Sensor Networks for Health Care Systems: patients, ambulances, hospitals

Αισθητήρες Δικτύων στην Υγεία: ασθενείς, ασθενοφόρα, νοσοκομεία

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Abstract

In the following paper it will be examined how new technologies in the area of networks have drastically changed the way health care systems operate. There are obvious changes when it comes to preventing life threating situations and overcoming them in the best possible way. In that aspect, it also crucial to see how emergency vehicles operate and the most efficient way to arrive in their destination with minimum loses in human lives. That mean both the route that the ambulance will follow and how to make sure that the patient will have maximum chances of survival while being transferred. Lastly, it is also examined, how sensors work inside the hospitals in order to optimize the quality of lives for patients and the most effective ways for the nurses to work. For all those cases there are real examples and some ideas that are already in process of implementation.

Περίληψη

Στην παρούσα εργασία θα εξεταστεί πως οι νέες τεχνολογίες στον τομέα των δικτύων έχουν αλλάξει δραστικά τον τρόπο με τον οποίο λειτουργεί σήμερα το σύστημα υγείας παγκοσμίως. Όχι φυσικά ως προς τον λειτουργικό του τρόπο αλλά ως προς τους αισθητήρες που χρησιμοποιούνται για την βελτιστοποίηση της αποτελεσματικότητάς του. Είναι σημαντικό να αναφερθεί πως οι αισθητήρες μπορούν να αποτρέψουν καταστάσεις επικίνδυνες για την υγεία και πως, εφόσον είναι αναπόφευκτες, να ξεπεραστούν με τον καλύτερο δυνατό τρόπο. Επιπροσθέτως, θα διευκρινιστεί με ποιους τρόπος ένα όχημα έκτακτης ανάγκης μπορεί να φτάσει στον προορισμό του όσο το δυνατόν γρηγορότερο. Αυτό έχει να κάνει τόσο με το την διαδρομή που θα πρέπει να ακολουθήσει όσο και με την φροντίδα που θα λάβει ο ασθενής κατά την μεταφορά του. Τελειώνοντας, θα εξεταστεί επίσης πως η νοσήλια στα νοσοκομεία θα μπορεί να βελτιστοποιηθεί με την βοήθεια αισθητήρων.

Introduction

The purpose of this paper is to examine how the modern technology can benefit the health care system to the maximum. Specifically, it will be discussed the importance of sensors in that process. A sensor is a device that detects objects, events, or the value of a physical quantity and converts it into an electrical signal. There are several types of sensors such as sensors of temperature, pressure, humidity, accelerometer, and magnetometer. [*1] They can be used in smart cities to improve the quality of life. Part of that life is the heath care systems, that might be said is the most vital in the survival of every society. For that reason, three aspects of the health care systems are examined. The first is about the patients and the right treatment, especially for the seniors. The second part is about how the ambulances can use sensors in order to be more efficient and minimize the time of the route and increase to percentage of patients surviving the transport to the nearest health center. Lastly it will be discussed how sensors can improve the quality of a patients stay in a hospital. There are many ways that can be achieved and here are some of the most import ones and how they are used in real cases.

Sensors for Heath Care Systems

In the modern society, where everything is related to technology one way or the other, there has been developed the concept of mobile health (mHealth). mHelath is a term used to describe the use of mobile telecommunication technologies for the delivery of health care and in support of wellness. mHealth is driven by the convergence of 3 powerful forces. First is the unsustainability of current health care spending and the recognition of the need for disruptive solutions. Second is the rapid and ongoing growth in wireless connectivity and the capability this brings for the transfer of information. Third is the need for more precise and individualized medicine. [*2] In order to connect those health issues with the mobiles, the use of sensors is mandatory. They are the mean to transmit the data to the application and translate it accordingly.

