Using RFID and Wi-Fi in Healthcare

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Abstract

Europe faces a considerable challenge in providing good quality health care in the forthcoming future as the aging population increases. The phenomenon also results in a considerable cost on society due to the dependency on the public health sector particularly because such individuals would not be able to contribute to the economy. On the other hand, younger persons would need to make alternative arrangements to assist their elderly parents or relatives, potentially affecting productivity. The project PervasIve Nursing And docToral Assistant (PINATA) seeks to tackle this matter through the merging of Ambient Intelligence (AmI) and semantic web technologies. PINATA utilises pervasive devices to aid doctors and nurses to focus on the patient and thus improve the quality of healthcare services. This project proves the significant importance of using wireless technology in healthcare. This paper focuses on the use of Wi-Fi and RFID in an effort to enable continuous and intelligent monitoring of patients' conditions remotely. Results show that the detection system performs well (over 80%) accuracy on fall detection and the manual readings mapped 100% with the results collected by the system over the Wi-Fi infrastructure discussed in this paper.

Keywords

Ambient Intelligence, Health Care, Mobile Technology, Context Awareness, Semantic Web, Ontology, Pervasive Computing

Introduction

The world's population is aging at an astounding pace (United Nations, 2002). As stated by a United Nations report (United Nations, 2002), the percentage of elderly people (over 60 years old) is set to go up from 10% in 2000 to 21% in 2050. Worryingly, this tendency is emphasised in Malta where 2005's approximation of an 18% aged population is anticipated to increase to 35% by 2050 (United Nations, 2006).

This communal occurrence will have major consequences in numerous aspects of life. Unavoidably, this longevity will have an effect on healthcare, family arrangements, family care and living arrangements. One of the consequences will be a larger demand for long-term care. The fundamental result of this will be a certain fall in the proportion of nurses and doctors to patients.

Novel technological solutions are essential in order to effectively address these challenges. For this purpose, scholars have been suggesting the employment of Ambient Intelligence (AmI) techniques to help nurses and doctors in their work (Rodriguez, Favelaa, Preciado, & Vizcaino, 2005), as well as to back the concept of ageing in place (Nehmer, Karshmer, Becker, & Lamm, 2006), (Friedewald, Da Costa, Punie, Alahuhta, & Heinonen, 2004). Medical personnel are very mobile and frequently share available resources. Given that the focus of their work is the physical health of patients, digital content should proffer assistance in decision processes (Kummer, Bick, & Gururajan, 2009). Ambient intelligence is well suited to assist medical practitioners in a number of areas. Together with mobile technologies it can improve patient identification processes, for example by using RFID tags holding limited information concerning the patient and therefore prevent mistreatments owing to errors at some phase in treatment (Andersen & Bardram, 2007).

This paper aims to build on this motivation behind the PINATA project in order to effectively explore the use of Wi-Fi and RFID in healthcare. After justifying the motivation behind such applications, this paper presents a survey of applications of RFID and Wi-Fi technologies in healthcare. A number of cost-effective applications are presented together with their respective standards that safeguard the effectiveness of these applications.

Technological Background

The (IST Advisory Group (ISTAG), 2005) claims that in an Ambient Intelligent (AmI) Environment, people will be surrounded by intelligent interfaces that are backed by networking technology and computing that is embedded in everyday items. In addition, they argue that an AmI environment should be receptive of the individual characteristics of human presence and personalities by changing in line with the needs of the users. They say that such an environment must be able to react intelligently to signalled or verbal requests and maybe even engage in an intelligent dialogue while being unobtrusive. Moreover, they assert that the interface should not entail great learning curves and should be comfortable and enjoyable to the user.

RFID in Healthcare

Minor errors can cost vast financial and personal losses in an area such as healthcare, thus a major aim for hospitals and healthcare systems is that of improving functioning effectiveness, however, upholding efficiency and watching over each patient is a difficult task (Pandey, 2011). RFID (Radio Frequency Identification) is a technology that makes use of electronic chips embedded on tags which transmit radio waves, and thus can help recognise products, medical records, assets and individuals (HIBCC).

Application

Appropriate protocols and the utilisation of RFID technology could avert outbreaks such as patients being exposed to diseases when infected equipment is used by making sure that instruments are correctly tracked and classified (Reiner & Sullivan, 2005). The authors claim that owing to RFID's robust application abilities, this technology is currently creating noteworthy appeal in the market. They maintain that since RFID functions with no line-of-sight at the same time as supplying read/write means for dynamic item tracking, it enables the stepping up of overall safety and operational efficiency at healthcare facilities. Although at first RFID came across an unenthusiastic reaction in this sector, it is turning out to be a vital function of healthcare (Pandey, 2011). Pandey highlights some areas in healthcare where RFID is being used including: deterrence for drug faking; inventorying and stock taking; instrument safety; packaging; accountability and product safety; and patient tracking and information.

