



A STUDY ON THE CURRENT STATE OF THE ART IN BODY AREA NETWORKS IN HEALTH CARE

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ABSTRACT

A body area network (BAN) is a collection of devices that can detect and react to changes in their immediate environment. BAN technology has been around for more than two decades, but in recent years it has seen a surge in popularity. In part, this is due to the availability of smaller devices, better communication protocols, and longer battery life. BANs are used in a wide range of industries, including healthcare, where they are used to capture information about patients and their environments. Physicians may benefit from having access to a steady stream of information on a patient's condition. The authors analyse BAN architectures, network topologies, energy sources, sensor kinds, applications, and their key problems based on recent publications in these fields of work. Also included are sections on the paper's emphasis on the most important criteria of security, safety, and long-term viability. Also highlighted are plans for future study and advancements in the field.

KEYWORDS: Body Area Networks, State of the Art, Healthcare, IEEE 802.15.6.

1. INTRODUCTION:

People around the world are living longer as a result of better access to health care, better nutrition, and better safety. As of 2017, there were 962 million people over 60, and that number is expected to climb by around 3% every year, according to the United Nations. There will be 2.1 billion people over the age of 60 in 2050, and 3.1 billion by 2100. In 2017, 27 percent of the Japanese population was over the age of 65. Unfortunately, a growth of this magnitude entails a number of drawbacks. As an example, this implies that the proportion of the people who are employed is falling year after year. In order to pay for social security and healthcare, many governments are having financial challenges.

In addition, the number of people globally with chronic diseases is on the rise. Chronic diseases accounted for 46 percent of all fatalities in the globe in 2001, according to the World Health Organization. According to the World Health Organization, chronic disease-related mortality will rise by 57% by 2020. In the elderly population, diabetes, obesity, and cardiovascular disease account for about half of all chronic disease mortality. Many people are afflicted by these illnesses, which can even show up early in life in some cases. Because of this, catching these diseases at an early stage is critical in the fight. Through the use of noninvasive devices, it is possible to monitor health status and diagnose and prevent chronic diseases utilising a body-area network (BAN) (BAN).

A BAN is made up of a variety of small devices that collect and communicate information from a variety of sources. BANs are used in a wide variety of fields, but healthcare and medicine are two of the most important. The medicinal and non-medical applications of BAN are typically separated. First, BANs are used to keep tabs on patients with long-term conditions like heart disease, asthma, or diabetes. When something goes wrong, the emergency services are alerted by the constant monitoring of the patient's vital signs in these applications. At any time of the day, the information is accessible. This aids doctors in making an accurate diagnosis and recommending the best course of action. BANs can also assist with physical rehabilitation and the support of those with disabilities.

Numerous BAN surveys have been published in recent years, which is not surprising. Research on BAN/WBAN communication kinds, sensors, physical and data link layers, as well as service and security was conducted in 2011 in two surveys [5,6]. Intrabody communication (IBC) emerged as an alternative wireless communication technology in a subsequent survey, which demonstrated mathematical models, IBC transceiver designs, and basics. A standard called IEEE 802.15.6 was used to examine WBAN models for on-body, in-body and off-body propagation in 2013. There followed an overview of WBAN applications, technologies and standards as well as the future of WBANs." Experiments and real-life examples are also presented by the authors.

In addition, polls on specific BAN concerns have been delivered during the last three years. As an example, network security is critical in any network where sensitive information is at risk. For this reason, many academics focus their efforts on the creation of defences against BAN attacks. Security in BANs has been discussed in depth, with the authors focusing on key agreement schemes and the methodologies used to evaluate security and performance in the introduction. In addition, there is a study of WBAN solutions' dependability and fault tolerance. Additionally, a new study examines current topologies and applications in IoT-based healthcare solutions for network architectures. They also look at security,

resource management, quality of service (QoS), real-time monitoring, and other issues in WBAN-based healthcare. A taxonomy for WBAN QoS-based routing is provided in another paper survey. WBAN apps and network design, routing protocols and data processing techniques have recently been reviewed by researchers to see how these features affect ubiquitous health monitoring.

This work, in our humble opinion, addresses a present void in BAN evaluations. The goal of this paper is to provide an overview of the current state of the art in healthcare applications based on BANs to the general readership. The remainder of the paper is structured as follows: 1. Introduction 2. Section 2 provides a brief introduction to BAN technology, highlighting some of the most common features and needs. Section 3 focuses on physical layer issues, Section 4 on data link needs, Section 5 on network layer setups, and Section 6 on middleware layer issues. Important cross-layer qualities are discussed in Section 6. The IEEE 802.15.6 standard, safety issues, privacy and security, and sustainability are all addressed in these parts. In addition, a range of wearable sensors (mechanical, chemical, electrical, and optical) are examined in the physical layer, with an emphasis on the benefits and drawbacks of each, as well as examples of their use in BAN healthcare. Lastly, Sections 7 and 8 describe the current issues in this subject as well as the study's findings and some potential future developments.

