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Exploitation of Wireless Technology in Remote Care Processes

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SUMMARY The average age of population is predicted to be raised universally but the number of nursing staff is not increasing at the same rate. This leads us to the situation where, e.g., we have too many patients for one nurse. On the other hand, sparse population in some regions, such as Northern or Eastern Finland, causes a severe problem that doctors are far away from patient. In this paper, we summarize the possibilities and applications that utilize wireless technologies in healthcare sector and which can be useful in nursing activities. The use of new innovations is one way to solve the problems that are based on the expected lack of professional staff in the future. Despite of the very natural hospital link, the developed technical solutions have applications outside hospital. Remote care of aging people and other special groups need to be done daily and almost real-time. Keeping people home instead of hospital is one way to decrease the entire care costs. In addition to the obvious human context, we derive some other applications where we can benefit wireless nursing and remote sensing techniques.

key words: *aging, remote care, UWB, WBAN*

1. Introduction

Recently it has been recognized that some processes at hospitals are inefficient. For example, in Oulu region in Finland, there has been a work within a, so called, *WILHO Consortium* [1] to define bottlenecks and new innovative procedures for hospitals. By reorganizing some of the current practices and developing new ones, it is possible to significantly improve these manners. New methods to monitor humans by using non-invasive techniques and devouring or implantable devices can improve the quality of care, and extend the possibilities of real-time patient observation. How can this be happened in practice?

One possible solution to improve care processes is a wireless hospital concept which utilizes all the possible solutions that new Information and Communication Technology (ICT) can provide [2], [3]. By utilizing wireless technologies and new innovative approaches to handle daily nursing procedures, the effectiveness at hospital can be significantly increased. By doing so, medical staff can redirect more time to nursing, instead of working with supporting actions. In addition to hospital environment, new solutions and ideas can be utilized in elderly, outpatient and children home care.

Also, utilization of wireless technology can open new directions. For example, in animal herding or corresponding areas, where modern technology has not yet been applied in large scale, except in a limited areas such as cow-houses, round-ups for marking reindeers, etc., wireless technology can give added value to whole production chain.

Also, e.g., in Japan, more attention to improve hospital, child and elderly care has been paid during the last years. One example of the Japanese activities in this field is the research centre at the Yokohama National University that is focusing only on medical ICT research, which gives also its name the Center for Future Medical Social Infrastructure Based on Information Communications Technology, MICT [4]. To promote more collaboration and education, Yokohama National University, University of Oulu, Yokohama City University, and National Institute of Information and Communications Technology (NICT) have started a global COE program "Innovative integration between medicine and engineering based on information and communication technology," which is sponsored by Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan during 2008.

2. Facing a Problem

One common factor in Finland's and Japan's inhabitant statistics is the age structure. In the future, the average age of population will be higher than nowadays, which increases the need of elderly people's care taking. The estimation of population age structure for year 2050 is illustrated in Fig. 1

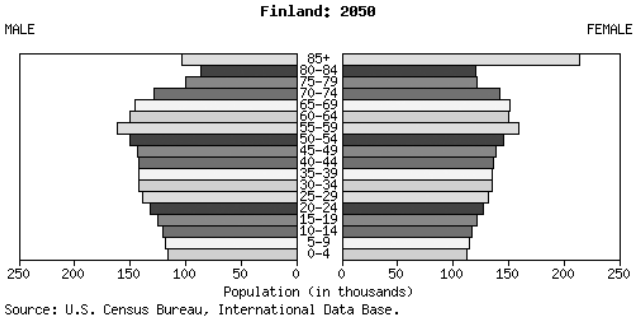

Fig. 1 Finland's age pyramid estimation for year 2050.