Patient Tracking

RFID is being used to follow and authenticate patients (Sini, Locatelli, & Restifo, 2008), (Datamonitor, 2004): bedside care and mother and baby matching employ LH (low frequency) and HF (high frequency) technologies while movement monitoring makes use of UHF (ultra high frequency) (GAO RFID Inc, 2011). Companies are at present using RFID technology in the healthcare industry as a means to improve patient safety and enhance inventory organisation abilities (Reiner & Sullivan, 2005). The United States Navy substituted a manual patient location system in Pensacola Fleet Hospital in Iraq with an RFID system, where RFID-enabled wrist bands are used to recognise, track down and get status updates of patients (Precision Dynamics Corp; Texas Instruments, 2003). Similarly, RFID-enabled wristbands are frequently used on newborn infants in order to give precise identification and maintain their safety and for Alzheimer patients, where coupled with RFID readers installed at doors, location can also be ascertained, thus preserving their safety should they go into unauthorised sections (Zebra Technologies, 2003). Benefits of such patient tracking systems include: less room for mistakes; faster and better care since the tag would have all the significant information that a member of staff might require such as what care a patient needs and what medication they have already received, thus allowing staff to be aware of what is going on with each particular patient (Lizl).

Asset Management

An RFID network will be employed in each of three Virginia hospitals managed by Bon Secours Richmond Health System so as to control the location of tagged medical equipment and movable assets; each hospital would be able to determine if about 10,000 items are in operation, obtainable or if in need of servicing (RFID Journal, 2004), (Datamonitor, 2004). The use of RFID is reducing the possibility of failing to notice things, like sponges, after an operation by means of tagging everything used in a surgery by LF technology and then, when the procedure has been concluded, the patient is scanned to confirm that nothing has been left behind (GAO RFID Inc, 2011), (Sini, Locatelli, & Restifo, 2008), (Lizl). High-cost items, whose supply chain is complicated, are often supplied in batch and necessitate a high degree of traceability from supplier to patient, such as, pacemakers, artificial joints and defibrillators, may also benefit from RFID tagging (HIBCC), (Sini, Locatelli, & Restifo, 2008), (Datamonitor, 2004).

Helping patients

One more application for RFID technology is in prescription bottles used by visually-impaired persons, where they can use devices located on prescription containers to verbally get information about the prescriptions and the dosage amounts owing to speech conversion technology (Zebra Technologies, 2003). It can also be used for helping out with self-medication

for seniors where patients would be able to track the location of their medicine and whether they have already taken it (Datamonitor, 2004).

Waiting Time Monitoring

Patient wait times can be checked in real time by reusable active RFID technology, such as enabling ER staff to observe precisely the number of patients in queue and the length of the waiting time per person (GAO RFID Inc, 2011).

Medication and Medical Items Verification and Management

RFID, typically HF technology, is used to make sure that the right medication is given to the right patient while providing added privacy to the patient (GAO RFID Inc, 2011), (Datamonitor, 2004). The Italian National Cancer Institute is attaining a superior ability for monitoring and controlling the transfusion system with the use of RFID, with the goal of enhancing safety, quality and transparency: tags are affixed on blood bags and patients are provided with wristbands, while staff use PDAs to register patients on admission and verify their blood type (Sini, Locatelli, & Restifo, 2008).

Hand Washing

Observance of hand washing protocols was improved with monitoring at the hand cleaning stations at touch points by having workers carry an RFID badge and hand wash stations equipped with RFID readers so that whenever the station is utilised it will record the user's identity and the duration of the stay facing it, the accrued data of which will permit an organisation to understand how well the protocols are being abided by (GAO RFID Inc, 2011).

Inventory

RFID can help with the management of the supply inventory by offering immediate and remote visibility and managing shared storage areas, for example, locked pharmaceutical cabinets, access to which can be controlled, restricted and reviewed using HF RFID (GAO RFID Inc, 2011), (Datamonitor, 2004).

Parking Management

RFID can be used to control parking, both reserved and public by recording the entry and exit times of each visit on which billing can be calculated depending on the length and the time of stay, which system can be automatic, standalone and unmanned: for public parking control HF technology is used while for reserved parking diverse technologies can be used, such as HF, UHF or even active RFID (GAO RFID Inc, 2011).

Access Management

Managing access to restricted areas can also be done through RFID where, for the most part, LF or HF technologies are employed since they require contact and thus permit for higher security while providing for unmanned access control with audit trail information (GAO RFID Inc, 2011).

Document Management

Patients' files and records can be located and tracked through UHF RFID (GAO RFID Inc, 2011), (Sini, Locatelli, & Restifo, 2008).

Facilities Management

Other parts of the healthcare facilities can benefit from RDIF including: tagging key service points with RFID will enable service technicians to know what and how to perform particular services; laundry management; and waste management (GAO RFID Inc, 2011), (Sini, Locatelli, & Restifo, 2008), (Datamonitor, 2004).

Cost

The healthcare industry has been slow in taking on RFID technology for a number of reasons, but mostly since pay offs are not noticeable right away as generally companies desire, and even though prices are falling, numerous companies are unwilling to spend money on a technology not extensively accepted up till now (Reiner & Sullivan, 2005). RFID costs are likely to decline considerably: RFID tag expenses dropped to around 20c while key chain sized and shaped readers cost less than €400. Thus, even now, RFID is expensive, not plug-and-play and has not established its reliability in major implementations up till now (HIBCC).