2. BODY AREA NETWORKS: MAIN FEATURES AND REQUIREMENTS:

A wireless sensor network has evolved into a BAN (WSN). For the first time, WSNs were used to connect personal devices such as telephones, laptops, and cameras. A personal area network (PAN) is formed by these devices (PAN). A BAN operates under the same principles. A BAN is a collection of sensor and actuator nodes that may exchange data.

The design of BAN solutions should take into account several basic needs, such as safety, privacy, and security, as well as long-term viability, in addition to those linked to the OSI model's lower levels. However, other criteria, such as service quality and usability, should be taken into account as well in order to give the optimal user experience. These problems can be summed up as follows:

In order to ensure the safety of the end user, these networks, which are in direct contact with the human body, must be built. Because sensitive parameters are measured in sensitive sections, this is a significant aspect in the development of BAN devices, especially when medical applications are being developed.

Access to sensitive information must only be granted to those who need it, and BAN applications collect a large deal of it. Abuse and prejudice might result from the unauthorised use of personal information. authentication and encryption must be implemented in BAN systems that have access to or generate sensitive information. Security measures, on the other hand, should not put BAN nodes under undue strain in terms of power usage.

In order to be truly sustainable, BAN goods must strike a balance between their use of and reliance on renewable sources of energy. An adequate amount of energy must be accessible at all times in order for the BAN solution to work properly. There are two types of energy supply models: (1) the

node is directly supplied by the harvesting energy source (SSCS), and (2) the harvesting source saves energy into a battery, and the battery gives energy to the node, (SBCS). In SSCS, the energy source (such as a solar panel or wind turbine) is directly connected to the computing device, with no energy storage in between. In order for this arrangement to be sustainable, the power supply and demand must be properly matched. Batteries are used to store energy for later use in situations where power is unavailable at all times, such as in the night when solar power is unavailable. To minimise waste, the amount of energy created by SBCS must be equal to the amount of energy stored in the battery. For a successful deployment, it's important to know how much energy each node uses.

Quality of service (QoS) is defined differently according on the type of BAN application being used. In order to assess quality of service (QoS), network latency, jitter, and bandwidth as well as data transmission statistics, error rates, and other valuable information are all important metrics to consider. Quality of service involves adaptability, timeliness, reliability, robustness and credibility for a wide range of applications. In each circumstance there are two types of QoS: application-specific and network-specific. User experience is a critical component of every application (UI). The user interface (UI) must be easy to use and satisfy all of the user's expectations. Using the network example, the application's information provider quality is evaluated (latency, reliability, error management, etc.).

When building BAN apps, this is another necessity that must be taken into account. People that have little or no expertise of information and communication technology (ICT) can quickly set up the solution, which is known as usability.

3. PHYSICAL LAYER REQUIREMENTS:

3.1. Properties According to IEEE 802.15.16 Standard:

Companies and industries use standards to build customer confidence and improve the safety of their products. Regardless of the manufacturer, standards aid in the creation of products that interact with one another. To guarantee that products meet specified technical requirements, standards include rules, protocols, and other parameters. In February 2012, the IEEE TG6 published the 802.15.6 standard. BANs can refer to this standard for guidance. PHY and data link layers are defined by IEEE 802.15.6. Short range, highly dependable, and low-power wireless communication close to or inside the human body is the goal of 802.15.6.

In the IEEE 802.15.6 standard, there are three PHY layers defined. There are three layers of PHY: NB-PHY, UWB-PHY, and the human body communication layer (HBC-PHY).

NB-PHY was developed for two types of wireless medical devices: wearables and implants. Wearable medical devices do away with cables in favour of extremely reliable wireless communication techniques, with one or both ends of the links being attached to the user's person or clothing. There is a frequency band, but no standard, for the implantable group. A device must operate in one of the following bands in order to transmit and receive data: 402–405 MHz for implanted devices and 420–450 MHz for wearable devices are the most commonly used frequencies.

Ultra-low power, great quality, and low complexity are all advantages of the ultra-wide band (UWB) layer. Impulse radio (IR-UWB) and wide-band frequency modulation (WBFM) make up this layer (FM-UWB). Low (3.25–4.75 GHz) and high (6.6–10.25 GHz) bands are separated into 500 MHz bandwidths inside this layer. There are two modes of operation for UWB-PHY applications. If you leave the system in the default mode, only IR-UWB and not FM-UWB will work. Medical and non-medical software can both benefit from the default mode. For high-priority medical applications, a high quality of service mode is employed. As a result, great service quality necessitates FM-UWB.

As a last point, HBC-PHY relies on the human body to exchange data. It transmits and receives electrical signals from the body to a gadget by means of an electrode. This layer's operating frequency ranges from 21 MHz to 5.25 MHz, with a bandwidth of 5.25 MHz.

