reservations felt by the end user.
- The benefit of using monitoring and/or assistive devices must be appreciable, and the balance between intuitive use and practicable teaching methods, addressing the learning needs of this age group, must be established [64].

User acceptance is the outcome of proper design and implementation considering always the usability requirements. However the opinion of both patients, especially in the case of the elderly, and caregivers should always be evaluated through appropriate experiments during the initial deployment of prototype systems [66], [67].

5.3. Security and Privacy

There are potential ways of information leaking [65] under many circumstances even when data have been de-identified and encrypted [63, 64] during transmission. For example, because of the continuity of motion data, locations of a single user (or object) can be tracked using various algorithms. If sensors periodically reports his/her location data to the server, then when the frequency of reporting is high enough and the density of users is low enough, a tracking algorithm can accurately estimate the trajectory of a single user. Furthermore, if a user's trajectory goes through sensitive or identifiable places, a user might see this as private information and these places may also provide connections to the user's identity. For another example, equipped with some devices, an attacker can determine the source location(s) originating messages by analyzing the traffic patterns even if the communications are all encrypted. Since it is then possible for them to interfere with the phenomena being sensed or even mount physical attacks on the monitored objects, the exposure of the source location information can be quite dangerous.

5.4. Data Monitoring and Prediction of Risk

In order to keep monitoring acceptable and handling the prediction of risk the system must be on a practical level, especially if it is a city-wide system. Redundant systems have to be in place take care of lost or missing sensors. Maintenance will always be a major challenge, for the systems have to be repaired quickly and economically. Also, like any intelligent system, the data has to be trained. Ideally, if a disabled person can fit a key, recognizable role, then a basic training set could be used to calibrate the system. (Hip replacement patient vs. diabetic vs. hearing impaired would all have both individual and overlapping patterns) The challenge in data monitoring would involve being able to combine the many different types of data into a form that was usable across a similar framework. Another challenge is how to best fit the risk information to the given data in a reasonable time frame.

5.5. Minimalistic Transportation Support

Even now, vehicles are mounted with location and tracking sensors. Such existing systems would have to be expanded to handle a real-time tracking of the vehicle. Alternatively, a digital city would have wireless access near key public buildings. When a vehicle comes close to a public building, the on-board computer could hand-shake with the public building to confirm its location and arrival time. An embedded computer could do this task. Alternatively, some wireless motes, given sufficient power support, could also meet this challenge by performing as an active tag for the vehicle. Also, public cameras can record the arrival of vehicles and even count the number of passengers who exit and enter a public building or embarkation area. The challenges that any of these systems face is three fold. The first challenge is to gather the practical, physical data and translate it into information that can be used by the computer. The second challenge would be to translate the data into a usable form. The third challenge would be to broadcast the result to where it would be useful.

6. Conclusion

Wireless networks now span most urban areas. Cell networks, mesh networks, and wifi networks are all in use for various purposes around the city. Everything from elementary schools to coffee houses now sports an antenna, and even young children have a cellphone to keep in touch with their parents. Such a saturation of technology suggests that a city-wide medium will emerge from the jumbled signals that can be used beneficially. With the arise of microelectric mechanical devices, smart-phones, and wearable medical devices, an individual living at home would be surrounded with a cloud of information to be shared, and have access to information that can be used. In turn, the individual user devices would work not just at home with the medical monitoring services, but also be able to interact with a citywide network to provide assistance with public transportation and appointments. Key issues arising from such a system include social issues about acceptance and training with the technology, and even the security needed to safeguard the user from both physical and digital attacks. The interfacing of multiple systems has to be addressed, and public vehicles would have to be altered with the minimum of cost. With the arrival of miniature electronic devices and the emergence of city wide networks, assistive devices would be extended to have multiple functions and operate beyond the home and in the city streets.

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