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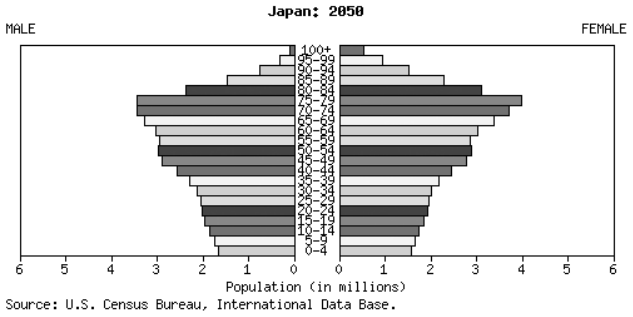

Fig. 2 Japan's age pyramid estimation for year 2050.

for Finland and in Fig. 2 for Japan [5].

According to the same reference, the total fertility rates in Finland and Japan are 1.7 and 1.2 children per woman, respectively. These numbers clearly indicate the problem which we are facing in the future: How to organize nursing in the future with less working age people? To manage this puzzle, new and more effective care processes are definitely needed.

3. Technical Possibilities

How the current situation could be improved in the future? If wireless technologies in healthcare will be adopted, the way towards more efficient, hence cheaper, processes could be smoothed. The need of some double work which is currently done, e.g., in medicine or other goods booking could be done faster, and in more reliable way, by obtaining modern technologies. For example, electrical systems allow that information is easy to carry forward to different electrical medical databases, ordering systems, and corresponding applications. This is also possible to do automatically. The important benefit is that all the records are always updated, so the latest patient's information is available, real-time, for all the medical staff members who might need it. By getting rid of the double writing, one important slip source will also be removed. In addition, added value comes from the fact that the access to electrical information becomes location independent. The use of open interfaces will increase the technology utilization and also opens the markets to several product manufacturers.

Ubiquitous monitoring using small, non-invasive sensor devices will offer new methods to collect medical information from patients. Intelligent clothes [6], sensor belts such as [7], coating materials with pressure sensors or other tiny devices which are easy to wear, which consume little energy, and whose operation is robust, are nowadays available. Even though the technology is at hand, it has not been utilized in medical applications in a full strength in practice, yet.

Medical sensors including 3D accelerometers could provide information on vital parameters simultaneously with the human posture or gesture. This is important help especially in remote monitoring when patient is staying home. A novel monitoring system could automatically provide medical information to a doctor, but also activity and behaviour statistics of a long distance patient. All this information is important extra to the all-inclusive nursing process. In addition, the consciousness of existing real time medical support increases the safety feelings of persons who do not need to be at hospital but still require external care.

Since late 1950's, in-body pacemakers have been used to help people who have heart problems. Also in human vital parameter measurements and monitoring, the use of implanted sensors or devouring devices will be a natural direction. Capsule endoscopes are examples for the latter application [8]. These devices can provide video stream inside a body in real-time and get energy outside of body. That makes capsule endoscopes easy and safe to use. Merging drug delivery to the capsule allows accurate medicine dosing into the diseased organ, minimizing the possible side effects at the same time.

Mechanical structures and materials used in the implanted devices need to be extremely safe for in-body use. Typically, these devices have long life times to reduce the need for battery changes. Fortunately, current technology provides active medical devices which are safe to implant inside a body. Furthermore, novel energy harvesting methods can be used to provide electricity to active implants.

The Electronic Communications Committee (ECC) has already defined frequency bands between 401–402 MHz and 405–406 MHz for use of ultra low power active medical implants [9]. The dedicated frequency bands made it possible to develop standardized apparatuses which can be used globally, which is the need for successful business. Fragmented markets typically increase the development costs and thus, also the final net prices.

4. Radio Protocols

In the modern remote sensing network, all sensors worn by human are connected to each others using wireless body area network (WBAN) structure. For that reason, the IEEE 802.15.6 task group is defining a standard for medical WBAN to guarantee the compatibility between different sensors and actuators linked in the system. According to the implementation technique, WBAN systems can be divided in wearable and implantable networks [10].

WBAN can be used to establish a connection from body sensors to home network and home server, which then could be connected to health service provider through Internet or mobile/fixed/satellite telephone or wireless local area network connection. Peer connection using standardized radio link could offer mobility aspect for WBANs and the connected devices.