3.2. Safety Issues in PHY Layer:

The safety of BANs, particularly in medical applications, is a major concern. The ISO 60601 standard for medical devices outlines the risks that patients may face when utilising these devices. Radiation, heat dispersion, biocompatibility, software mistakes, mechanical problems, and electric shocks are all listed in the standard. The primary goal is to avoid inflicting any injury on the patient. In medical BAN uses, patient safety is essential. Because of this, it must be examined in the same manner as the requirements for the technical implementation. When creating BAN systems, it's important to consider the following from three angles:

A systematic approach must be used to deal with any and all potential critical occurrences. There must be no living test subjects, like human skin substitutes or radiation monitors, if the solution has a property that could harm the user. Patients' lives can be saved by avoiding potentially dangerous situations.

To achieve the solution objective, BAN solutions make advantage of networking to communicate all data collected from peripheral nodes. A fatal mistake can be produced by a networking failure in medical applications. Delays and package losses can have a significant impact on key operations. A thorough examination of potential issues in key operations is necessary for developers to improve the design of a solution that minimises them.

Medical applications rely heavily on software. Any problem caused by a bug in the software could be harmful to the patient. The software must be thoroughly checked for coding faults and thoroughly tested for all possible scenarios it may encounter. The software must be able to get feedback from the patient's body in order to avoid harming the patient due to the nature of the continuous engagement.

As previously said, there are numerous ways to ensure one's safety. Experiments investigating the impact of devices on human physiology are undertaken in order to ensure that BAN gadgets are safe for patients. In order to minimise the potential harm to the subjects, these tests have been constructed. In medical applications, hardware models can also simulate a component of the body. These models can be used to test the software and control systems of the device. A vast number of test cases are needed to confirm that the software on BAN devices is functioning properly.

These tests simulate a wide range of real-world situations that the devices could face. In order to ensure the safety of the BAN applications, automaton devices are used.

Model-Based Engineering: The safety of BAN systems is evaluated using model-based engineering (MBE). For the purpose of verifying the system's requirements, a model of the genuine system is built and examined. There are two stages to this model's creation: model development and model evaluation. The attributes of a system are listed in the model development process based on the system requirements. In order to ensure that the final model meets all of its specifications, it is subjected to extensive testing. An example of the process can be seen in Figure 1.

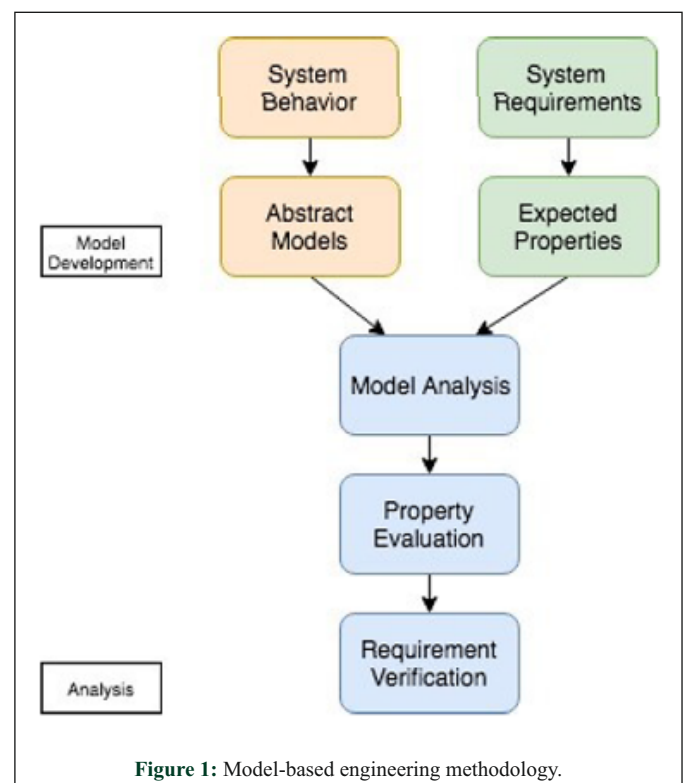


Figure 1: Model-based engineering methodology.

Analysis of medical device hazards begins with the design of attacker models and possible security flaws in the systems. The design of each component is scrutinised to ensure that there are no holes in the system.

3.3. Wearable Sensor Types:

3.3.1. Mechanical Sensors:

When strained or compressed, mechanical sensors measure the degree of deformation. Electrical signals are generated by converting the sensor's shape changes into signals. Piezoelectric, piezoresistive, capacitive and iontronic mechanical sensors are all subclasses of one other.

Piezoelectric Sensors: Material strain, stress, or pressure can cause a piezoelectric effect, which is the basis for piezoelectric sensors. Zinc oxide (ZnO), gallium nitride (GaN), and lead zirconate titanate (PZT) are the most commonly utilised inorganic materials for piezoelectric sensors, whereas ZnO nanoparticles are

employed to develop nanosensors. Processing costs and the use of hazardous lead are associated with the use of inorganic materials. Polyvinylidene fluoride is a strong contender to take the place of genuine inorganic piezoelectric materials (PVDF). Flexible, biocompatible, low-cost, and chemically inert are just a few of the advantages of using this material.