Other Limitations

HIBCC list other limitations for RFID:

- Tag reliability can be influenced by environmental conditions like humidity, metal surfaces and extreme temperatures, which make tagging objects such as surgical instruments more complex.
- It is not easy to apply and read tags on metal and fluids and this restricts tagging to cardboard, plastic or paper at present, thus limiting its application.
- At this stage, interoperability between various RFID standards is not offered, for instance, having tags with multiple frequencies being read with a single reader.

Standards

HIBCC explain that RFID, being a complex technology, comprises many components each of which need standardisation so as to attain interoperability. The authors continue to claim that as there are many standards related to RFID, they can be confusing. They maintain that standards can be split into two broad groups: those associated with the transmission frequencies and parameters for communication between tag and reader; and those related to RFID systems. ISO/IEC (International Organisation for Standardisation / International Eurotechnical Commission) is the principal global organisation that supervises these standards. The ISO/IEC 18000 series ("Information technology – Radio frequency identification for item management") specifies air interface standards which contains a number of parts: specification of the reference architecture; and several communication for item management – Data protocol: application interface) and the ISO/IEC 15962 ("Information Technology – Radio frequency identification for item management – Data encoding rules and logical memory functions") describe data and application standards.

Wi-Fi in Healthcare

Wireless networking has rapidly become a significant feature of everyday life in hospital IT environments which has led to a rise in the correctness and effectiveness of hospital processes, which has in turn led to patients who are more content and better assisted (AirMagnet Inc, 2005). Wi-Fi systems are adaptable to extend and modify to the altering needs found in hospital settings ranging from PC networking development to the large number of Wi-Fi devices on the network, varying from smart phones and tablets to monitoring devices (Wi-Fi Alliance, 2011).

Application

Electronic Medical Records (EMRs) access

EMRs can be accessed wirelessly, medical administration can be made more precise with the help of technologies like RFID, and tests or prescriptions can be ordered at the bedside through handhelds (Thornycroft, 2010). Prescriptions can be sent to the patient's pharmacy and the system can automatically check for the patient's identified allergies and incompatible medicine, thus improving accurateness and safety at the same time as reducing paperwork (AirMagnet Inc, 2005).

Instant Communication

Through Wi-Fi phones nursing staff will be able to communicate and be contacted wherever they are currently working through the use of messages and nurse call systems (Thornycroft, 2010).

Services for Guests

Internet services and connectivity targeted for guests, such as visitors, can be provided (Thornycroft, 2010).

Patient Monitoring

Cardiac patients can be monitored as they walk round the hospital through cardiac telemetry systems, while, in general, patients can benefit from portable bedside monitoring, thus avoiding the requirement for bedside Ethernet connections and from other mobile equipment, for example wearable monitors and smart pumps (Thornycroft, 2010).

Real-Time Location Systems (RTLS)

These systems permit for the tracking of hospital staff via the Wi-Fi devices, in addition to the monitoring, tracking and retrieval of mobile equipment, for instance wheelchairs and infusion pumps (Thornycroft, 2010).

Standards

The list of apprehensions when setting up any wireless LAN is characteristically topped by security, and surely hospitals are no exception especially considering that patient information is certainly one of the most sensitive data to pass through any network; thus, federal HIPAA (Health Insurance Portability and Accountability Act) have set up far-reaching standards stating how this data should be protected and while allowing organisations to decide on which technology best suits their exclusive requirements, they are unambiguous as to what quality standards these solutions have to meet (AirMagnet Inc, 2005). For Wi-Fi client devices and networks, the main part of the Security Rule is section 164.312, which registers technical precautions in the fields of access control, audit controls, integrity, authentication and transmission security (Wi-Fi Alliance, 2011).

PINATA - A proof of concept

PINATA is a system that uses AmI to aid doctors and nurses in upholding high levels of service (Dingli & Abela, 2008). This demonstrates the importance of wireless technology in healthcare. The results of this project were attained due to an amalgamation of Wi-Fi enabled tags related

to and worn by doctors, nurses and patients and Wi-Fi software tags, which are software clients installed on handhelds so as to accomplish the identical functionality as the physical tags. A particular kind of tag that reports location and temperature readings is utilised in the store's refrigerator to monitor its ambient. Pharmaceutical boxes have passive RFID tags affixed and are then tracked by an RFID portal and RFID handheld readers. The Kinectⁱ camera, which is a 3D camera, is used as an alternative to traditional video cameras, which produce a flat image. These are set up in patients' rooms, with the aim of keeping an eye on and ensuring patients' wellbeing. Handhelds are used by doctors and nurses to manage patients' records and to receive alerts when required. In combination with these handhelds, keychain sized and shaped RFID readers are used so as to provide interactivity with a variety of tagged items.