Due to the several wireless standards that are available at the moment, health monitoring systems could easily be modified to fit regional regulatory requirements. Radio techniques such as ultra wideband (UWB) [11]–[13], ZigBee [14], RFID[†] [15] or IEEE802.11-family [16] could be used

[†]Radio frequency identification.

in different kind of applications at homes. In Finland, IEEE802.11 based wireless local area network (WLAN) is generally used also at hospitals. In addition, all the cellular mobile phones are allowed to be used inside hospitals with very few limitations, such as intensive care unit.

The average power consumption of the radio used in the sensor nodes must be reduced below 100 μW [17]. Today's low power radios such as Bluetooth and Zigbee cannot meet this stringent requirement [18], and therefore, new innovative solutions must be found. UWB communication is believed to have strong advantages which are promising for WBAN applications [19]–[22]. UWB communication is a low-power high and low data rate technology with extremely large bandwidth signals that provides robustness to interference and has low probability of interception [20], [21]. UWB's low transmitting power requirements, which are mainly used in low data rate networks with low duty cycles, allow longer battery life for body worn units [23]. Moreover, UWB can be used to monitor vital parameter such as respiration and heart-rate [23], [24]. In addition, UWB offers good penetrating properties that could be applied to imaging purposes in medical applications [24]. Low transmission power level makes UWB a safety radio system for body area network. Issues such as cell heating are not problematic due to the extremely low electromagnetic radiation. Moreover, non-coherent UWB receiver, such as [25] allows simple transceiver module realization. These are the main reasons for UWB being a potential candidate for medical WBAN. It allows all the listed features at the same time while other radio technologies are suited for only some of those requirements.

There are also many standards available for long haul links from home to service provider. Existing satellite or cellular technologies with coming extensions (GSM[†], GPRS[††], 3G LTE[†††], etc.), vehicle area network (IEEE 802.11p) or WiMAX[††††] (IEEE 802.16d/e) could be used to transfer vital information from homes onward. A general overview of a system utilizing WBAN networks at home and hospital, and connecting them to database or doctors using commercial networks as a backbone, is shown in Fig. 3 [26].

As mentioned, UWB is a good candidate for being applied in WBAN. The range of WBAN covers also sensor nodes on/in the body and an access point. Four different use scenarios are shown in the general architecture description in Fig. 3; in a hospital, at home, in an ambulance van and in a helicopter. In addition, medical staff can have access to latest data easily. The communications between access points to the backbone network are dependent on the scenarios. The connection from hospital to backbone network can be employed, e.g., by IEEE 802.11 WLAN or wired connection. Besides WLAN, a traditional cellular network can be used, especially in the home cases. IEEE 802.11p VANET[†††††] [27] or IEEE 802.16e WIMAX [28] is proposed for the ambulance van case. For the ambulance helicopter, IEEE 802.16e mobile WIMAX is also a good candidate to maintain connection with the backbone network. Inside a vehicle, UWB based WBANS are usable.

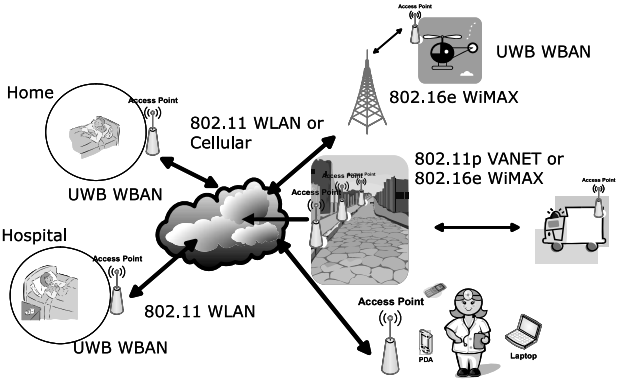

Fig. 3 Overview of a remote medical sensing system.