To fully understand the value of Sensors in the health care system we need to firstly see how things worked before sensors were introduced and commonly used in that area. Health care is a vital aspect of a community and is connected not only with the quality of life but most importantly with saving lives. The health care system includes*[3] This area includes Individual health professionals or working as an employee in a health care. Examples of health workers are doctors, nurses, dietitians, paramedics, pharmacists and others. In that point it should be noted that any aspect of everyday life is connected directly with the internet of things. (IoT). It is the IoT that gives us the ability to connect all of the devices with other devices that were primarily meant for different purposes. It has the ability to connect homes, buildings, hospitals and the entire community and share information with each other and with cloud. Given those things together we will proceed to see how they can cooperate and use sensors in the health care to upgrade it and put in in use.

The first thing that usually comes to attention in that area is prevention. It is always better to avoid a threat rather than dealing with it after it happens. There have been developed by the University of Missouri some sensors that are placed in the walls of the seniors or even in a retirement home (like the one it has already been applied to). Those sensors can keep track of the walk of a senior and understand when that changes. That means the walking pattern, the shakiness, the pace etc. When the sensors understand the change in those, one of the caretakers (or close relative) is being notified via e-mail and can then check if there truly is a problem. That method is mostly used as a precaution, before something happens. *4 The sensors capture 3-D images and reduces them into two dimensions that appear as silhouettes. That way in can predict patterns using algorithms and preserve the patients' privacy. In case a patient falls, it issues a Fall Alert —and delivers it using secure text or call system integration, depending on what the institute decides. *5

Sometimes though, there isn't the right precautions so something, like a senior falling, could happen. If that is the case, there are some sensors about that as well. It is mostly addressed to seniors living alone who may have other needs and require monitoring. Sensors can be used in the homes of elderly people to detect fall and send a message to close relatives and the closest medical center. That way the health providers can arrive to the place of the incident much sooner and maybe that time is critical to the survival of o person *6 Wireless sensor-based systems gather, capture and share vital data through a secure service layer (SSL) connecting to a server in the cloud. It combines sensors, microcontrollers, microprocessors, and gateways where sensor data is further analyzed and sent to the cloud and then on to caregivers. Data is captured via sensors, complex algorithms analyze the data, and medical professionals can wirelessly access the information and make diagnoses and treatment recommendations. The connection is

accomplished with IEEE standards for LANs define Wi-Fi (IEEE 802.11) and ZigBee (IEEE 802.15.4) networks. *6

Between those to we can clearly see that the first sensors are much more useful since they can detect abnormality much sooner. When it comes to health it is always said that precaution is so much better than dealing with something that has already happened. That is why in the first case there are already real examples in use and maybe the second one should not be preferred if there should be a choice between those two.

In the second part of that paper, there will be a discussion about the ambulances. Having solved the problem where someone may need immediate help at their homes, there should be a discussion about the route the ambulance will follow to arrive in site on time and the route back to the hospital. In that matter there are 2 major subjects. The first is about the time it will take for the vehicle to arrive at the place that is needed and how long will it take to get back to a hospital as soon as possible. The second issue is the treatment the patient can receive in order to increase his/hers chances of survival (in the worst case scenario) until they arrive at the destination. As for the first one there are already some practices. Emergency vehicles should always be ready to arrive at their destination on time. Given the traffic nowadays, especially in large cities, that can be a very serious problem. Given the fact that the traffic is controlled by traffic lights what has been proposed is that there should be a measurement of distance between emergency vehicles and traffic lights. Of course something like that could benefit other vehicles as well, such us police and fire trucks. *7

The first approach combines the measurement of the distance between the emergency vehicle and an intersection using visual sensing methods, vehicle counting and time sensitive alert transmission within the sensor network. A Medium Access Control (MAC) protocol is used

to deliver the emergency vehicle information to the Traffic Management Center (TMC) with less delay.