PINATA's design was based on a number of possible scenarios. Some of these aim to provide higher safety for the patient. For instance, the system intends to supervise the associations between items, drugs and patients. All items are tagged, like blood and medicines, with RFID tags. Patients are tagged and tracked via Wi-Fi tags. When drugs are going to be administered to a patient, the system checks that the right drugs are going to be given to the patient. Same goes for blood, for instance, the system checks that the right blood is going to be given to the right patient, otherwise the system will immediately alert the nurse or doctor who is in the room. The system is also planned to realise, for instance, when incompatible medicine is within range of the particular patient. Other scenarios tackle hospital equipment. All equipment is tagged with Wi-Fi tags. When equipment is to be used on a patient, the association is made. The idea behind tagging the equipment with Wi-Fi tags is so that at any given time, PINATA can locate the equipment to room level accuracy. The same RTLS used to track patients and staff is being used to track equipment, obviously with appropriate tags. Other scenarios tackle the location of patients. For instance, when a patient is taken into an operating theatre, the system will check whether that specific patient should be in the operating theatre at that particular moment in time. If, according to schedule, the incorrect patient is tracked in the theatre, alarm will be raised. The system will also check that no patients or visitors are in unauthorised zones. In case it detects people in such zones, the system will alert the nearest member of staff and/or the carer associated with the particular patient. The system might also check that when a particular operation is taking place, the right part of the body that was scheduled to be operated upon is actually being treated.

Ubiquitous and Seamless Monitoring

Through PINATA, the movement of patients and medical staff is tracked via RFID sensors while an automated camera system observes the interaction of people within their surroundings. The system acts in response to specific circumstances autonomously by guiding medical staff towards urgent situations in a timely manner and supplying them with only the information they need on their handheld devices. This makes sure that patients are given the finest care possible on a 24/7 basis particularly when the medical staff is not near.

Ambient Assisted Living (AAL) systems can be used for a variety of tasks such as monitoring the patient's permanence in the hospital, locate medical records, examine patients' diets, track movement and sense unpleasant incidents, such as falls. Back-end intelligent systems are expected to examine the feedback gained by means of the diverse sensors situated all-round the hospital and advise a reasonable option for the medical staff.

AmI builds on three important technologies: ubiquitous computing, ubiquitous communication and intelligent user interfaces (Bravo, Hervas, Chavira, & and Nava, 2006). Ubiquitous computing denotes the addition of microprocessors into everyday things like clothing, toys, furniture, paint and white goods. Ubiquitous communication allows these things to communicate with each other and with the user by unplanned wireless networking. Intelligent user-interfaces facilitate people in the AmI environment to manage and interrelate with the environment in an innate (gesticulation, speech) and personalised method (context, preferences) (Ahola, 2002). In AmI, people are empowered via a context aware environment that is responsive, adaptive and receptive to their requirements, behaviour, motion and feelings. It is expected that by presenting intelligent environments, cost and quality control can be enhanced and new intelligent personal health services can be developed.

The five rights of patient care are frequently specified as right patient, right drug, right dose, right route and right time (Jervis, 2005). Due to technologies such as RFID, it is likely to promote incorporation of the digital and the healthcare worlds to uphold those five rights and to link care and processes. This technology was employed to provide personalised visualisation of patients' information, including images as well, to doctors during clinical sessions (Bravo, Hervas, Chavira, & and Nava, 2006). In another case, a pilot implementation was done which consisted in monitoring of person and patient logistics in operating theatres, tracking and tracing of operating theatre materials and tracking and tracing of blood products (Capgemini, 2007). RFID technology is being foreseen as playing a very significant role in the healthcare sector (Reiner & Sullivan, 2005).

In PINATA, the patient has a WI-Fi enabled tag. A Real-Time Location System (RTLS) perceives the movement of the patient and transmits the information to the system. This makes certain that the patient's locations are constantly known by the medical staff. Handheld devices are used to give the staff a variety of kinds of information including alerts related to patients' medication schedule. When a nurse is in the proximity of a patient, the system realises this and can automatically show the patient's information.

PINATA makes use of a camera-based monitoring system which tracks the movements of patients, via image processing and in case of an emergency warns the nurse. To guarantee that this system by no means causes a threat to the patient's privacy, images are not recorded by the cameras. A characteristic situation in which this system turns out to be vital is that in which a patient passes out and falls in his/her room. Information captured through the camera is collected and studied by the system which activates an alert that is sent to the nurse. The RLTS is used to track the nurse who is in the closest vicinity to the patient in distress. The system, in addition, uploads automatically on the nurse's handheld device, the entire information necessary for that precise context.

After patients go back to their homes, a home version of PINATA can be installed in their homes. This is possible because of the fact that PINATA is based around SOA architecture. Therefore, it is possible to have cameras and sensors installed in houses while the processing and interpretation of the captured data is sent to the main hospital servers for continual observation. By doing so, the care offered by the hospitals can be extended to the community, consequently making it likely for more patients to spend less time in hospitals and more time recovering in their homes. Once in homes, PINATA can be further extended to deal with other facets of health-care and safety so as to enrich the quality of life.

Marsh et al state that effective care co-ordination tools can provide a non-invasive health status monitoring that could also have a positive effect on the quality of life of the individual being monitored, in addition to decreasing the endeavours of the care givers (Marsh, et al., 2008).