Safety regulations play a key role when adopting new technologies, devices and services, especially into healthcare and welfare markets. Because the applications are touching human's health, and eventually life, the fault tolerances are much smaller than in typical consumer applications. The global standards create a common platform for medical applications and devices, and make it possible to utilize those in a clinical work all around the world.

Different requirements and data transmission protocols that could be used in home monitoring will raise also new problems that have to be faced up. Patients are not willing to install several radio transceivers in their homes to serve all the complementary applications. This might require more complicated solutions and installations for home terminals. Fortunately, software defined radio (SDR) [29] or multimode radio could link different radio technologies and protocols into one device. SDR could exploit several radio standards by software changes instead of installing several, individual radio modules into the home terminals. This is a general feature of SDR, not related only to medical ICT applications. Depending on the data transmission needs and available networks, the radio device could reconfigure itself to the required service. Modern digital signal processing solutions do not increase the price of the radio device in a same ratio than it could offer new services. However, is SDR with its more complex architecture cost efficient for simple medical remote care applications is another issue? Producing as comfortable, small and light weight end user devices as possible is target in increasing the utilization of new technologies, and simultaneously it diminishes the resistance to their deployment.

5. Care Path: Example for Remote Care

A remote care path will start from a medical sensor stimulus. If the value of the measured vital sign exceeds the predefined threshold, an alarm to backbone network is sent.

[†]Global system for mobile communications.
[††]General packet radio service.
[†††]Long term evolution.
[††††]Worldwide interoperability for microwave access.
[†††††]Vehicular ad hoc networking.

Depending on the sign measured, the backbone system or service provider will return instructions for patient's self-care. The measured vital sign could be such as electrocardiogram (ECG), oxygen saturation (SaO_2), blood pressure, temperature, respiration, perspiration, etc. common and easily measurable medical parameter.

In the case of emergency, such as sudden heart attack etc., the home system could make instant alarm straight to the emergency centre. Simultaneously, the measured vital parameters will be directed to responsible doctor. This procedure might save the critical minutes from the healing or even mortality point-of-view. On the other hand, the patient's medical history saved to electrical patient record (EPR) is available for a doctor or other nursing staff. This additional information could be automatically linked to the new alarm event. This renders an effective way to prepare more detailed and tailored treatment plan for the far patient.

If the vital signs and all the available medical information could be linked to the patient in early phase of treatment, the possibilities for customized care will be improved. A natural continuation for extending care path is to include all patient transportation services, such as ambulances, into it [30]. Cellular or satellite networks have globally a coverage that fulfils these needs. The VANET standard (IEEE 802.11p) fits also well to this purpose. Currently, there are already solutions available to transfer patient's health information to hospital during transportation to prepare hospital site instant and optimized nursing procedures before the ambulance arrive hospital.

To improve personal data security, the use of designated data networks, such as Tetra[†] [31], could be used by the authorities, hospitals and ambulances. However, the home application and home network should be based on some open radio standard, still having a strong encryption to guarantee personal data security.

It should be noted that increasing and unsupervised utilization of automatic measurements could increase the number of false alarms created by the system. This might raise a new problem that needs to be solved before the technology is used ubiquitously. In medical applications, every fault could lead to loose of life. In that sense, remarkable benefits from the new technology could be filtered out if the security level is not high enough. At the same time, the numbers of false alarms and wrong diagnoses have to be minimized. To find out a reliable solution for that is an important issue before only the automated health monitoring system can be trusted.

Wearable sensors with artificial intelligence and advanced decision making algorithms could also be used to recognize emotional feelings [32]. The referred web-site of EU IST e-Sense project lists some examples about the possible applications for emotional feeling monitoring and how this information could be used.

Taking into account the technological improvements the previous sections discussed, aftercare procedures and programs could be made effective in rehabilitation. Technology makes it possible for a doctor to monitor remotely that disbanded patient is following given instructions and exercises at home, and is taking the medicine as ordered.

