Body Sensor Networks Architecture and security issues in Healthcare application

Vinod Kumar¹, Dr. Neelendra Badal² and Dr. Rajesh Mishra³*

¹Computer Science & Engineering, Career point University- Kota, India
²Computer Science & Engineering, Dr. A.P.J. Abdul Kalam Technical University, India
³Computer Science & Engineering, Kamla Nehru Institute of Technology Sultanpur, India
Electronics & Commuinication, Gautam Buddha University, India

Corresponding Author’s e-mail: vinod242306@gmail.com

Abstract. This paper exhibits the idea of Body Sensor Systems (BSNs) which can be broadly utilized in healthcare applications and all. It investigates systems and related applications for medical issues and discussed vital challenges and metrics of BSNs. Of late, miniaturized health observing gadgets have turned out to be essentially plausible with other current advances in the Wireless Sensor Networks (WSNs) and Embedded Designing technologies for computing. However, BSN provides the means to analyze the low cost which can sense the existing environment as well as their wireless nature for which it turns out to be suitable to develop the subject. Sooner or later, the reconciliation of a huge swath of Wireless Network into existing specific medical technology and so forth can be seen. These kinds of systems, by and large, comprise radio frequency-based correspondence abilities. Every sensor in a sensor network comprises of the three kinds of subsystems: first is the sensor subsystem which can sense the environment, the second subsystem helps to apply the calculations on the detected information as well as the third subsystem handles the exchanging of the messages with their neighboring sensors. Wireless Sensor Networks (WSNs) consist of small wireless computers that sense, process and impart environmental stimuli including temperature, etc.

Keywords: BSN, Bio-sensor, Radio Frequency, WSN

1. Introduction

Inroads into coordinated, insightful computations are empowering the sensor network that helps to keep tracking the record of environment, complex collaborations, and frameworks to use them in the scope. Body Sensors Networks (BSNs), for example, guarantee novel uses in medicinal services, entertainment, and wellness. Each BSN comprises numerous nodes that are interconnected, inside or
close to the human body which together gives detecting, communicating, and handling capacities. BSNs can change how individuals collaborate with and advantage from information technology though their pragmatic reception must defeat substantial technical and social difficulties [1].

In the existing framework, the growing needs of real-time security in BSNs and technological enlargements, the quantities of active frameworks for the real-time system are expanding persistently all through the world[2].

According to IEEE 802.15, BSN can be defined as a correspondence standard advanced to the gadgets which have low power and to on the activity, in the activity or around the body to serve an assortment of utilizations that include the electronics consumers, medical devices, and own amusement. Wireless body sensor systems are the best approach, nevertheless, Wireless correspondence postures critical difficulties from the usable range to the significances for the human body. As per the protocols, there are other issues such as security, interference-free communication, and robustness which are the key requirements [3].

The most trusted part of WSNs, especially in the healthcare sector can be extended, additionally. In the coming years, the smart spaces which are enabled with WSNs can able to sense the environmental conditions as well as can take the other preventive actions which are based on the presence of humans. Therefore, the system can reach its ubiquity, where every individual will have an evaluation module that can deal with the other smart space available in the system, eve it helps to prevent the other health issues. It is trusted that the application used in IP as a protocol, in terms to connect the BSN in the healthcare environment, it seems to be challenging [4].

The other integrated IP which is available inside the smart sensor nodes to present the advantages in the environment of self-configured as well as data capture, but, it provides communication overhead whenever it is needed to compare to the existing approach. Moreover, it comprises the current behavior that we may expect from such systems to display. A wireless sensor network comprises of too many numbers of WSNs gadgets functioning cooperatively for accomplishing the common objective. Those sensors which are embedded in the human body will gather different biological variations to keep in mind the end goal to monitor patient’s wellbeing status regardless of their physical location. [5].

To transmit the information wirelessly to its external Processing Unit, then the device ends up being to a great degree valuable in transmitting the information to the concerned person such as doctors or others. Accordingly, in the off-chance, the emergency has been notable, the doctors’ advice to their patients by using their PC to send the appropriate message or their whereabouts.

Presently, the level of information has been given by the system, and vitality assets fit for powering the sensors are constraining variables. Accordingly, this paper just shows the research and development stage in the innovative work of wireless sensor networks and concerned sensors for wellbeing observing.

