Personal Life Signaling Device for Weather or War Disasters

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Abstract

Day after day we are facing with new challenges created by natural or man-made factors. In the first group we can mention earthquakes, heavy storms, earth slides etc, and in the second are wars that unfortunately are taking way people lives even though we live in 21st century. During and especially after every disaster the most difficult moments are to check for survivors under the ruins. In this work we propose a personal and easy to use device based in sensors technology that would make it possible to signal the presence of life signs from persons under the ruins such as pulse or oxygen level. The wireless network created from those devices would make it possible to transmit the signal even in long distances to reach the help emergency teams. To optimize the transmission distance and quality, we propose a new communication protocol for ad-hoc wireless networks. We can consider the network created by the sensors used for personal devices installed in patient wrists. The sensors communicate through a virtual infrastructure that helps to collect the data from the personal devices in an efficient way even in the areas affected by disasters where no wireless infrastructure can function. The communication scheme proposed here ensures a hierarchy of nodes that gives the possibility of saving by using simple devices for most of the population

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and more expensive and sophisticated ones only for the higher hierarchy rank nodes represented by prechosen individuals. For this reason, the protocol that we propose is a hierarchical protocol. The critical condition area, might be a city or village, is divided into virtual cells where each cell is represented from one main node that holds the communication for all the surrounded nodes and forwards its information towards the next cell main node found in the direction of the sink. This protocol gives the possibility to communicate even in the areas without any wireless infrastructure. The life signals collected from people leaving under ruins in the critical condition areas such as earthquakes, wars etc,

Keywords; *Wireless sensors networks, virtual infrastructure, wireless sensors protocols, nanotechnology, personal life signaling device.*

Introduction

Even though we live in the 21st century the horrible wars continue to take way the life of many people. Natural disasters such as earthquakes, earth slides or floods continue to be a big threat for millions of people. The Personal Life Signaling device that we propose here will be a big help to ease the horrible anxiety and to give a chance to live to people under ruins.

The research community always has works toward finding new practical and not expensive solutions to help people. The work in this direction has multiplied, especially during Covid 19. Here we propose a new communication protocol to be used in the critical condition areas. This is a hierarchical protocol LifeSignalsComm as an advancement of our previous work related to communication protocol used in the case of patient monitoring System,

In this paper we study and design a new ad hoc communication protocol that makes possible to have personal life signaling devices sense the need for emergency assistance by comparing the life sign data with the threshold registered ones and communicate with the nearest health or emergency management services even in disaster affected areas.

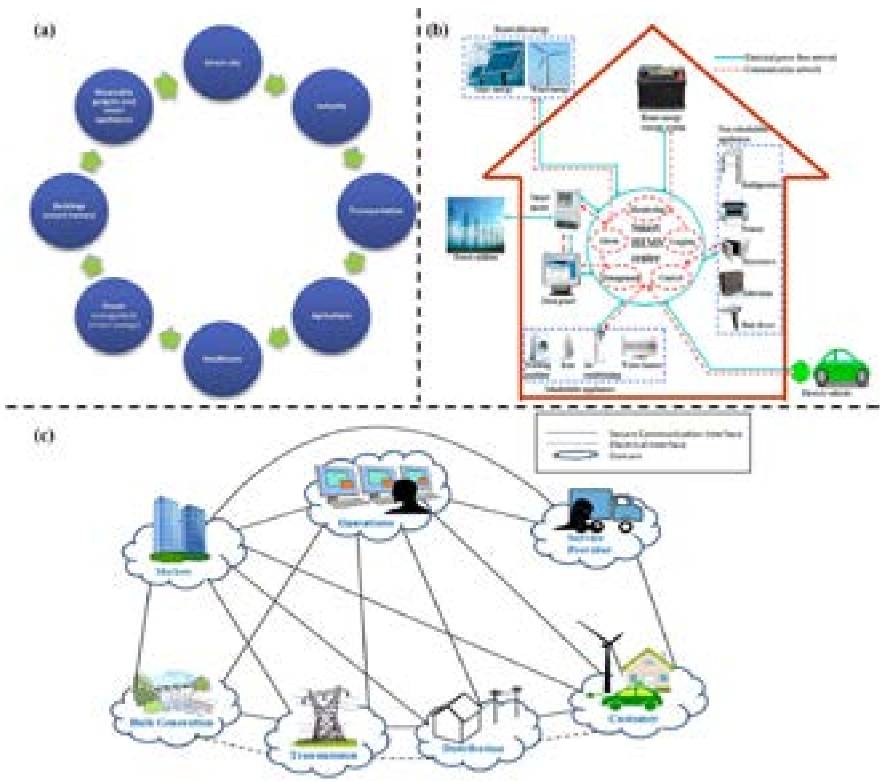
Internet of Things (IoT)