Non-invasive measurement of human artery wave velocities using piezoelectric pressure sensors has been demonstrated in classic research studies. It is the goal of this article to develop a non-invasive method for reliably monitoring arterial pressure in patients with arterial disease, as well as in those who are undergoing surgery or other treatment. The arterial pulse wave velocity is a measurement of the elasticity of peripheral arterial blood vessels. In order to get an accurate reading, they take two pulse waves, one at the wrist and the other near the elbow. It is possible to determine the pulse wave velocity by measuring and determining both the pulse transit time and distance between the sites previously mentioned. They are piezoelectric sensors, which produce a potential difference when they are subjected to a mechanical stress. The arterial pulse wave velocity is measured in three ways in this study:

One is based on the foot-to-foot velocity of the pressure wave; the other two are based on the peak-to-peak velocity of the pulse wave (proximal and distal) and the third is based on the cross-correlation of the arterial pulse coefficient at the proximal and the distal measurement positions.

As a result, piezoelectric sensors are an excellent choice for monitoring body movement or vital signs because of their high frequency response, accuracy, and sensitivity. However, the low spatial resolution and charge leakage of these sensors are both downsides.

Piezoresistive Sensors: A mechanical deformation can alter the electrical characteristics of conductive materials used in these sensors. The piezoresistive effect is the name given to this phenomenon. They are good at detecting tension or strain. Piezoresistive sensors As a result, human joints may be monitored for movement using these sensors. Thin layer conductors on silicone elastomers are commonly used to create these types of sensors. Strain sensors, which can detect movements like an elbow or knee bending, can be mounted on the human body because of their modest size. When worn by humans, sensors must be flexible and comfortable to wear. These conditions are met by textile-based strain sensors. Contrary to popular belief, novel materials such as conductive yarns or inks are being used in textile strain sensors instead of the more traditional strain sensors embedded in the fabric itself. Sensors may now be made more comfortable and water resistant with the help of these new materials.

In a recent study, a composite of carbon black, a matrix of thermoplastic polyurethane, and silver nanoparticles is used as a sensing material to make piezoresistive sensors easily and cheaply. When compared to bare carbon black-based sensors, the sensitivity of this strain sensor is roughly 18 times higher at maximum strain. This sensor is capable of detecting finger bending, elbow flexion, and wrist rotation with great precision. Human body movement can be accurately tracked by wearable applications that use sensors with a higher sensitivity. Professional athletes can use these applications to improve their performance, patients can use them for physical rehabilitation, and the elderly can use them to keep tabs on their activity.

Capacitive Sensors: Two parallel conductive plates separated by a gap are typical components of capacitive sensors. These sensors monitor variations in capacitance, an electrical characteristic. The conductive plates' response to a potential difference is known as their capacitance. An electric field exists between the two plates as a result of this voltage discrepancy. Positive and negative charges exist on each plate and these charges shift with changes in polarity. The polarity of capacitive sensors is constantly changing, resulting in an alternating electric current. The capacitance determines the amount of current that can flow through the device. As the plates are separated by various materials, the capacitance fluctuates accordingly.

As an illustration, biocompatible ionic hydrogel sheets have been used as conductive plates in the development of a capacitive sensor. The sensor's elasticity allows it to be used to measure skin stretch and pressure. As a result of their great sensitivity and low power consumption, capacitive sensors are widely employed. Problems arise when these sensors are incorporated into wearable devices. Anthropogenic or environmental parasitic noise can affect sensor data. It's not a good idea to utilise capacitive sensors in wearable devices since they need to be insulated from the outside world. In spite of this, these sensors are a fantastic choice for human-interaction devices like touch screens because of their high sensitivity and low power consumption.

Iontronic Sensors: Iontronic sensors outperform capacitive sensors in terms of sensitivity and parasitic noise, making them a better choice for delicate applications. A nanoscale double-layer supercapacitor serves as the foundation for these sensors. Electrode capacitance is measured between the electrode and the electrolyte. Comparing identical-sized capacitive and iontronic sensors, the latter has a 1,000-fold larger electrical capacitance and is impervious to parasitic noise. Because of this, iontronic sensors are ideal for wearable devices.

An epidermal-iontronic interface was recently developed by researchers in a recent publication (EII). This noise-immune, extremely sensitive, and adaptive wearable interface is designed to be worn by everyone. Flexible and curved surfaces having electrical conductivity, such as human skin, are used as part of this sensor's construction. Fast reaction and long-term stability are possible thanks to its design. Both internal (from the body) and exterior (from the environment) stimuli can be detected by the EII. Authors were able to demonstrate the sensor's ability to detect cardiovascular pulse waveforms, muscle activity tracking, breathing rate, and grip pressure.

For these reasons, iontronic sensors are ideal for use in emergency and medical settings. These sensors can also be used in robotics, allowing robots to feel their environment through touch. For example, robots that can sense pressure applied to a person's body can be developed using this function.