This technology is very exciting with infinite potentials for several other application areas such as transportations, disaster management, medical, military, entertainment, etc. These applications for the healthcare areas have already gathered enough attention from people. The new innovating development of these beautiful wearables has been empowered the Bio-Medical Sensors for the human wellbeing evaluating has already gathered attention from scientists, academics, and industrialists. [6].
2. Literature Survey
The expectancy of life has been increased by the five years rate, since the year 2000 because of the enhancement of the facilities in the medical field. As per the World Health Organization, by the year 2050, the existing population of the old people will be increased by 8.5%, to represent 20% of the population of the world. This is the main reason for which many countries are ready to adopt these healthy aging policies to help elderly people can able to lead an active as well as an independent life. With the high rate growth of old age group people in the upcoming future, it has become extremely important to dedicate noteworthy efforts to explore the enhanced technologies and concepts for instance elderly care in the smart IoT. The wide ranges of solutions are given to address the requirement of the elderly by compensating the predictable mitigating and deficiency consequences [35]. The intentions of many large, medium, and small projects have been also introduced to handle the needs of the elderly with distinct objectives. In terms of exploring the main IoT-based services and applications which have been already launched for monitoring the health of the elderly at remote locations. The necessity to monitor the elderly is to give them attention by using distinct approaches, so that, it could give them benefits and ease to live their regular life by using the applications in different areas, i.e. social network, to monitor health, to monitor nutrition, to monitor their safety, localization, navigation, to detect cancer, to monitor glucose level, etc.

The system has been created that offers the application that can able to monitor remotely and also provides the reports on a daily-weekly-monthly basis. This system shares the details of the elderly to the agent (third party), who can be anyone such as medical experts, caregiver, or belongs to any emergency unit. This system can gather the feedback which is received from the agent so that it could offer the user personalization to improve the user’s performance. These systems provide several other problems such as data authenticity, data integrity, as well as data confidentiality [33, 34].

The mechanism to work automatically for fall detection has been categorized into two categories i.e. Ambience Device and Wearable Device approaches [36]. This paper [37] proposed a mechanism to use floor vibration sensors. By using the vibration system, these sensors are capable to tell that where the occupant. This processor helps to detect the fall and to analyze the data location. IR sensor array can be put on walls that help to detect the fall activity. These arrays are able to see a warm moving object, it lacks to detect the static background [38].
The developed system for fall detection that consists of a very tiny adhesive sensor patch to the sacrum, then it detects the normal events such as walking, climbing, stairs pacing, etc. [39]. This work [40] proposed a tool to detect after installation on a walking stick, so that if a patient falls, then it could be detected dynamically by measuring the stick’s angular velocity through a gyroscope chip that has been fitted into the stick.

3. System Design & Applications
To communicate wirelessly is an important part to coordinate nodes. BSNs are exclusive in their ways, they challenge to constrain the radius to communicate within the body’s circumference. By limiting the transmission range, that helps to reduce the power consumption of nodes, maintain privacy, and also reduces the neighboring BSNs interferences. WSNs use radiofrequency (RF) channels for communication. The wireless BSNs being tested by the attenuation of emotional by transmitting the signals or signs whichever is coming about the body, due to the shadow of the body which has a viewable pathway to ingest the RF energy that gets combined with the causes, developments, criticalness and the other factors affecting path loss. Utilitarian efforts are required to maintain the self-organizing properties available in the sensor networks [7].

The wireless system to communicate in between the electronic devices and the IoT smart gateway which can be established by the IPv6, i.e. 6LowPAN technology that supports wireless low power centered on the IEEE 802.15.4 standard. This technology has been designed to support the interoperability, compatibility, and connectivity of heterogeneous WSNs, that too at very low-cost and low requirement comparative to other existing technologies of either Bluetooth or Wi-Fi. 6LoBR is important to provide communication inside or outside of the existing 6LowPAN network, which is responsible for exchanging data between cloud and wearable devices, as well as it provides routing and forwarding capability inside the network.