After discharge from hospital, certain conditions, such as congestive heart failure, will require close monitoring by doctors. Yet, this can present lots of impediments, like lack of ample resources and facilities and patients not acting in accordance with the health care plan, which can lead to aggravation of the disease (Reynolds, 2009). Recent studies have found that patients' remote home monitoring can link the after discharge care which leads to more positive outcomes. Reynolds refers to a study by Sally C. Inglis (Inglis SC, 2010), of Baker IDI Heart and Diabetes Institute in Melbourne Australia where 27 studies involving over 9500 patients receiving heart failure management support, either through telephone support or through telemonitoring with digital, broadband, satellite, wireless or Bluetooth transmission of physiologic data were reviewed. The patients' condition calls for vigilant monitoring of vital signs such as blood pressure and heart rate, as well as weight, since rapid weight gain can be a sign that the patient is retaining fluid and that can worsen the heart failure. Both approaches resulted in a drop in heart failure related hospitalisations, in addition to an improved observance of the suggested treatment plan by the patients. Additionally, in nine of the studies, a significant improvement in the quality of life was evident. Dr Inglis is quoted by Reynolds as saying that monitoring the condition of patients in their own home frequently, may potentially allow for the identification of the moment when the patient's condition is waning.

Thousands of critically ill patients are already relying on computerised health trackers to help out in keeping them safe at home (Freudenheim, 2010). Freudenheim refers to a system being currently tested at the Mayo clinic. The article describes a device that reminds the patient to monitor their health in the morning by lighting up and beeping. Patients are cued to pull on a blood pressure cuff so that their pressure and pulse readings are displayed and to slip their forefinger into a sensor used to measure blood oxygen. A scale linked to the device checks the patient's weight. The device tells the patients if they are well. The device will also display a series of Yes/No questions and a nurse would contact the patients if the replies are a cause of concern. According to researchers, devices such as this can be of assistance in motivating patients, especially elderly ones, who are suffering from chronic conditions to follow the doctors' and nurses' advice and to participate in their own care. Doctors are reported as claiming that home health monitoring is often less expensive and turns out better health results than sporadic checkups and repetitive hospital stays.

According to another study, heart failure patients using interactive telehealth systems with motivational support tools at home spent less time at hospital and their quality of life was reported significantly improved over an evaluation period lasting 12 months (Monegain, 2010). Patients were able to take vital measurements at their home and then pass on the information to their doctors via the system. They were also able to receive educational and motivational information from their doctors in order to help them manage their health. Monegain quoted Josep Lupon, the head of the Heart Failure Unit and main researcher of the study as claiming that providing educational support to patients via their television drastically contributed to their empowerment. Lupon also claims that the study showed that circulating disease and patient specific information via their television ameliorates the family members' understanding

of how to support their loved ones well in dealing with the disease and this looks as if it has a very strong impact on the results.

Particularly with cardiovascular care, telemedicine and home health monitoring are not something new, however, with new technology it is taking on new dimensions (Chappell & Vanden Plas, 2008). Jonathan Edwards (Edwards, 2010), research vice president for Gartner and a lead analyst on telemedicine is quoted as saying that the home monitoring field now embraces technology such as sensors for remote diagnosis, remote cardiac monitoring, teleretinal imaging, video conferencing, teleradiology, home and mobile health monitoring and advice to patients. Edwards (Edwards, 2010) is quoted as saying that daily monitoring allows doctors and nurses to keep an eye on their patients both in the event of an emergency and in order to plan for any new developments in their condition upfront. It may also be possible to, one day, allow for a patient's family to access the information remotely, but it will depend on the issues surrounding patient privacy. This would allow for the fantastic proffering for families to care for their loved ones remotely since they would be able to check, for instance, that their vital signs are in line or that they are taking their medications or even monitor them via camera.

Such systems provide the relief and autonomy of staying at home on top of the security of being monitored daily and being given proper medical attention (Aurora Health Care, 2011). Typical existing systems consist of compact monitor and a scale. The system accumulates a variety of vital signs such as oxygen saturation, heart rate, temperature, blood pressure and body weight on a daily basis. The data would be sent to hospital where medical staff reviews the information and takes action aptly. Should there be a change in a patient's health status the medical staff will contact the patient. Benefits from such monitoring include proactive and preventative care; early detection of clinical needs, modification to the treatment plan and medications; reduction in emergency room visits and unexpected hospital stays; improves patient conformity while encouraging patient education and management of themselves.

Technology Concerns

Marsh *et al* record a few main features for the challenges of health care monitoring technology (Marsh, et al., 2008). These include:

- Reduced cost of care, which is predominantly high for older adult populations;
- Reduced strain and better mental and health conditions arising from the decreased burdens on the care givers;
- A widely accessible complete, active and dignified life for the people forming part of the low-income band of society;
- Involving the recipient in activities that promote health and decision making;
- Implementing the system using straightforward and not expensive sensor technology so as to make it affordable to the lowest income earners;
- Adaptively fits into existing home constructions, with least impact, change and cost;
- Exclusive health status reports could be generated through data mining components, which reports could be made accessible to the medical advisors, physicians and family members;
- Systems should be customisable to the needs of the individual on top of numerous cultural needs.

The utilisation of numerous devices from diverse vendors can result in a range of problems, like uncommon standards for data exchange and wireless and wired connectivity; different models of usage like using devices with the same function in another way; and having no connectivity between the devices (Isken, Frenken, Brell, & Hein Offis, 2011). Isken *et al* claim that with a general standard for AAL technologies and data exchange, such problems could be managed. However, they also point out that even if the same vendor provides all devices, stationary devices continue to be a problem. This is because the devices have to be adapted to every individual home and person and this could prove pricey.