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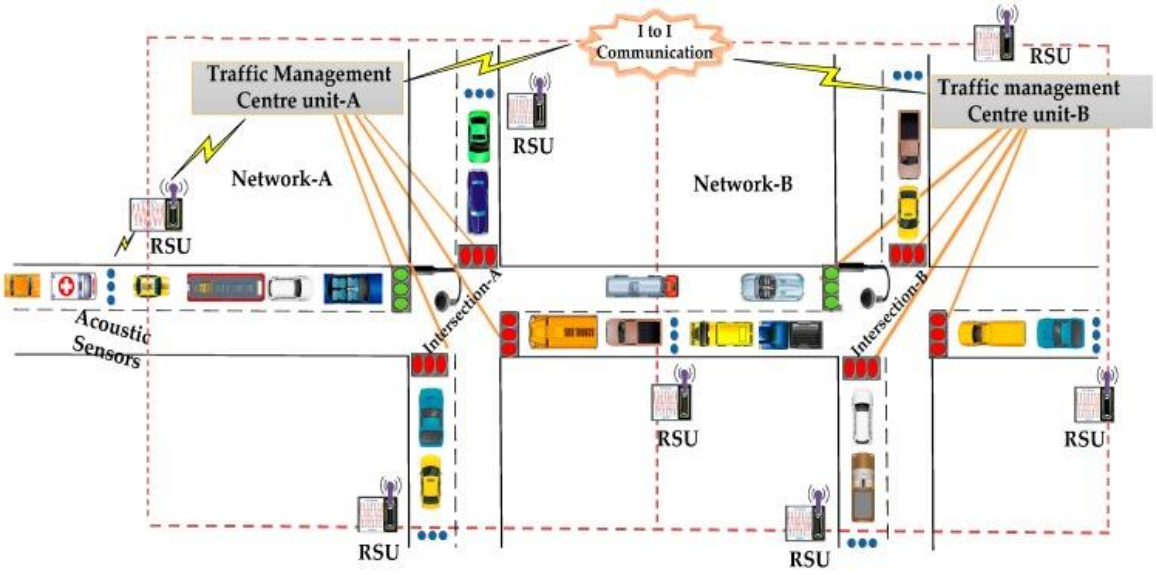
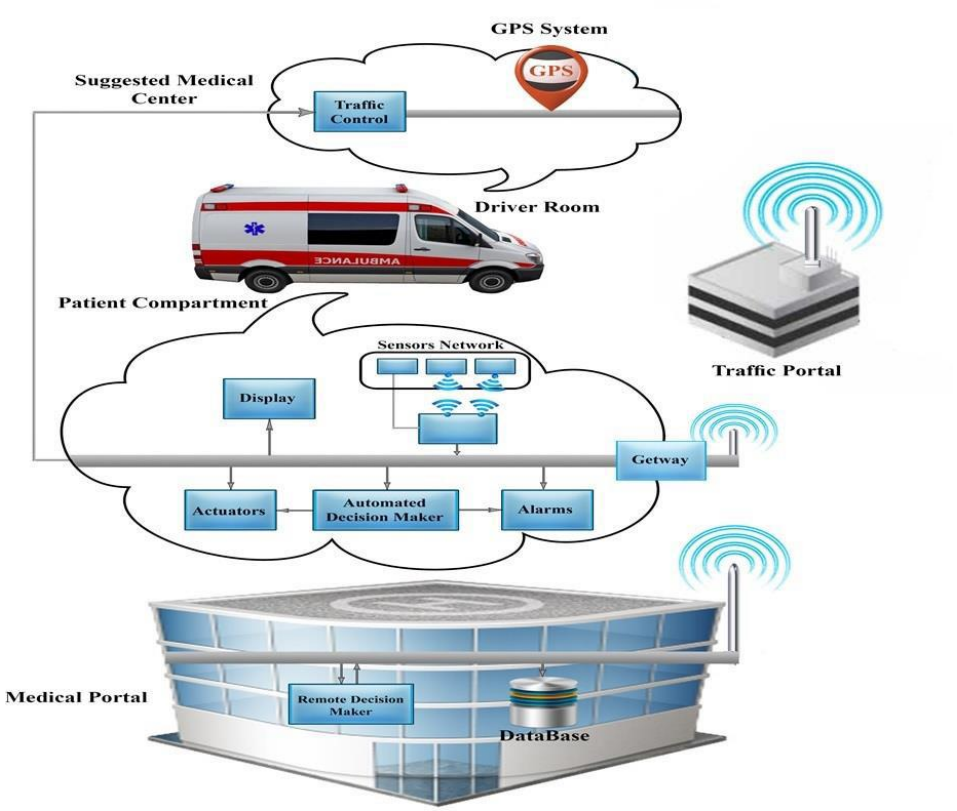