The smart IoT gateway has three following steps:

a) Model Creation
This is completely based on the decision tree model which is built from the dataset of SisFall. This decision tree is extensively used in the classification of data. The best method to classify data and regress data among other existing algorithms. It supports the non-parametric design for its structure that makes it highly effective to handle the datasets which are in huge number without over fitting the problems as ML algorithms. Firstly, decision trees convert to the classification rules, then use the BigML Data analysis tool to make the model. It helps to design creative models by predicting them and embedding them into the useable software application by the RESTful APIs.

b) Model Training
This is an important feature to design any system, to train a model. The model learns by detecting the fall events with the help of a smart IoT gateway. SisFall is the openly available dataset for developing and benchmarking Fall Detection System (FDS). It contains the 38 participants’ record, in which 15 people belong to the elderly age group i.e. 60-75 years old. All the participants from the elderly group simulated activities of daily livings (ADLs) activities; one of them gets both ADLs and fall, the one who is a Judo expert. Then the captured signals after an experiment by using 3 inertial sensors in which two accelerometers (ADXL345, ITG3200) and one gyroscope (MMA8451Q), which is assimilated in the self-developed embedded device. The sampling rate of the experiment is approximately 200 Hz. They have performed 19 ADLs types and 15 fall types. After the training of
the model, it classifies the fall and ADLs event. The leaf node of the decision tree constitutes the decision based on prediction. Those accelerated data will be in bits, then it converts into the gravity following the described equation in the complementary material which available online i.e. SisFall.

c) Fall Prediction
The big data analyzer that creates the model local instance. The estimates have been created, then computed by taking it as a piece of input information that is arriving from the transformation module used by the REST APIs which is given by the BigML. The predicted results are a fall, the invoke system to alert for an emergency handler, and then it sends the falls data by using the cloud services.

The reliability dilemma in the healthcare system is really important, i.e. the data requires being very sure about its reliability and security. This brings high overheads in terms of power consumption, scalability, and data size. This requires proper attention through an appropriate study about WSNs, BANs, BSNs, etc. BSNs would be documented as unique sensor networks that are required and quite different from other general WSNs. Also, one ought to acknowledge those wireless gadgets, which are unhurried than wired due to the congestion of traffic, and henceforth expands the test to make the gadgets that can be reachable to the better execution. This helps to create a greater challenge for the programmers, developers, and designers, to make a secure network of sensors. Guaranteeing about the patient’s data to be secure, it can be a noteworthy concern while conveying these applications. Security of the client information that is available in the wireless environment can be another significant concern. Many medical gadgets of WSNs can be extremely constrained as far as the processing capability and power accessibility. In this manner guaranteeing security without utilizing the complex algorithms for encryptions can be a major problem for medicinal gadgets designers [8].

![Figure 2. BSN system working mechanism](image)

a) Cardio Vascular Disease
The smart sensor nodes which can generally be utilized to avert a huge number of deaths caused by cardiovascular ailments. Also, the concerned medical staff can do the treatment preparation in advance as they receive meaningful information regarding the heart rate or so.
The mobile-health is such a project which targets to provide persistent observing of patients outside the hospital.

b.) **Detection of Cancer**
The second primary reason for death in the USA, with rising numbers of death every year, and nowadays, it has become one of the greatest dangers for human life is cancer. A sensor having the capacity to identify nitric oxide (radiated by cancer cells) can be put in the presume areas. These sensors can separate cancerous cells, between various sorts of cells.

c.) **Monitoring of Elderly People, Patients, and Detection of Depression**
The latest study showed that around one/third of the area in the USA, where the entire adult serves as an informal caregiver, especially to the elder people. Generally, WSNs that way can able to help the homebound as well as sold individuals who have felt such as desolate and depression by recognizing any strange condition and notifying the people associated with the WSN and closest doctor's facility [9].

d.) **To Monitor the Glucose Level**
Diabetes may yield the other complex ailments such as high Blood Pressure, heart strokes, blindness, kidney disease, etc. An implanted biosensor can able to help the patient to provide a consistent and accurate technique by checking the level of glucose in the body. At that point, by transmitting the readings to wireless terminals as well as by automatically insulin injection at whatever point a limit of glucose level has been reached.

e.) **Prevention of Medical Accidents**
The sensor networks can able to maintain the log of the previous medical accident history and it can notify whenever its repetition occurs. Therefore, it can very well reduce the redundancy of such accidents. The e-Watch is such a wearable sensing and computing platform. It generally senses motion, temperature, audio, visual and tactile notification.