3.3.2. Chemical Sensors:

Electrochemical, electrical, or optical signals are used by these sensors to detect changes in chemical composition. The chemical sensor can be permanently damaged by prolonged contact with biofluids. Chemical sensor designers encounter a lot of difficulties because of their reliance on long-term stability. Stability, sensitivity, and selectivity are all requirements for these sensors.

The epidermis, as previously said, is a natural information barrier. So, the body's biofluids must be measured using a non-invasive chemical sensor. Large analytes in these biofluids are diluted, and certain fluids are released in very small volumes. As with every sort of sensor, there are advantages and downsides to each type of chemical sensor. Chemical-to-optical sensors require no localised electronics or detectors, making them extremely low-cost and simple to operate. The use of light or optic sensors, which might be impacted by external sources, is a downside of these types of sensors, as is the requirement for user intervention to examine or record data. There is no requirement for a light source, detector, or optics with chemical-to-electrical sensors because they work immediately upon coming into contact with a biofluid.

Analytes that can be detected by chemical wearable sensors can be reduced in size by using nanomaterials like graphene, conducting polymers, carbon nanotubes, and nanowires. Graphene has shown to be a powerful tool. One of the most important properties of graphene is its hexagonal configuration. Exceptional qualities in the areas of electrical, optical, mechanical, and thermal can be found in this material. The ability of graphene to detect hydrogen peroxide (H₂O₂), an important component for pharmaceutical analyses, heavy metals, biomolecules like dopamine that in abnormal levels can indicate schizophrenia or human immunodeficiency virus, and toxic industrial chemicals has been demonstrated by researchers.

Special features of graphene allow it to be employed in a wide range of applications. There is only one problem to graphene: it is expensive to produce. Graphemes are being researched by a slew of organisations. In order to identify diseases or pollutants that could harm the environment, chemical wearable sensors can be extremely helpful. However, more research is required to improve wearable devices based on this material in order to reach reliable and low-cost uses.

3.3.3. Electrical Sensors:

In addition to sensing changes in capacitance or conductivity at the skin's surface, electrical sensors can also detect changes in skin's electrical resistance. In order to obtain accurate readings, these sensors need to have strong electrical contact with the skin. Wet and dry electrodes are used in electrical sensors. The skin's resistance is reduced by using wet electrodes, which combine a solid conductive pad with an electrolyte gel. While wet electrodes are placed to the skin, dry electrodes are applied directly to the skin. It is possible to use dry electrodes that are not in direct touch with the skin but rather have an insulating barrier between the electrode and the skin. These electrodes are free of irritants and allergens, and they also guard against electrical shorts.

When it comes to monitoring breathing, the authors used a paper-based electrical sensor. As a result of their work, the authors have developed a low-cost, single-use respiration monitoring system. Hygroscopic properties of paper are used to determine the paper's humidity. When the humidity varies, the sensor turns the changes into electrical impulses. These impulses are sent to a computer for processing. The ionic conductivity of the sensor is enhanced when the user exhales, increasing the amount of water in the sensor. In contrast, as the user inhales, the water level drops. Although less precise than sensors used in laboratories, this gadget is nonetheless portable and can be utilised outside of a lab environment.

Electrical sensors can be used in a variety of ways. As an example, they can be utilised in skin-monitoring medical applications (sweating, hydration level, etc.). Other uses for these sensors are emerging, however, due to their suitability as feedback interfaces for augmented reality.

3.3.4. Optical Sensors:

The light rays are converted into electrical impulses by these devices. The sensor converts the amount of light into a form that can be read by an instrument. The use of optical sensors has a number of advantages, including immunity to elec-

tromagnetic interference, high sensitivity, and the ability to multiplex. Light and temperature can have an impact on optical sensors. In this context, an optical fiber-based gait monitor is presented in a research paper. Transmittance changes in the plastic optical fibre are detected by the sensor. This sensor is affixed to the patient's knee, where it can monitor joint angles. Once the system has been calibrated, it employs a photodetector to assess how much light is received and calculates the flexion angle. Fiber optic sensors are favoured by the authors due to their low weight, low sensitivity to electromagnetic interference, and adaptability. The results of the tests show that the system is capable of detecting tiny angles. Researchers believe it can identify hyperextension, but further testing is needed.

Low-cost, durable, and easy-to-handle wearable sensors can be made possible through the use of plastic fibres. Professional athletes can benefit from optical wearable sensors in their rehabilitation and performance tracking.

3.4. Wearable Sensors in Healthcare:

Medicine is constantly looking for non-invasive techniques to monitor the health of people. With a wearable sensor, you can monitor your health without having to put an external sensor in your body. As a result, in the majority of cases, sensors must be affixed to the skin. By its very nature, the epidermis serves as a barrier. An important part of our immune system is our skin, which serves as the first line of defence against external threats. In order to collect data from the body, sensors built into clothing must first overcome an epidermal barrier.