Internet of Things is one of the newest technologies with a fast advancement and infinite applications that have opened up many new possibilities in technical developments in all areas of life (Zheng et al., 2020). This is one of the so called "smart" technologies as the digitalization represents the core center of all previously not imaginable applications. This technology completes the connection of the physical devices that might be industrial equipment or home device so called “things”. As a result, the cities will be called “smart cities” but at the same time are most likely to face tremendous infrastructure pressure due to increased urbanization. The IoT applications represent a very wide range of smart applications, being those devices or networking services. Those applications are from different fields such as construction, logistics, medicine, transportation, and manufacturing.

3. IOTs in healthcare

One of the main applications directions is medicine as it is directly related to people’s life and their well-being. This technology brings the high possibility for various applications. The new characteristic of those applications is that patients are getting more involved in their treatment due to the IoT invasion, which would allow them to reach their doctors, organize appointments, and access their health records via a portal. The hospital or medical center’s staff could also access real-

FIG. 4. (a) Application areas of IoT technologies**;** (b) Schematic representation of a smart home system using smart home management system (HEMS) (c)Smart grids



time patient information using the home monitoring systems, providing benefits for even non-hospitalized patients.

Smart devices used in health care are infinite, but we can mention only the portable ones as those are related to the objective of our work such as portable devices including body clothes (pants, underwear, and coats), heads (helmets and glasses), wrists (gloves, bracelets, and watches), somatosensory modulators, like, body and feet sensory control devices. The blooming of those applications creates a big challenge especially in security. This brings the risk of harming the IoT, because when every piece of data and gadget is connected to the network, hackers may access it and use it for various frauds. The other new advancement in healthcare is Artificial intelligence (AI). This is applied to improve the quality of life in various ways through wearables. Recently AI has become quite popular for transforming computers into logical human beings, making it possible to enhance picture analysis, diagnosis, patient care, and staff efficiency.

Wrist mounted wearables

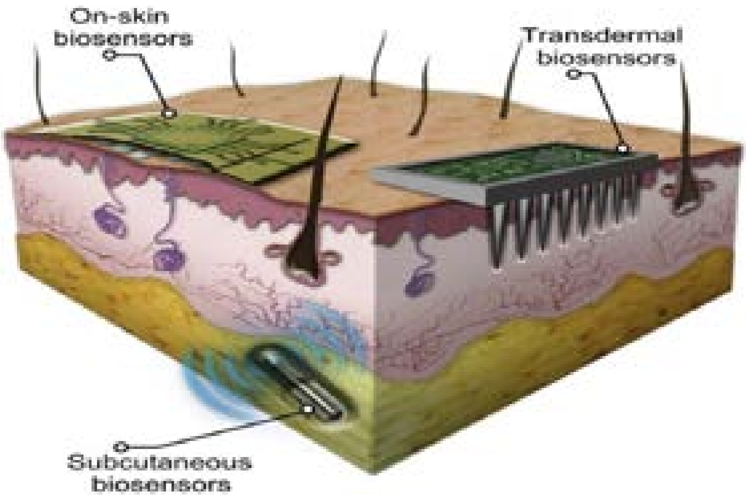
The wrist-wearable devices are usually used to monitor, because of the minimized dimensions as well as the recent increase in battery life for converting the raw signals to real-time interpretable information. Those devices have been used for decades, from the old primitive versions to the most modern and recent ones such as: Screening of hypertension or high blood pressure which is a major, crucial, and important variable risk cause for investigations. As a matter of fact, blood pressure monitoring has become one of the essential physiological measures for monitoring an individual's health condition. Not only that, but wrist-based wearables can be used to monitor even other health related data such as sports and entertainment. Here we can mention wrist-based devices such as smartwatches or fitness bands, that are used to track daily activities.