f.) **Health Monitoring**
To monitor health remotely mends the quality of life, especially for elders, who don’t have a caretaker in an emergency. It helps to monitor their health without any requirement of hospital stays and nursing, which needs unnecessary costs for healthcare. The monitoring activities include the act of doing something for instance eating, walking, sleeping, number of meals, etc. These contributions have been introduced to utilize the different sensory data and methods for offering the monitoring activity for old people [17-20].

g.) **Nutrition Monitoring**
The health lacking nutrition in a person, who is suffering from malnutrition because of lack of deficiency due to their age or other reasons, which are required to be controlled. Especially for elderly people, malnutrition negligence can create several diseases such as cerebrovascular...
disease, cardiovascular disease, osteoporosis, diabetes, etc. This is important to track or to monitor the nutrition intake, weight, diet, etc. by using the IoT based remote monitoring system to improve the well-being and health of elderly people [21-25].

h.) Safety Monitoring
The regular issues of elderly life demands security. Aging causes many serious issues to health such as frailty, forgetfulness, and impairments so that they can live safely and independently, though the crucial part is to monitor their safety. For this real-time monitoring is important as it is capable to detect the injurious situations that can give an awareness of elderly status to their relatives so that they can feel relieved. Robust fall detection has been proposed to monitor or to detect their motions as well as actions by using different techniques combination [26-28].

i.) Localization & Navigation
‘The fear of being lost’ is termed as ‘Mazephobia’, which is in an unacquainted environment, to reduce cognitive and physical capabilities, as well as the confronting risk of those odd places without any aid, due to this most elderly people spend time at their home by staying there. The IoT based approaches have been introduced to address the previous issues of real-life and those inevitable difficulties to mitigate their associations [29, 30].

j.) Social Networks
In terms to promote the social networking life for senior citizens, especially those who live alone. This becomes important for them because living alone brings isolation and inadequate interaction with family, relatives, or friends. It may cause mental issues such as anxiety, social anxiety, depression, etc. In this scenario, to enhance their social network or social life becomes an important task to do. A device or system which is connected to the home appliances, television, smart phones, tablets, helps to create a social network for them to communicate and also provide the other facilities such as shopping assistance, meals on wheels, and medical assistance. It also helps to remind for daily activities [31, 32].

Thus, this is highly needed not only for a system that can able to work in any circumstances, but there is also for function cooperation and data sharing that can be acquired among several systems. Much empirical training is inclined to focus on the state of improvement of the body sensor network applications in the coming future. In terms to enhance the system universality, the results of researches show that to shape an ultimate standard of data to use for data sharing, it can able to promote the function to cooperate among the BSN applications. The other potential advantages of the network sensors over the very convenient approaches that can simply summarize as much as greater the reliability is, coverage and accuracy, at a very relatively lower cost [10].

4. Challenges & Proposed Work
The body sensor network research this much far, which already concentration on the applications of healthcare, especially emphasizing the shortcomings of the traditional methods to collect data of the patient, which gives imprecision due to needing as well as market demand. Then again, body sensor systems can unfailingly capture quantitative information from various kinds of the sensor for a longer time. The body sensor networks can enable telehealth applications medicine yonder the clutches of the hospitals and due to their functionality will provide highly personalized care. BSNs coordinate with the huge amount of foundation that may probably help in the services related to medicinal, to serve the needy person, individually. BSNs which can be bidden during detecting and handling can expand and protect body functioning although defer impervious applications, for example, longitudinal evaluation [11].

4.1 Safety
Wearable sensor systems will be needed to be biocompatible to check any harm to the intended person or not. However, to make safer critical applications, that should have the fault tolerance operation.

4.2 Security
Generally, unlicensed access to the system function can be able to make severe damage to the system. The measures for security, for example, authentication of the user, can help to prevent the system from such unwanted incidents to have happened and so on.

4.3 Privacy
The BSNs can be trusted with possibly subtle information about the concerned persons. However, protecting user privacy requires appropriate resolutions. The encryption will be important to procure the sensitive data, as well as the mechanism of encryptions, will need for aware resources.[12].

4.4 Easiness of use
On-off body user’s interface and representation of info. Wearable BSNs nodes should be fewer, small, and ergonomic in numbers.