A patient's vital signs can be monitored using wearable sensors. This wealth of data aids medical professionals in making more accurate diagnoses, as well as professional sports in honing their skills. A person's well-being can be assessed using a variety of physiological indicators. Doctors can discover illnesses by analysing the roles each feature plays and how they interact with one another. These indicators are broken down into three categories: (1) body motions, (2) vital signs, and (3) metabolism.

Strain and pressure sensors are commonly used to assess movement of the body as a whole. Rehabilitation, gesture recognition, gait detection, and facial expression recognition are all possible uses for these sensors. Please take a look at ADAM, a wristwatch application (Advanced Daily Activity Monitor). ADAM is just one part of a larger BAN system. "Elderly people's everyday routines are tracked by this solution. Fall detection, gait change detection, and activity recognition are all part of the BAN application. Health monitoring systems that incorporate IoT sensors include electrocardiograms (ECGs), temperature sensors, pulse rate sensors, and oxygen saturation sensors, among others.

For example, in the field of sports, body motion detection is essential. BANs in sports are used to aid amateur and professional athletes in identifying and correcting performance flaws. They are also frequently utilised in the treatment of sports-related injuries. Data from sensors such as accelerometers, gyroscopes, magnetometers, and pressure gauges is often collected as part of the measurements. Analyzed data from these sensors can be used to determine, for example: a user's physical capabilities; the speed at which the movement was completed; the quantity of calories and fat burned; your heart rate; or the distance travelled. To make use of virtual items, BANs are also used in virtual and augmented reality to detect body motions and hand gestures. Additionally, a wearable with three-axis absolute orientation sensors, accelerometers, and gyroscopes has been proposed as a third option.

Temperature, strain, pressure, and humidity sensors are used to monitor vital indicators such as heart rate, skin temperature, and breathing. Cardiovascular disease, heart failure, apneic control, and wound healing can all be detected with these sensors. Patients with hyperthyroidism, sleep apnea, or sudden infant death syndrome may be monitored using a biometrics (BAN) system. An aberrant breathing pattern can be detected with the use of a wearable digital respiratory sensor and a breathing pattern monitor. The programme has been tested and found to be effective in detecting aberrant breathing patterns. However, the method has only been tested eight times with six different people. This solution needs to be tested more thoroughly before it can be considered accurate. Photoplethysmography and electrodermal activity have been used to estimate psychological distress in a few recent studies.

Chemical sensors in sweating areas and cavities measure concentrations of alcohol, pH, lactic acid, and other electrolytes to assess the body's state. Depending on the application, these sensors can be configured in a variety of ways. In order to help professional athletes perform better or warn patients with heart disease about heart failure, sensors such as gait detectors, temperature sensors, heart rate sensors, and respiration sensors may be combined.

Finally, it's worth noting that physiological data collected by wearable sensors is used for purposes other than healthcare. An electrocardiogram-based biometric authentication system, for example, has been proposed. The next approach is used for authentication:

Obtain the electrocardiograms from the mobile sensor, apply a noise cancelling filter to the data, extract the heartbeat features, and then verify the user's identity. In a study involving 175 participants, the team of scientists tests the answer.

Around 5% of authentication trials utilising a single heartbeat failed, while around 2% of authentication experiments using 15 seconds of heartbeat data failed. It is clear from these findings that the authentication system is a feasible option.

Mechanical, chemical, electrical, and optical sensors all fall under the category of wearable sensors. Each group's utilisation is determined by the specifics of the application. There are certain requirements for each sensor. A chemical sensor must be able to quickly and accurately detect chemical concentrations. The main problem with chemical sensors is their inability to maintain a steady reading. False positives might occur when people are exposed to biofluids on a regular basis. Continuous usage of mechanical sensors can lead to deformation, mechanical degradation, or even breakdowns. Because there are fewer moving components in optical and electrical sensors, they tend to be more reliable and robust. There are drawbacks to using each type of sensor. As a result, researchers from all over the world are working to find ways to make these sensors more stable. In the following sections, we'll go over the pros and cons of various sensor types.

4. DATA LINK LAYER PROPERTIES:

4.1. Properties According to IEEE 802.15.16 Standard:

Subclasses of MAC govern access and contention to channels in a data link layer (DLL). Time-domain multiplexing is used to convey data. Using the hub, the time axis is divided into multiple super-frames. Medical implant communication service (MICS), QoS, emergency communications, interference mitigation, and macro- and micro-power management are all supported by the MAC specification. IEEE 802.15.6 supports three different modes of operation: beacon mode with super-frame borders for beacon time, non-beacon mode with super-frame boundaries, and non-beacon mode without super-frame boundaries.

For radio BANs, a comparison of several MAC protocols may be found. In a study, the focus was on integrating a time-division multiple access MAC protocol with fuzzy-logic-based routing. It has also been addressed to improve the IEEE 802.15.4 MAC protocol in According to the authors, the so-called "BANMAC" MAC protocol can monitor and predict channel fluctuations, schedule transmissions, improve packet loss, and reduce power consumption all at the same time.