Fitness bands or wristbands can be used to measure fitness activities monitoring continuously and recording data related with different health requirements. Commercially are many well-known brands such as prHuawei Talkband B3, Fitbit, and the UP4 band ("UP by Jawbone"). Some of those are designed to measure and monitor walking, or to record the sleeping cycle. This can be achieved by using sensors mounted inside the band that are able to capture data generated by the skin reaction such as body temperature, heart rate etc.

Nano-integrated based wearable biosensors Nanotechnology is one of the most recent and advantageous technologies leading to innumerous existent and futuristic applications. This success is completely related to the possibility to reach where the human hand or eye can't be due to the very small size of the nano sensors. Besides the possibility of recording the data, the nanoparticles act as a theragnostic agent in the biomedical field, which means they can be used as both therapeutic and diagnostic methods. (Nayak et al., 2021). Besides that, the nano sensors are used as wearable biosensors creating this way futuristic devices able to monitor personal or public health and are widely recommended by health experts and physicians. Today, various types of biosensors are available in the market, which are used to monitor heart rate, sleep time, temperature, stress management, oxygen level, steps, voice, breath, motion, humidity, pressure, force, voice, etc. The infinite applications and wide range of nano biosensors utilization in smart wearable devices has been highly advanced and will reach $97.8 billion in the upcoming five years. Those devices are becoming more practical every day having very easy to use and functional characteristics by using flexible, stretchable, non-invasive, and high-performance biosensors.

Epidermal based wearable biosensors Those represent a very useful category of biosensors related to the fact that epidermis covers most parts of our body. As a result, the skin-based wearable biosensors are being successfully for so many applications. The epidermal wearable biosensor can detect the biomarkers present in the epidermal fluids like sweat, interstitial fluid (ISF), blood, etc., which facilitates real-time analysis of an individual's fitness and health parameter monitoring. The very specific epidermal-based biosensor works by detecting the biomarkers present in the sweat and ISF from the skin surface and transporting it to the transducer

FIG. 5. Schematic illustration of different skin-based biosensors embedded in skin layers (reproduced with permission from (Dervisevic et al., 2020)).



surface, as shown in Fig. 5. The transducer can be electrochemical, optical, or mechanical, combined with either bio-catalytic or ion-recognition receptors, that convert the chemical signals into detectable signals and process the obtained data into a readable format. In recent years this kind of biosensor is used in two main ways such as: either directly transferred onto the skin in temporary tattoos, as printed e-skin, or in the form of patches and wristbands. Besides that, many of those biosensors are integrated in smartwatches and are in direct contact with the epidermis allowing the sensor to detect the physical activities and mechanical stress that occurs due to the physical movements. The epidermis-based wearable biosensors have already started to rule the market by exceeding their value of USD 1 billion.

Previous research

The challenges are those who give the highest incentives and create new objectives for everyone, especially for the scientific researchers. Many studies have been developed, especially in the past three years regarding the possibility of using wearable equipment to function as Personal Signaling Device that can monitor life signs in people under critical conditions and save lives. Here following we analyze the most recent research published in this direction. The main challenge faced in all those publications is that there are two main issues: the communication protocol and the individual sensing equipment. The system needs to ensure an efficient communication protocol for having the quickest possible notification of critical health conditions toward the nearest health services. Also, it is important to develop a low-cost wearable equipment that would sense the vital parameters as pulse, oxygen levels, blood pressure etc.

The Personal Life Signaling Device system involves the integration of many personal wearable equipment distributed over a large geographical area that would serve as nodes of an ad-hoc network, capable to communicate with each other according to a specific communication protocol. The people in critical situations can be not only in large distance but even under ruins and it's not possible to communicate through their phones with the members of the nearest emergency centers. As a result this communication protocol between the nodes of the virtual sensor network need to fulfill the following requirements: long communication distance between even in very difficult situations of the critical health condition patient and the local emergency teams, good communication quality even in rural areas; high integration range of wireless sensors as part of the personal life signaling devices distributed over a large geographical area; immune to radio interference; the same technology distributed and implemented by many under critical conditions local municipalities; ensuring continuous monitoring service for all the populated areas; practical wearable equipment and low-power consumption for ensuring long life battery usage, providing a good ratio cost performance solution.