Source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5134551/

When the ambulance gets in time to the patient, in many critical conditions the patient loses his life while inside the ambulance. For that part, sensors can actually help with that. Wearable Biosensors will be attached to the patient's body. That way they can monitor their pulse, heart rate, blood pressure and oxygen saturation. Those data will be sent to the experts in the closest health center. There it will be analyzed in real time and provide with an immediate response as to what should be done next. Those applications will communicate with each other with Wi-Fi or even Bluetooth.

Now, regarding the route an ambulance driver should follow it will be monitored by a GPS in the vehicle. The GPS will be able to locate the closest hospital and the shortest route to that and help the driver by showing him the map and the route to follow. [*1]



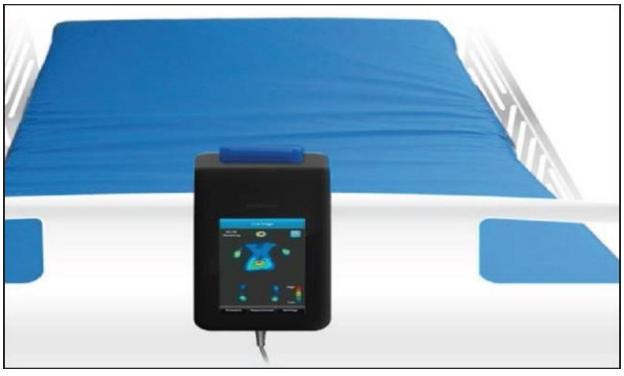
Source: The 5th International Conference on Current and Future Trends of Information and Communication Technologies in Healthcare (ICTH 2015)

For the final, and perhaps biggest part, there are the sensors that can be placed inside the hospital. This includes sensors that are using connected application to improve the delivery of healthcare in hospitals and track treatments to boost the effectiveness of healthcare providers.[*8] Those of course can have may uses. The first one that will be mentioned in that paper is sensors laced in the beds of the patients'. This sensor is already in use in a New England hospital. The sensors are being situated below the patient's bed mattress and it tracks their vital signs. For example, the heart rate, respiratory and motion. If any of the signs show an abnormality that could mean something life threating to the patient, a nurse is being notified and checks the patient. Those sensors can provide the health providers with hundred of data that would be

impossible for any doctor or nurse to collect on their own. Furthermore, the sensors have proven that the response time drops to two minutes and sometimes even lower. It is unarguable that health situations, even a few seconds can be crucial to the patient. Such sensors like the Panasonic's Grid-EYE® can help track the activity of a patient while avoiding any of the privacy concerns raised by other monitoring systems such as cameras. This Sensor works by continuously sensing IR radiated energy of a source, even if there is no movement, and can be employed in patient care when wearable Sensors are not useable. *9

In regard to an other very specific problem that patients face at hospital, and not only of course, is decubitus ulcer, or commonly known as pressure sore or bedsore. This is a very common yet serious problem. As in most cases prevention is better than treatment. Smart beds placed in hospitals can really help with this. Using wireless sensor networks in those beds could mean the following:

- Assessing the risk of bedsores' progression.
- Skin care and primary treatment such as skin health.
- Use of pressure-reducing supportive surface such as wavy mattress and smart beds.*10



Source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4746860/

In order to further assist the nurses in their task to look after the patients, sensors also can be placed in the patients' rooms in order to prevent noise. Noise a very import factor that causes