4.5 Vulnerability
This is the most essential part of any system. This is the main area for researchers, generally in the area of WSNs. Wireless media is usually greater susceptible than wired media for attackers. This is more essential in healthcare applications since a security breach can result in life-threatening situations. The security threats can happen throughout routing the data where intruders may alter the destination, routing can be made inconsistent and data can also be stolen through eaves-dropping the Wi-Fi communication media. Hackers can track the user's location or can track a user’s activity. They can additionally wage the Denial of Service (DoS) attack [13].

Body Sensor Network researchers need to work to enhance deep brain stimulation, heartbeat, prosthetic actuation, and drug delivery. Physiological and bio-kinetic sensing applications are increasing as fitness enthusiasts and athletes seek to improvise a human performance. The BSNs are perfectly placed to send feedback and interactivity important for the fitness applications for the next generation. BSNs contain many sensor nodes each of them can do communication, samplings, and processing the vital signature such as oxygen level, heartbeat, physical activity, blood pressure, and other environmental parameters such as location, temperature, humidity, etc.. Generally, these network sensors set deliberately on the human body as minor fixes or covered up in the clothes of users permitting complete health checking in their related environment for a long time duration.
Additionally, the close relationship between human health or BSNs there generates moral and other legal constraints in the actual applications. As per the requirement of industries, it provides littler as well as feature-rich sensors as a node. Furtherly, these new little nodes in body networks can become advance by turning on their utilization, normally, for example, to wear a cloth on the body. Patients, who need to check remotely, can be handled by operating their mobile systems.[14].

![Figure 3. BSN network and its environment](image)

The networking among devices in, on, and around the body presents exceptional difficulties for resource allocation, Quality of Service (QoS), co-existence, and privacy. On one hand, modest networking techniques increment system run time and decrease obtrusiveness; on the other, compromise with privacy or QoS is intolerable for life-critical or sensitive medical applications. BSNs present an extensive variety of application situations yet it isn’t sure whether a unified network solution is the finest option over application-specific protocols and typologies. BSNs have fewer chances for redundancy as compared to WSNs [15].

Thusly, the emphasis must be on producing cooperative and intelligent QoS for the sensor nodes. By using the technique of in-body implantation and by using sensors on-body, these show some heterogeneity as a result, that shows the report of placement constraints and sensor necessities. Some call for multiple wired networks in a single garment, others call for multiple wirelessly networked devices securely attached at various body locations and still others call for miniature, biocompatible implanted devices with less frequent communication to the outside world. They capture large quantities of data continuously and naturalistically, which microprocessors must process to extract actionable information. Data processing must be hierarchical to exploit the asymmetry of resources, preserve system efficiency, and ensure that data is available when needed [16].
To evaluate the system, several tests have been performed by using some parameters of the system. The results have been obtained after analyzing the experimental values at other statistical parameters such as Gain, Recall, Precision, or Accuracy. These parameters define the concept of false-negative (FN), false positive (FP), true positives (TP), and true negatives (TN).

\[
Accuracy \text{ Value} = \frac{TP + TN}{FP + FN + TP + TN}
\]

\[
Precision \text{ Value} = \frac{TP}{FP + TP}
\]

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Gain \text{ Value} = \frac{TP}{FN + TP}
\]

5. Conclusion
BSNs are used to associate sensors with the human body to monitor and collect physiological information. This data can be widely used in the area of health care, social welfare, sports, entertainment. The omnipresent network is the method in which, the human body is considered a part of a communication network. Therefore, BSN has broad application prospects and market potential. BSN, WSN, and other wireless techniques, without any loss of its signals as well as any damage in the human body, because wireless communication possesses remarkable challenges from the spectrum that can be usable, and can able to affect the human body.

In terms of protocols, several issues like robustness, security, and interference-free communication are key requirements. Even though, the arduous research reports in the area of BSNs, still, many open issues remain for future work. For example, more attention should be paid to node size minimization and energy consumption reduction for designing of sensor nodes.

There may be possibilities for designers, they could focus on a particular region to ignore the human damaged tissues, which can because due to the sensor’s heat, when it comes in contact with the human body. In short, BSNs represent the integration of multi-disciplinary areas, aiming to solve many key issues in several of these areas, which requires researchers to do further exploration.

References

[1] J. Luprano, J. Sola, S. Dasen, J. M. Koller, and O. Chelelat, "Combination of Body Sensor Networks and On-body Signal Processing Algorithms: the Practical Case of MyHeart Project," in International Workshop on Wearable and Implantable Body Sensor Networks (BSN 2006), Cambridge, MA, USA, 2006.