The abovementioned challenges are critical considering the small communication distance capability of the Personal Life Signaling devices due to the limited access resources of sensors like processing capabilities, available data storage or limited power sources. Those are the main judging criteria of previous work analyzed here following.

Previous research in the field

Advancement in the health monitoring services has always been of great interest from research communities all over world, especially in the past three years. As a matter of fact, we must note that there exists a lot of work previously done in the field of health monitoring of patients not hospitalized. Here following we mention several of them: 1)The research work presented from collaborative work of Nanoscience Institute and Indira Gandhi University in presented in (Verma at al., 2022).Their solution is very interesting but it is considered as a stand-alone device that would need high processing power and battery to communicate in distance, not considering the traffic and QoS problems caused by simultaneously messages send to the same destination point. In the research work presented from the collaboration of Shanghai Universities (Zhang et al.,2021) is presented a device for COVID-19 prevention that monitors and records continuously the important health data of a patient. According to their solution the equipment installed in the patient's wrist records two main parameters: the patient's body movements and the patient's body temperature. The data collected is transmitted to a computer using Bluetooth. The main problem with this solution is the short range of communication, about 10m. This solution is to be used in urban areas where the wireless infrastructure will support the data transmission from the PC to the local Health Services. This requirement makes it difficult to be used in emergency and war situations.

The second work to be mentioned is the research done from the collaboration of Islamabad, Pakistan-Aerospace University and South Korea (Ullah et al., 2021). According to their solution they propose a patient quarantine monitoring system using multiple sensors distributed over patient's body that will measure temperature, respiratory, accelerometer, pulse, SpO2 and the patient's location data given by GPS (global positioning system). As in the previous work the data are transmitted by using the Bluetooth towards the microcontroller and then toward the local server by using the Internet connection.

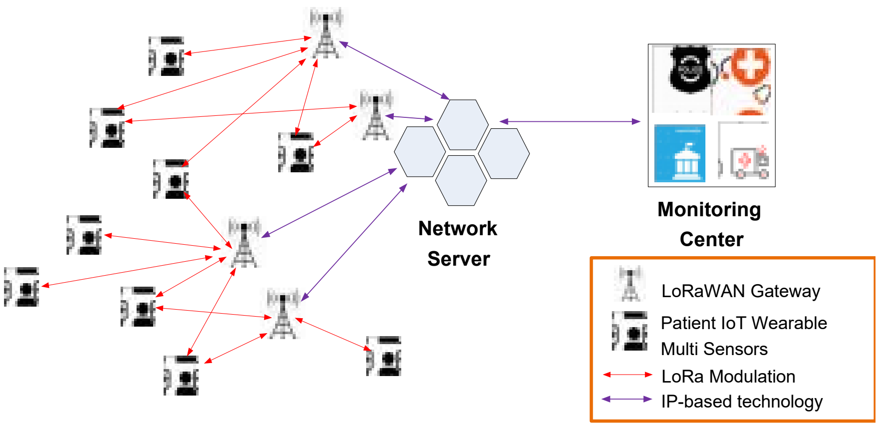
The system monitors the patient's health and his location to notify the services in the case that the patient would break the quarantine rules. As in the previous work mentioned the system works only in the presence of the Internet which means it doesn't support the use in the absence of the wired or wireless infrastructure as it can be in emergency and war regions. The other disadvantage is the complexity of the system as the sensors are distributed over the patient's body which means that will be very uncomfortable and prone to technical defects.

The other solution that we studied is proposed by the research developed at (Mukhtar et al.,2021) which is very similar to the previous one and has the same disadvantage of using sensors distributed over patient's body and not practical equipment. Regarding data communication their solution is based to the use e of the wireless infrastructure as the data collected are sent and processed to the Cloud even though they use the IEEE 802.11 protocol only at the first hop.

Similar problems are related to the work from Salerno University presented in (Hoang at al., 2021) where they propose the use of a similar patient monitoring system. They use an accelerometer for recording the patient's movements and two temperature sensors (a contact one and an IR—infrared sensor) for recording the patient's temperature. In addition, their solution includes two sensors to monitor the ambient condition such as temperature and humidity which are positive additions especially in the case of patients living alone. The data collected are transmitted toward a web-based application by using the Bluetooth which means that the system can't be used in the absence of the internet connection.