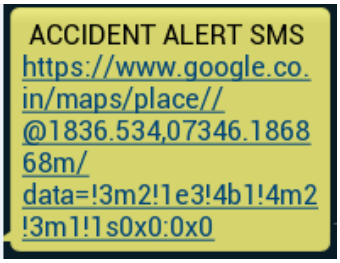
great discomfort to people especially when they are being hospitalized. There is a company that can place noise detectors to the rooms and then create a score for each nursing shift by looking at noise levels for each room. It can be compared to the data that has been collected the previous days and hours and release where and when there is noise problem. Given that, the staff will be able to know how to better organize the patients and even propose solutions for the elimination of that problem. [*11] The sensors measure the key elements of the sleep environment transmit it via cloud servers for intelligent solutions. There an admin report is created and maintained at the hospital. [*12]

Inside a hospital, wearable sensors can also be able to continuously monitor the patient's heart beat, blood pressure and other critical parameters in the hospital. The system is able to carry out a long-tem monitoring on patient's condition and is equipped with an emergency rescue mechanism using SMS/E-mail.[*13]

A new proposed idea is the Emergency Medical Services (EMS) systems. Hospitals need to communicate with each other using EMS. That wat they can exchange information about patient condition expected time of patient arrival, and occasionally inquire about the ability to accept more patients. Those consist of wearable sensors for vital sign monitoring and sensors for location tracking tags in buildings. The ideal EMS system should provide real time information and tracking of patients, staff and emergency vehicles.[*14]

At the International Research Journal of Engineering and Technology was published an article with the title "Accident Detection & Ambulance Rescue System Using Wireless Technology". Its focus is on the process that should be performed during an accident using sensors. This consists of three parts: the vehicle, the ambulance and the hospital. For the first part a sensor is placed in a vehicle, which senses vibration. If the vibration is above the threshold

value then accident alert message is send to an ambulance, a police station & family member of accident victim.



The message sent to the family member

Source: International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056

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When the ambulance arrives to the place of the accident another sensor will be able to collect data about blood pressure, heart beat and temperature. Then this value is send to nearest hospital for analysis. That way the doctor has access to all the information necessary for the patient. *15

Regarding the use of wireless sensor networks, it should be mentioned that there are some issues raised from the use. Of course they have their advantages, like reliability and quality of service, but they also face some challenges, like power consumption and environmental cost.

Advantages	Disadvantages and challenges
Dependence on the application[15]	Hardware constraints[16,17]
Interaction with the environment[15,16]	Typology[17,19]
Scalability[15]	Reliability of use[16,18]
Energy[16,19]	Scalability[18]
Self-configuration[16–18]	Environmental conditions[16,18]
Reliability and quality of service[16–19]	Cost[19]
Data-driven[17,18]	Increasing network lifetime[16,20]
Simplicity[15,18]	Power consumption of the nodes[17,20]

Source: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4746860/

As seen in the table above, a unit should first take into consideration all these aspects, and decide which one of those sensors is most suitable for them. That doesn't necessarily mean that they are obliged to use any of those sensors at this point. Though such a choice could cost the credibility of the institution and their ability to adapt to change whenever that is required.

Conclusions

As seen in this paper, there isn't a sensor that can be considered better than the others. The sensors that are being used to prevent s condition, like the ones monitoring the movement of a senior to detect the possibility of falling, is surely more efficient ti prevent a situation. So it is the one that should first being used in such cases. That of course doesn't mean that all the others that are there to deal with situations aren't as useful. Of course if a health center should have to make a choice, it should definitely focus on preventing situations and then to the ones that improve the response times in situations of emergency. That means the sensors for ambulances and monitoring the vitals of the patients'. In regards to the time of sensors that are best in use, there should definitely being stated that the ones that doesn't violate the privacy of the patients' are surely better. For instance, cameras can identify people and violate their rights for privacy. Nonetheless, even cameras can transform the image so as to only monitor the patient without getting him exposed.

It definitely is interesting to see how the existing sensors will be used in the future to prevent conditions even faster with, most likely, wearable sensors. Perhaps it should be consider that not only patients, but everyone could have such sensors, provided by the health care insurance. That way with the slightest abnormality, the patients could be notified and examine a potential problem as soon as possible. It is clear after all that prevention saves lives.

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