[2] R. Jafari, A. Encarnação, A. Zahoory, F. Dabiri, H. Noshadi, and M. Sarrafzadeh, "Wireless Sensor Networks for Health Monitoring," in Second Annual International Conference on Mobile and Ubiquitous Systems: Networking and Services (MobiQuitous 2005), 2005, pp. 479-481.
[3] MEMS Technology page, URL: http://www.memsnet.org/mems/what-is.html, Accessed on 10 April 2009.

[4] I. Khemapech, I. Duncan, and A. Miller, "A Survey of Wireless Sensor Networks Technology," in 6th Annual Postgraduate Symposium on the Convergence of Telecommunications, Networking and Broadcasting, Liverpool, UK, 2005.

[5] I. F. Akyldiz, W. Su, Y. Sankara Subramaniam, and E. Cayirci, "Wireless Sensor Networks: a Survey," Computer Networks (Elsevier), vol. 38, pp. 393-422, 2002.

[6] U. Varshney, "Pervasive Healthcare and Wireless Health Monitoring," Mobile Networks and Applications, vol. 12, pp. 113-127, March 2007.

[7] K. W. Goh, J. Lavanya, Y. Kim, E. K. Tan, and C. B. Soh, "A PDA-based ECG Beat Detector for Home Cardiac Care," in IEEE Engineering in Medicine and Biology Society, Shanghai, China, 2005, pp. 375-378.

[8] H. Zhou, K. M. Hou, J. Ponsonnaille, L. Gineste, and C. D. Vaulx, "A Real-Time Continuous Cardiac Arrhythmias Detection System: RECAD," in IEEE Engineering in Medicine and Biology Society, Shanghai, China, 2005, pp. 875-881.

[9] H. T. Chu, C.C. Huang, Z. H. Lian and T. J. P. Tsai, "A Ubiquitous Warning System for Asthma Inducement," in IEEE International Conference on Sensor Networks, Ubiquitous and Trustworthy Computing, Taichung, Taiwan, 2006, pp. 186-191.

[10] Sriram Cherukuri, Krishna K Venkatasubramanian and Sandeep K S Gupta BioSec: A Biometric Based Approach for Securing Communication in Wireless Networks of Biosensors Implanted in the Human Body Proceedings of the 2003 International Conference on Parallel Processing Workshops (ICPPW’03), 2003, IEEE.

[11] Cardio Micro Sensor, Available at http://www.cardiomems.com, Accessed: June 2009.

[12] M. Alwan, S. Kell, B. Turner, S. Dalal, D. Mack, and R. Felder, "Psychosocial Impact of Passive Health Status Monitoring on Informal Caregivers and Older Adults Living in Independent Senior Housing," in 2nd Information and Communication Technologies, Surabaya, Indonesia, 2006, pp. 808-813.

[13] J. A. Stankovic, Q. Cao, T. Doan, L. Fang, Z. He, R. Kiran, S. Lin, S. Son, R. Stoleru, and A. Wood, "Wireless Sensor Networks for In-Home Healthcare: Potential and Challenges," in High Confidence Medical Device Software and Systems Workshop, Pennsylvania, USA, 2005.

[14] L. Schwiebert, S. k. S. Gupta, and J. Weinnmann, "Research Challenges in Wireless Networks of Biomedical Sensors," in 7th annual International Conference on Mobile Computing and Networking, Rome, Italy, 2001, pp. 151-165.

[15] B. Krishnamachari, Networking Wireless Sensors: Cambridge University Press, 2006.

[16] G. Mulligan and L. W. Group, "The 6LoWPAN Architecture," in 4th Workshop on Embedded Networked Sensor, Cork, Ireland, 2007.

[17] Pfuntner, Anne, Lauren M. Wier, and Claudia Steiner. "Costs for hospital stays in the United States, 2011: statistical brief# 168." (2014).

[18] Rafael-Palou, Xavier, Eloisa Vargiu, and Felip Miralles. "Monitoring people that need assistance through a sensor-based system: evaluation and first results." Proceedings of the 4th International Workshop on Artificial Intelligence and Assistive Medicine (AI-AM/NetMed 2015). Pavia Italy, 2015.