The work done by a group of researchers from University of Sucieva, Rumenia, (Lavric, at al., 2022) lead to the development of the system showed in Fig.1. Their Health Monitoring System uses LoRaWan, which means that their solution provides a better solution regarding the absence of the infrastructure, but still only in the first hop.

FIG 1: LoRaWAN multi-sensor patient monitoring architecture.



By analyzing the previous research and the specific condition of the Personal Signaling Device we conclude that a combination of the first wearable device or skin installed patches with the ad hoc communications protocol would bring the best results/

As mentioned before there are two challenges for Personal Signaling Devices, the distance to reach the gateway and the convenience of the device. LoraWan has the possibility to communicate in longer distances than other protocols, but still considering the rural areas this isn't sufficient. On the other hand, the data rate is too low and the traffic toward the gateway, is high which causes extra delays and low signal quality.

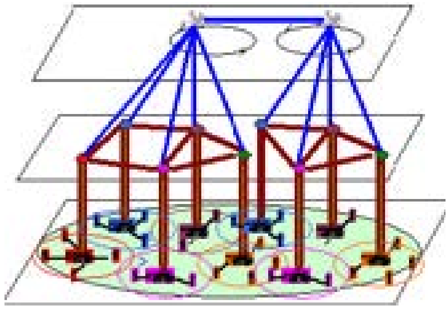
To have a better and longer communication distance in the absence of any infrastructure we develop a new communication protocol presented here as LifeSgnalsComm protocol. This protocol creates a new virtual infrastructure by the specific communications of Ad Hoc network Cell nodes represented by the wearable devices of all population living under the critical conditions. This would enhance the communication distance range in the absence of any fixed or wireless infrastructure and overcome the main challenges of previous systems.

LifeSignalsComm Protocol

Our approach is based on our previous work on intervehicle communication protocols further developed for health monitoring systems. The population under critical conditions in the neighborhood area is divided into virtual cells. Everyone's device is considered as a node inside a certain virtual cell. The density of the nodes inside a cell is changeable, depending on the populations' density and the neighborhood architecture.

In this work we propose a virtual infrastructure created from distributed Personal Signaling Devices which will be considered as nodes of an ad-hoc network. To have a low cost and controlled signal quality according to our approach the communication scheme will be a hierarchical one using up to three levels of hierarchy (only 2 levels for rural areas). (Fig.2) The first level represents by a simple personal signaling device monitoring unit (PSD) that transmits to the PSD's neighbor with a higher scale of hierarchy. The second level of the hierarchy is the PSD that has a certain number of neighbors (less than N), is located somewhere in the center of the cluster and will be considered as a Main Cell Node. The second level of the hierarchy when the PSD that has several neighbors > N, is found near the center of the cluster and will be considered as a MainSubCell Node. The third level of hierarchy in the most populated areas will be created by the MainSubCell nodes that are neighbors and will be considered as simple Cell Nodes, by transmitting their data to the Cell Main Node located at the center of the considered area.

FIGURE 2: Multi-level Virtual hierarchical ad hoc infrastructure



Using hierarchical communication scheme is very beneficial as makes it possible to communicate through larger distances between the personal signaling devices centers, emergency teams working to save people's life even in rural areas. The other benefit brought using the Hierarchical scheme is the low network load. According to this solution less traffic will be generated between the individuals suffering critical conditions and the local emergency service as only the MainCell nodes will be transmitting the data of all the nodes in their respective cell in a certain moment of time. This can be clear if we consider for example as the Main Cell node the wearable device worn from one person living in a group of apartments. The other benefit is the low cost of the hardware. Only the MainCell device needs to have more complex design such as memory, and transmission power. Also, it is important to note that only the high hierarchy nodes (devices) will have a higher consumed power which means that for the rest of the personal devices the battery will have a longer life.

FIG. 3: Communication between Main Cell devices using the Virtual Infrastructure

Depending on the severity of the critical situation that is created by natural or human factors the functionality of PSD can be altered in time which means not all devices will be sensing and transmitting at the same rate and all the time. This can be completed by using the sleep-awake scheme for certain nodes in the case of people moving away from the area or no longer under critical conditions.