Edwards, in (Chappell & Vanden Plas, 2008), claims that the major barrier is not the devices themselves but the transmittal of data from the devices and the deficiency in an infrastructure to monitor and perceive the data. The information assembled cannot be compared to normal health criteria without an apt recording system, and as a result is of limited use to the doctors. Developing such record system can be expensive which in turn can prove a problem.

Recommendations

When deciding on what technologies to use for the project, four major technologies used in locating systems were reviewed. Whilst all of the solutions analysed can be used for some of PINATA's scenarios, not one of them fully satisfied PINATA's functional requirements. Passive RFID tags are the only ones suitable to tag all assets including small consumables. All the other technologies, on the other hand, outperform RFID in terms of proximity detection. Due to this conflict, the team decided to opt for a hybrid solution in which different technologies would locate different resources. Pharmaceuticals would be tracked through passive RFID tags, and hence a portal reader will be installed at the store room where consumables are stored. Installing the RFID portal reader at the remote store room site also eliminated the risk of interference with medical equipment.

Ultrasound solutions were eliminated because they provide a coarse room level granularity, do not provide sensor tags, are limited in multi-tag reading and have a poor track record with regard to hospital deployments.

RFID/IR solutions were also eliminated as they relied on IR for room-level accuracy, and not all required tags are IR enabled. This meant that some assets could be tracked exclusively via RFID readers and only a few via both RFID and IR. Furthermore, IR locators require a line of sight for the tag to be read which is rather unfeasible in practice.

Hence it was concluded that Wi-Fi would be the most appropriate technology to track assets other than consumables. Wi-Fi suppliers provide a wide variety of tags, including sensor tags, and have a very good track record in the medical industry. Moreover, Wi-Fi systems do better than other technologies with respect to technical criteria, and are competitive cost-wise.

Technology Components

Context-awareness is of significant importance within AmI projects. Hardware that is capable of sensing a variety of contextual components, for instance location, light level and temperature, can be used to obtain contextual information. Furthermore, such systems call for unobtrusiveness. Therefore, wireless networks are used for data transfers. This section examines PINATA's infrastructure detailing the devices and the types of networks utilised.

Devices

Four device systems are used in PINATA – two of which provide input while the other two provide both input and output. Hospital resources are tracked by the Real-Time Locating System (RTLS), while the Visual Tracking System (VTS) keeps an eye on the patients making sure of their welfare. Handheld devices are used by staff so that appropriate and context aware information is presented to them, consequently assisting them in their job. Guest devices brought into PINATA's range are also looked for and utilised.

Real-Time Locating System (RTLS)

The RTLS tracks and locates tagged resources. The movement of humans and objects inside the hospital is tracked within PINATA using such a system. Four main technologies employed in locating systems were assessed: passive RFID, active RFID/Infra Red, Wi-Fi and Ultrasound. As argued above, while all of the solutions examined could have been used for a number of PINATA's scenarios, none of them completely fulfilled the functional requirements. Passive RFID tags proved suitable to tag all assets including small consumables however the technology failed when compared to the others when it came to proximity detection. Because of this shortcoming, the team chose to adopt a hybrid solution where different resources are located using different technologies. RFID tags are being used to tag pharmaceuticals and Wi-Fi is being used to track the rest of the resources including staff members and patients.

Visual Tracking System

Computer vision has, in recent years, made giant strides both in hardware and software. The constant improvement in cameras' picture quality means that today inexpensive webcams can be used for varied scenarios. This technology's non-invasive qualities make it favourable to pure AmI solutions and this is why the visual tracking component in PINATA was held as necessary. At first, the use of wireless, IP cameras that exhibited night-vision, two-way audio, together with pan and tilt features was considered. Nevertheless, the latest release of Kinects allowed for additional thought. The Kinect controller was preferred because of its reasonably priced sensing abilities. Through it PINATA will provide for the creation of a 3-D map of a patient's room, the identification of the human presence in the room, in addition to the capacity to react to human movement or the lack of it.

Handheld Devices

New and important developments in the area of handheld computers now let them deal with much of the standard functionality traditionally associated with desktop computers. Some of these computers have as features extra input peripherals which could be linked to AmI systems, for example, RFID readers which are essential for location awareness, microphones which provide for sound awareness, and cameras which provide visual awareness. Handhelds provide portable and unobtrusive information access in PINATA. Within PINATA handhelds are the most important output devices. As handhelds support Wi-Fi, they can integrate with the Wi-Fi based RTLS system with no extra hardware tags necessary. However, since these handhelds were going to be used by doctors and nurses while on the go, a larger screen size was preferred. This requirement rules out RFID-enabled handhelds right away for the reason that they tend to have small displays. It was thus decided to go for internet tablets, so that it would be comfortable enough to work with and not too bulky to carry around. These handhelds need an external RFID reader given that they do not come equipped with internal

RFID capabilities. There are diverse readers currently on the market. A key-chain sized and shaped reader that communicates with the tablets using Bluetooth was chosen.

Guest Devices

PINATA takes advantage from guest devices, which can be thought of as free resources. Since mobile phones operational at present have a lot of diverse capabilities, network support and platforms, PINATA will query each device and alter its services according to the particular device.