[19] Anzanpour, Arman, et al. "Internet of things enabled in-home health monitoring system using early warning score." Proceedings of the 5th EAI international conference on wireless mobile communication and healthcare. 2015.

[20] Atzori, Luigi, Antonio Iera, and Giacomo Morabito. "The internet of things: A survey." Computer networks 54.15 (2010): 2787-2805.

[21] Stratton, Rebecca J., Ceri J. Green, and Marinos Elia. Disease-related malnutrition: an evidence-based approach to treatment. Cabi, 2003.

[22] Hickson, M. "Malnutrition and ageing." Postgraduate medical journal 82.963 (2006): 2-8.
[23] Azimi, Iman, et al. "Internet of things for remote elderly monitoring: a study from a user-centered perspective." *Journal of Ambient Intelligence and Humanized Computing* 8.2 (2017): 273-289.

[24] Maronidis, Anastasios, Anastasios Tefas, and Ioannis Pitas. "Frontal view recognition using spectral clustering and subspace learning methods." *International conference on artificial neural networks*. Springer, Berlin, Heidelberg, 2010.

[25] Maronidis, Anastasios, et al. "Improving subspace learning for facial expression recognition using person dependent and geometrically enriched training sets." *Neural Networks* 24.8 (2011): 814-823.

[26] Sposaro, Frank, and Gary Tyson. "iFall: an Android application for fall monitoring and response." 2009 Annual *International Conference of the IEEE Engineering in Medicine and Biology Society*. IEEE, 2009.

[27] Fang, Shih-Hau, Yi-Chung Liang, and Kuan-Ming Chiu. "Developing a mobile phone-based fall detection system on android platform." *2012 Computing, Communications and Applications Conference*. IEEE, 2012.

[28] Doménech, Sara, et al. "Involving older people in the design of an innovative information and communication technologies system promoting active ageing: the SAAPHO project." *Journal of Accessibility and Design for All* 3.1 (2013): 13-27.

[29] Carmien, Stefan, and Michael Obach. "Back on track: lost and found on public transportation." *International Conference on Universal Access in Human-Computer Interaction*. Springer, Berlin, Heidelberg, 2013.

[30] Kalian, Kristin, and Wolfgang Kainz. "ASSISTANT—aiding sustainable independent senior travellers to navigate in towns." *Proceedings of the European navigation conference*. 2013.

[31] Caon, Daniel, et al. "vAssist: the virtual interactive assistant for daily home-care." 2011.

[32] Sansen, Hugues, et al. "vAssist: building the personal assistant for dependent people: Helping dependent people to cope with technology through speech interaction." 2014.

[33] Jara, Antonio J., Miguel A. Zamora-Izquierdo, and Antonio F. Skarmeta. "Interconnection framework for mHealth and remote monitoring based on the internet of things." *IEEE Journal on Selected Areas in Communications* 31.9 (2013): 47-65.

[34] Henze, Martin, et al. "A comprehensive approach to privacy in the cloud-based Internet of Things." *Future Generation Computer Systems* 56 (2016): 701-718.

[35] Azimi, Iman, et al. "Internet of things for remote elderly monitoring: a study from user-centered perspective." *Journal of Ambient Intelligence and Humanized Computing* 8.2 (2017): 273-289.

[36] Yu, Xinguo. "Approaches and principles of fall detection for elderly and patient." *HealthCom 2008-10th International Conference on e-health Networking, Applications and Services*. IEEE, 2008.

[37] Alwan, Majd, et al. "A smart and passive floor-vibration based fall detector for elderly." *2006 2nd International Conference on Information & Communication Technologies*. Vol. 1. IEEE, 2006.

[38] Sixsmith, Andrew, and Neil Johnson. "A smart sensor to detect the falls of the elderly." *IEEE Pervasive computing* 3.2 (2004): 42-47.

[39] Diaz, A., et al. "Preliminary evaluation of a full-time falling monitor for the elderly." *The 26th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*. Vol. 1. IEEE, 2004.

[40] Almeida, Oscar, Ming Zhang, and Jyh-Charn Liu. "Dynamic fall detection and pace measurement in walking sticks." *2007 Joint Workshop on High Confidence Medical Devices, Software, and Systems and Medical Device Plug-and-Play Interoperability (HCMDSS-MDPnP 2007)*. IEEE, 2007.