According to LifeSignalsComm protocol a flexible Virtual Infrastructure is created and maintained to enable scalable and effective communications (Fig 3). The number of nodes inside a cell can be modified. In each cell only one node (PSD) will be pre- or self-chosen as a Main Cell Node according to its location being approximately at the geographical center of the Virtual Cell. This node will behave as a Base Station for a certain period. The hierarchical distribution of Cell Main nodes will be transferred to the hierarchy of their costs, which means that only the devices corresponding to the cell main nodes need to have larger memory, processing power and battery consumption. The Hierarchical Virtual infrastructure created enables the optimization of the routing process.

At a certain rate each node updates the data from the GPS, which gives the Coordinates (x,y) for each node at a certain moment. Every node has its geographical position given by Global Positioning System (GPS). Then the higher ranked nodes transmit the data along each-other using the sequential Cell main Nodes as intermediate communications points and finally transmit the data to the Gateway when it reaches an infrastructure covered area as in Fig 3.The Information Management System might be a server or the smart equipment used by the emergency team or Local Emergency Services Center that will do the process of analyzing the data collected from all the population living in a certain area and decide about a certain action to be taken accordingly.

The device we propose to be used is similar to the wrist wearable device used in (Mishra, R, K et al., 2018) combined with a microcontroller board with add-on sensors that will sense the patients vital signs such as temperature, oxygen levels, blood pressure etc. It will include a peripheral GPS receiver and a cellular modem. It can be in a more sophisticated and practical form especially for those that don't have the function as Cell Main Nodes, such as patches or tattoos being installed previously or in an appropriate moment.

LifeSignalsComm Benefits

As a conclusion this protocol will benefit and can be used everywhere even in the absence of wired or wireless infrastructure, especially in natural emergency such as earthquakes or under war areas. The protocol to be used gives the possibility of using tunable fine-grained sensing regarding the Data acquisition rate, threshold health alert values or node activity status. This system gives the possibility of using a mixed protocol routing scheme such as ZigBee for inside cell communication, and IEEE802.11 for intracell centers communication. As we explained above the other benefit is that the hierarchical levels are tunable too, depending on the severity of the situation, complexity of the device used, neighborhood architecture and population density ensuring good communication quality, low latency, and low power consumption but at all moments giving the possibility to save people life by looking in the data and giving the right help to the people under critical conditions.

References

Aljohani, A.J.; Shuja, J.; Alasmary, W.; Alashaikh, A. (2021). Evaluating the Dynamics of Bluetooth Low Energy Based COVID-19 Risk Estimation for Educational Institutes. Sensors 2021, 21, 6667.

Bahle, G.; Rey, V.F.; Bian, S.; Bello, H.; Lukowicz, P. (2021). Using Privacy Respecting Sound Analysis to Improve Bluetooth Based Proximity Detection for COVID-19 Exposure Tracing and Social Distancing. Sensors 2021, 21, 5604. [CrossRef] [PubMed]

Dervisevic, M., Alba, M., Prieto-Simon, B., Voelcker, N.H. (2020). Skin in the diagnostics game: wearable biosensor nano- and microsystems for medical diagnostics. Nano Today

Durresi, M. (2016). Biosensors for Sustainable Food: New Opportunities and Technical Challenges. Comprehensive Analytical Chemistry; Continuity Publishing, Books Elsevier Ltd.

Durresi, M., Durresi, A., Barolli, L. (2007). Wireless Communications for Health Monitoring on Highways"; ICDCS Workshops 2007, Toronto, Canada, 37.

Durresi, M., Durresi, A., Barolli, L. (2005). Inter-Vehicle Communication for Safer Highways, AINA 2005: 599-604.

Fernández-De-las-peñas, C.; Palacios-Ceña, D.; Gómez-Mayordomo, V.; Cuadrado, M.L.; Florencio, L.L. (2021). Defining Post-COVID Symptoms (Post-Acute COVID, Long COVID, Persistent Post-COVID): An Integrative Classification. Int. J. Environ. Res. Public Health 2021, 18, 2621.