4.2. Sustainability:

Recent years have seen an increase in environmental consciousness. Products that are good for the environment are being developed by large and small enterprises. There are two ways that computer systems have an impact on the environment: by using energy and by making use of renewable resources.

In BAN applications, energy efficiency is a must. Many years should elapse before it is necessary to replace batteries in these devices. This objective can be met by employing energy-saving techniques. Typically, communication is the most exhausting task. Efficient media access methods can reduce energy consumption. It is possible to disable the transmitter using these protocols. Slots can also be allocated in a dynamic manner. This prevents the waste of time and energy when a transfer fails.

Nodes in a BAN system can be powered by a variety of sources. Sunlight power, pressure changes, airflow and temperature variations are a few examples of these energy sources. The power density of a human's body heat is about 20 mW/cm². Thermoelectric generators can be used to collect this energy. The node is powered by a battery that these generators can charge. Human body utilisation in BAN applications may lead to more energy-efficient solutions than would otherwise be possible. Even though this technology has been around for some time, new studies are being conducted to improve it.

There are a variety of ways to reduce the energy consumption of the nodes.

In order to maintain an even distribution of work among the system's many nodes, workload management is employed. A higher power usage is prevented by this. It is also feasible to postpone a project till the energy source is ready (without changing the requirements).

Energy consumption can be reduced by better power control. During non-use, the processor is put into sleep or idle mode. Communication devices can benefit from the same method.

Most of the energy used is for non-computing purposes. The application's power consumption can be greatly reduced if these processes are managed well.

In addition to protecting the environment, this is a major concern. BAN applications must have a suitable design in order to limit pollution. When creating BAN solutions, environmental protection is achieved through the application of two distinct strategies: (1) utilising recyclable, eco-friendly materials; and (2) creating long-lasting nodes that do not require partial or complete replacement, hence decreasing waste.

This may be a problem for those who use green energy to power BAN applications. In most cases, the devices can't be operated because of a lack of energy.

Unknown load characteristics are to blame for this issue. Three solutions to this issue have been proposed by researchers in the field of sustainability:

Energy harvesting efficiency can be improved, and device duty cycles can be matched with energy sources, so that more power can be generated. Finally, we have the implementation of computing systems that are low on power consumption.

The goal of these methods is to maintain a healthy level of energy. When a system consumes the same amount of energy as it generates, it has achieved energy neutrality. This problem can be solved using harvesting theory, an analytic method. A stochastic model of the harvesting source and the gadget is used in this theory. The best duty cycle for a device while still maintaining an energy balance can be found using the harvesting hypothesis. There is still a lot of focus on energy considerations in BANs. In order to boost revenues, a new study aims to determine the ideal QoS and energy consumption.

To create this harmony, you need a well-thought-out design. The three phases of the design methodology are:

The first three stages are profiling, modelling, and analysis and design. Similar to MBE, the implementation of both methods can be done at the same time. It's necessary for both approaches to collect and evaluate the information needed to simulate the interactions between the various components. MBE focuses on the efficacy of the solution by ensuring the safety of the solution and its design approach. Processor workload data, radio power, and thermal properties are also measured during this stage. Various power-management algorithms are used to evaluate the power consumption of devices. The amount of energy that can be gathered from each source is assessed in this step.

The modelling stage makes use of the data collected during the profiling stage. This phase's objective is to model the BAN system's and the human body's behaviour. In the final stage, there are two substages: the analysis stage and the design stage. Analyzing the model and the set of requirements from the modelling phase, the analysis phase selects one. The model relies on these specifications as both inputs and outputs. In order to come up with a long-term BAN design, the analytical phase is used in the design step. This phase is faster than a brute-force search in finding the optimum solution.

Maintaining access to healthcare in the long term Industry 4.0 and other cutting-edge fields can help BAN-based applications. BANs are, in fact, being implemented to help and supervise workers. A new piece aims to improve the industry's social sustainability. Engineers have put an intelligent band to the test in an imagined industrial setting, where it was used to correct the actions of a worker to prevent injury.

5. NETWORK LAYER COMPONENTS, CONFIGURATION AND MIDDLEWARE LAYER:

Nodes in a BAN's network have sensors and actuators, as previously indicated. They are worn on the body and collect information on the wearer's environment, activity, and/or physical condition. There are two broad groups of BAN nodes:

Devices having a low processing platform are referred to as "peripheral nodes." Communication interfaces and sensors allow peripheral nodes to monitor their surroundings.

Nodes capable of processing and communicating more efficiently are known as "central nodes." The central nodes are responsible for aggregating and disseminating the data from the sensor nodes (usually through the cloud).

The development of wearable applications is impossible without a sound architectural foundation, and this is especially true for emergency and medical systems, where timely data collection might mean the difference between life and death. There are a variety of hardware options for BAN nodes. The following types of nodes are recommended by IEEE TG6: Sensors that monitor the environment are coupled to a very low-power microcontroller

There are also nodes for medicinal uses.

Information gathering and aggregation devices

There are also nodes that control the infusion-pump-controller kind of nodes

Devices that operate as a gateway or access point.