Architecture

PINATA is mainly enabled to use the Wi-Fi network infrastructure for data communication between its diverse devices. In addition, Bluetooth is utilised for communication with guest devices that do not support Wi-Fi, even though these days, Wi-Fi enable smart-phones are on the rise. The architecture consists of a range of decentralised applications referred to as *nodes* and a centralised application referred to as *manager*. *Nodes* are custom-applications written purposely for a specific device or device system. The RTLS, the VTS, and every handheld and guest device are regarded as *nodes*, as can be seen in Figure 1.



Figure 1 PINATA physical design

A desktop computer will host the *nodes* for the RTLS and VTS since they are both limited resources. On the contrary, each handheld device hosts its own node since they are looked upon as autonomous devices. The input *nodes* (RTLS, VTS and handhelds) will provide the required context while the handhelds act also as output *nodes* since they are reporting devices. The function of the *manager* is twofold: (i) to support the development of the *nodes* through the provision of shared libraries via web services and (ii) to direct the events and services of all the *nodes*. All communication within the system is through Wi-Fi. As a result Wi-Fi communication channels exist between the Wi-Fi tags and the desktop hosting the locating node; the VTS and the desktop hosting its node; and between each handheld and the desktop. The requirement that the *manager* might need to call a particular device, makes this loose coupling between the *manager* and *node* compulsory. In the case of the RTLS and the VTS loose coupling is

not essential since the applications hosted on the same desktop can be logically merged into a single software application.

A vital design task has been the choosing of a development and semantic web framework with which to write the application code. Preference was given to Java and Jenaⁱⁱ. Jena provides an RDF and SPARQL API and a rule-based inference engine. This choice was influenced by the fact that Jena, which is a Java-based semantic web library, has strong developer and user backing and has a wider assortment of APIs and reasoners. In addition, aside from offering an RDF and SPARQL API, Jena boasts high-quality inference support that comprises RDFS and standard rules-based reasoners. Additionally, using Jena is also in line with the team's commitment to use Open Source and thus keeping costs low.

Services offered via RFID and Wi-Fi

In case of an emergency, such as there being a fire in the hospital, the system would know how many people are present in the building and where they are. PINATA would provide this data to the hospital's health and safety officers and direct people in the hospital to the nearest exit. The RTLS reports on the presence and location of the people. PINATA would advise staff via their handhelds and visitors via their guest devices such as smart phones.

PINATA also monitors unauthorised zones so as to make sure no visitors step in any of them. Should this happen, the system would first warn the person concerned via their guest devices, and if they persist, a nearby staff member would be alerted via their handhelds. Similarly PINATA monitors exits so as to ensure that no one exits the building in an unauthorised manner, in which case the system would alert the person's carer or immediate supervisor via their handhelds.



PINATA's knowledgebase associates patient history, allergies, and other relevant information to the patient's tag. For that reason, when a member of staff enters a patient's room, the system would direct the patient's data to show up on their handheld and it should also realise if a

patient is in the vicinity of incompatible medicine, or that the person in the operating room is not the right one for surgery.

A temperature tag is attached to a refrigerator so as to monitor its ambient. Should it detect incorrect ambient conditions the hospital staff is alerted. Similarly, such tags can be attached to products like blood, organs, drugs, vaccines and tissue samples, in order to detect if they are stored in the correct ambient conditions and hospital staff is alerted otherwise.

PINATA is also able to help staff locate equipment by providing location information of missing assets. The system is also able to provide statistics like average waiting time by patients to be seen by consultants.

Benefits of PINATA

Following the implementation of PINATA, one can easily identify the following numerous benefits, including:

- Administrative mistakes are decreased;
- Labour expenses are lessened as there will no longer be a need for scanning bar codes, which are typically processed one by one, unlike RFID tags which can be scanned simultaneously;
- Internal theft and misplaced supplies are diminished;
- Inaccuracies in shipment of goods will be cut down;
- Inventory levels can be trimmed down;
- Once there is better efficiency in the supply chain, there will be lower overheads;
- Reduce out-of-stock situations;
- Diminish the time staff uses searching for inventory;
- The use of current inventory can be optimised;
- Inventory replacement can be enhanced;
- Superior identification of inventory to be ordered;
- Real-time knowledge of staff's, patients' and items' location;
- Processes and people can be better managed;
- Since existing network infrastructure was used, there are no costs, construction and disruptions for installing equipment;
- Improved security and monitoring results in safer working environments.

Social Concerns

Pervasive architectures such as the one presented here raise several issues of security and privacy. In fact ISTAG lists security as one of the top five foundation technologies for the AmI vision (ISTAG, 2001). The following security features need to be built into such systems:

• Authentication: Authentication is the process by which one proves his/her identity. A number of authentication protocols exist, of which Kerberos (Communication Magazine, 1994) is one of the most widely used. Kerberos-based authentication has been used successfully in AmI projects.

- Authorisation: Authorisation is the act of granting access rights to a particular entity. Authorisation typically entails defining and enforcing access policies, and thus a policy language can be used.
- **Encryption**: Information transmitted between devices and the centralised system is sensitive and confidential. For this reason, this information has to be encrypted. To provide transport layer security, SSL certificates are commonly used in distributed networks.