Hoang, M.L.; Carratù, M.; Paciello, V.; Pietrosanto, A. (2021). Body Temperature—Indoor Condition Monitor and Activity Recognition by Mems Accelerometer Based on IoT-Alert System for People in Quarantine Due to COVID-19. Sensors 2021, 21, 2313. [CrossRef] [PubMed]

Jiang, X.; Niu, Y.; Li, X.; Li, L.; Cai, W.; Chen, Y.; Liao, B.; Wang, E. (2020). Is a 14-Day Quarantine Period Optimal for Effectively Controlling Coronavirus Disease 2019 (COVID-19)? medRxiv 2020. [CrossRef]

Lauer, S.A.; Grantz, K.H.; Bi, Q.; Jones, F.K.; Zheng, Q.; Meredith, H.R.; Azman, A.S.; Reich, N.G.; Lessler, J. (2020). The Incubation Period of Coronavirus Disease 2019 (COVID-19) from Publicly Reported Confirmed Cases: Estimation and Application. Ann. Intern. Med. 2020, 172, 577–582.

Lavric, A. (2019). LoRa (Long-Range) High-Density Sensors for Internet of Things. J. Sens. 2019, 3502987.

Lavric, A.; Popa, V. (2018). Performance Evaluation of LoRaWAN Communication Scalability in Large-Scale Wireless Sensor Net.

Lavric,A., Petrariu, A., Mutescu, P,, Coca,E., Popa,V. (2022). Internet of Things Concept in the Context of the COVID-19 Pandemic: A Multi-Sensor Application Design, Sensors 2022.

Mukhtar, H.; Rubaiee, S.; Krichen, M.; Alroobaea, R.(2021). An Iot Framework for Screening of COVID-19 Using Real-Time Data from Wearable Sensors. Int. J. Environ. Res. Public Health 2021, 18, 4022. [CrossRef]

Mishra, R.K., Barfidokht, A., Karajic, A., Sempionatto, J.R., Wang, Joshua, Wang, Joseph. (2018). Wearable potentiometric tattoo biosensor for on-body detection of G-type nerve agents simulants. Sensor. Actuator. B Chem. 273, 966–972.

Nayak, V., Singh, K.R., Singh, A.K., Singh, R.P. (2021). Potentialities of selenium nanoparticles in biomedical science. New J. Chem. https://doi.org/10.1039/ D0NJ05884J.

Nemiroski, A., Christodouleas, D.C., Hennek, J.W., Kumar, A.A., Maxwell, E.J., Fernandez-Abedul, M.T., Whitesides, G.M. (2014). Universal mobile electrochemical.

Zhang, L.; Zhu, Y.; Jiang, M.; Wu, Y.; Deng, K.; Ni, Q. (2021). Body Temperature Monitoring for Regular COVID-19 Prevention Based on Human Daily Activity Recognition. Sensors 2021, 21, 7540. [CrossRef]

Ullah, F.; Haq, H.U.; Khan, J.; Safeer, A.A.; Asif, U.; Lee, S. (2021). Wearable Iots and Geo-Fencing Based Framework for COVID-19 Remote Patient Health Monitoring and Quarantine Management to Control the Pandemic. Electronics 2021, 10, 2035. [CrossRef]

Verma, D.; Singh, K.; Yadav, A.; Nayak, V., Singh, J.; Solanki, S.; Singh, R. (2022). Internet of things (IoT) in nano-integrated wearable biosensor devices for healthcare applications.

Zaki, N.; Mohamed, E.A. (2021). The Estimations of the COVID-19 Incubation Period: A Scoping Reviews of the Literature. J. Infect. Public Health 2021, 14, 638–646.

Zhang, P., Durresi, M., Durresi, A. (2021). Internet Network Location Privacy Protection with Multiaccess Edge Computing, *Computing 103 (3)*, 473-490

Zheng, C., Yuan, J., Zhu, L., Zhang, Y., Shao, Q. (2020). From digital to sustainable: a scientometric review of smart city literature between 1990 and 2019. J. Clean. Prod. 258, 120689. https://doi.org/10.1016/j.jclepro.2020.120689.

Zheng, X., Zhang, F., Wang, K., Zhang, W., Li, Y., Sun, Y., Sun, X., Li, C., Dong, B., Durresi, M. (2016). Wireless Sensors Networks for Food Supply Chain Monitoring, DSSH 2016, UET, Tiranë.