Though the discussion above relates on hospital related application, the remote control of vital signs could be obtained, for example, in military environments. The status of a wounded soldier could be transmitted to medical care centre, and the forthcoming healing actions can then be planned based on the seriousness of the injury. This gives tools to better heal badly wounded soldiers in a battlefield conditions.

6. Telemedicine

Finland has only about 5.4 million inhabitants, which is the same amount that several metropolitans all around the world merely have. Evidently, the population density in Finland is quite sparse. To make the situation more tangled, inside Finland, the population is not evenly distributed either. In spite of being a highly educated country, there are no doctors available evenly all over the country. Especially, this is a problem in regions which suffer leaving population problem. This situation has been observed and one solution to provide medical help to such regions is tele-health services. There are lots of experiences in, e.g., Asia-Pacific region in tele-medicine. It is almost the only way to offer high quality medical services for all inhabitants in large developing countries.

However, the technology fits well also to other regions than poor countries. Typically, special nursing does not have resources in every hospital but some activities are centered on big hospitals. Using the possibilities that tele-health could offer the expertise and knowledge is possible to spread for much larger areas than inside one hospital or hospital district. Tele-health can also be seen as a way to extend the care processes to home. As a service providers' viewpoint, the technology could save lots of money and improve the efficiency of whole regional nursing system. Again, if the patient does not need to travel to hospital for every medical treatment or check give savings to overall care costs.

Within a WILHO Consortium in Oulu, a tool to calculate the cost reduction in healthcare procedures by exploiting wireless technology has been developed, and the calculus tool is now in test use.

Not only in a clinical use, tele-health approach can be used in video conference type connections in (medical) education activities. Far located experts could help in regular teaching at regional medical schools, and other subjects. In addition, the experts could give lessons even from another continent via virtual connection. Asia-Pacific region is a good example where this kind of activities is exploited in medicine context.

7. Increasing the Technological Scope

People are just one target, which new technologies could

[†]Terrestrial trunked radio.

be utilized in remote medical monitoring. In sparse populated areas, such as Finnish Lapland, the technology could bring help in other activities, such as reindeer herding. Typically, the animals are herding freely in the wilderness but at the end of each year reindeers are collected together during round-ups. Lot of work nowadays is required to find the reindeers from the wilderness and then guide them to the round-up enclosure. If the animals are equipped with low cost sensors that offer also positioning information, the collection work could abate significantly. Cheap global positioning system (GPS) chips could nowadays be implemented in very cost effective way in small remote sensor apparatuses. On the other hand, energy consumption of the GPS devices is currently too high for real-time location of the animals. However, the position information is possible to send every now and then to the reindeer owners' data bases.

More benefit from the animal monitoring could be reached if simple sensor devices are attached to the reindeers. Then, it is possible to monitor health condition of each animal remotely. This gives added value for utilization of new technology in food production. The biomedical signs similarly than originated by human could be monitored from animals. Due to the individual sensor tags, the life cycles from new born animal to the finished food could be traced unambiguously. Of course, when talking about equipping wild animals, light weight and low power consumption requirements for the wearable devices are emphasized even more than with people. Efficient energy harvesting methods could be used to generate energy for the electronics used by the devices which reduces the use of interchangeable batteries.

Naturally, reindeers are just one possible animal group which could be equipped with tiny medical sensors. The application field covers also more common animals and all farms with cows, horses, etc. During the transportation of cows etc. from farms to slaughter-house requires continuous monitoring of conditions at container. The novel technology gives method to simultaneously monitor both animals and containers, and transmit information real-time, periodically or just download it only at destination.

8. Conclution

As presented in this article, wireless remote monitoring services could be used in several types of applications in healthcare. Modern technology could increase the level of nursing in far and sparsely populated regions as well as give possibility for patients to stay at home. Hopefully, the positive impacts could be seen as decreasing nursing work load and reduced cost that whole care system have. In many countries like in Finland, main medical services are provided by the government and the expenses are covered by the tax payers.

In addition to human medical care, the remote monitoring systems could be used in military field and animal herding. These applications are giving added value to the technology developed for hospital, or remote human care.

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