Further to these security features, systems should be considerate to its users' privacy requirements. The technological elements of AmI systems collect personal information about users, and some users might feel threatened. Thus, users should have the possibility of switching off any of the devices that are monitoring them.

Discussion

Results

This system was tested using a module that was challenging to test as this involved simulating falls by people within the view of the Kinect Sensor. Furthermore, the results collected from this module were successfully transmitted using the infrastructure discussed above. A parallel observation was held manually in the room with the test subject and matched exactly the results registered on the framework. This showed that the infrastructure was capable of correctly processing the feeds from its satellite modules.

When simulating falls it is difficult to act exactly in the same way as a normal person would fall, since the person simulating the fall will instinctively try to break his/her fall in order to not get hurt.

Testing was performed by 4 different subjects and 3 different types of falls were tested: forward fall, sideways fall and backwards fall. Apart from the previous tests another was performed were the user would bend forward to determine whether the module detects false positives as well.

Fall Type	Attempts	No. of	No. of	Accuracy
	_	Detected	Undetected	-
		Falls	Falls	
Forward	40	36	4	90%
Sideways	40	38	2	95%
Backwards	40	32	8	80%
Bend (No	40	10	30	75%
Fall)				

Table 1: Results of Pose Recognition Testing

The results show that the implementation suffers from detecting false positives when some users bend. Upon further testing it was discovered that the issues are being caused because of the accuracy of the joint co-ordinates that are determined by the Kinect Sensor when the user is in certain positions as well as on the angle that the subject can bend to. (More flexible people can cause the angle to be very close to 90 degrees). Due to this we have added functionality to

this module that will ask the user whether s/he's ok when a fall is detected, and only send the alert if the user does not reply that s/he's ok,

The results also show reasonable accuracy when testing the forward, sideways and backwards falls. It was discovered that most of the failures were occurring due to the slow frame rate of the skeleton recognition and if the user falls at a sufficient speed the module was not changing to the falling state before the unknown state is reached (when the posed is not recognised by Kinect).

Policies

Oranje et al claim that in spite of all the benefits, unenthusiastic insights amongst diverse groups of users exist and have to be taken seriously (Oranje, Schindler, Vilamovska, & Botterman, 2010). They maintain that a constant, approachable and open sharing of information concerning possible communal threats related to the use of such tools, as confidentiality violation, is necessary, and nonetheless should engage every involved stakeholder and user of healthcare organisations. They suggest that every one of these issues is to be sustained by suitable state and global policies directed at generating an innovation friendly environment and at backing healthcare organisations in looking further than their present technological infrastructure to solutions that can perk up their functioning structure providing they mirror the interest and objectives of all involved stakeholders. On the other hand, the authors call for prudence when considering extra regulation so as to create equilibrium between the policy objectives and the risk of imminent roll-out of valuable applications.

Practical Implications

RFID and Wi-Fi technologies have come a long way in recent times and are likely to enhance efficiency and effectiveness in the healthcare area. Implementation by big companies has helped out in making the technologies become a lot more cost-effective in per unit price in addition to the supporting equipment and training expenses. The results from this research project have significant implications for researchers and practitioners alike. From a research point of view, the healthcare IT area is an up-and-coming discipline that calls for additional academic and experiential research contributions. This project attempts to make a vital contribution in this environment by investigating the related issues and effects of RFID and Wi-Fi enabled system on healthcare processes and performance. By comprehending the impacts of such a system, practitioners can efficiently use these systems for improving their information visibility, validity and tracking, thus increasing the performance.

Limitations

The Wi-Fi network inside the facility can limit the Wi-Fi-based RTLS. Resources, including humans, can "vanish" into spots with no sufficient Wi-Fi coverage. On the other hand, the system can still offer the benefit of at least directing staff in the right direction by identifying where assets were last detected. With passive RFID technology there is the potential of RF interference with other hospital and medical devices.

Future Research

Further research on and assessment of acceptance of such technology by staff and patients is necessary. This should be integrated with mobile functionality for personnel. The use of

mobile devices should be exploited and such a project should be directly integrated within a mobile application. Such an application would aggregate all information why personnel are visiting different patients and can also be informed about the condition of a patient in a remote location. In the near future, devices that are owned by the patients can also be used to transmit a set of readings from their sensors. This would enable the medical practitioner to know the situation of the patient within the context of the room. Modern phone sensors are capable of measuring temperature, air pressure and humidity. These metrics can be transmitted together with the patients' readings and thus contribute to a more accurate diagnosis by the medical professional.

Conclusion

This paper aimed to present a variety of applications of Wi-Fi and RFID within a healthcare environment. The PINATA project was used to illustrate the relevance of such technology in this domain. This project was successfully implemented and strongly contributed to these conclusions. The experimentation with wireless technology in an effort to improve the patients' quality of life also resulted in the discussion of policies that can ensure significant improvement in healthcare. The findings of this project also emphasise the need of the integration of such technology with mobile devices since they can also help to provide better context and quality information to the medical practitioner.

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ⁱ http://www.xbox.xom/en-US/kinect

ⁱⁱ http://jena.sourceforge.net/