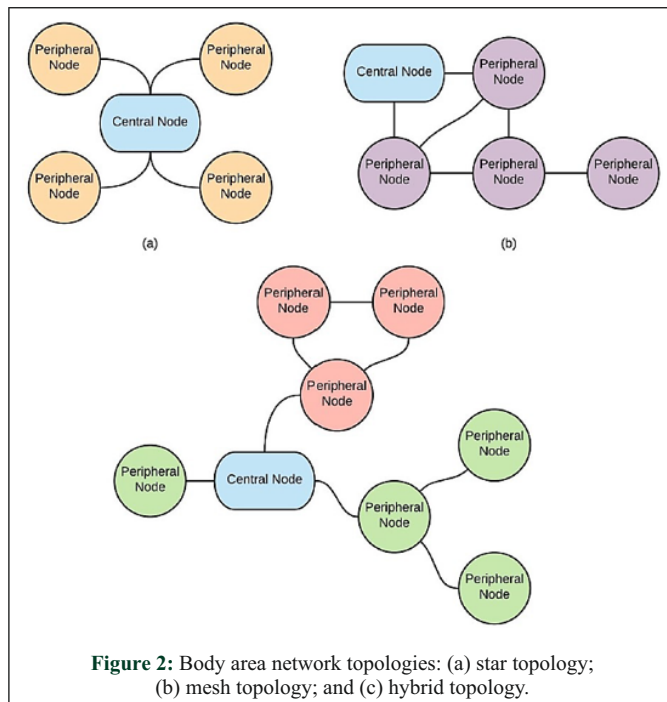


Figure 2: Body area network topologies: (a) star topology; (b) mesh topology; and (c) hybrid topology.

The hardware needed to implement a BAN system is determined by the system's specifications. This is why it's so critical to understand the problem at hand before deciding which components to use to develop the system in the first place. Perimeter nodes with low-power microcontrollers, as well as central nodes that manage the information generated by the peripheral nodes, make up a BAN, as previously stated. The topology of a BAN's network describes how nodes communicate with one another. There are a variety of ways to join BAN nodes. Figure 2 depicts the three network topologies recommended by IEEE TG6. With the star architecture, each peripheral node connects directly to the central one's. Figure2b shows a mesh topology, which is another preferred topology. All nodes in a mesh architecture are not connected directly to the centre node. Figure2c displays a hybrid architecture, which combines the previous topologies.

An abstraction method that enables the system to easily interact with various components is provided by the middleware layer in addition to network layer settings. The issue of interoperability between different IoT platforms geared toward healthcare services and the fusing of sensor data to detect emotions are addressed in a few articles that provide specific platforms to enable the use of various devices as coordinators of the body sensor network and body-side of the cloud platform [52,53]. The data fusion in body sensor networks field has several interesting items to offer on this subject. Emotion recognition and general health articles were the subjects of a survey conducted by the writers. Finally, an ECG analysis is done to automatically assess the patient's mental and health status by analysing the heart's defence response.

6. CROSS-LAYER PROPERTIES:

6.1. Privacy and Security:

The vast majority of BAN applications are used to store sensitive data. Protect this data from unwanted access and change. Basic system requirements must be met in order to protect sensitive data:

In order for the solution to be effective, it must produce accurate and unaltered data.

- Only authorised parties have access to sensitive data.
- The system must be able to identify any and all users.
- Only the relevant information is accessible to entities.
- The application's generated data must be readily accessible when needed.

A potential security breach is a hazard to the safety of the public. Attacks are carried out by entities referred to as attackers, who carry out threats against their targets. There are three types of threats:

In this case, the attacker observes the system's communication with another authorised entity and intercepts the transmitted data without tampering with it. Eavesdropping is the term used to describe this type of assault.

Spoofing is the act of altering, deleting, or adding data to a system by an entity that has legitimate access to that system.

A denial-of-service attack occurs when a hacker prevents the system from performing its normal functions. 3. Blocking or damaging the hardware is one method of carrying out this attack.

6.2. Common Security Solutions:

There are two components to secure communication: trust and communication. For the first portion of this statement, it refers to the veracity of the communication. Encryption is a popular tool for this. Symmetric keys are those in which each thing has a duplicate. Encryption and decryption of messages are both possible with the help of this secret key. With asymmetric keys, each device has a pair of keys: one for encryption, the other for decryption, as an alternative. Systems that utilise just symmetric keys are more energy efficient than those that employ asymmetric keys.

BAN systems, on the other hand, are made up of many layers. Following is a breakdown of the significance of each layer's security:

A BAN device and a smartphone's data transfer must be protected because of the sensitive information that is exchanged. This type of communication is frequently protected by use of cryptography.

Smartphones use wireless internet connectivity to send sensitive information to the cloud. Information exchange is safeguarded using WPA2 or WPA protected access (WPA).

There must be adequate safeguards in place to protect the confidentiality of any data stored there. When it comes to protecting sensor storage, secret sharing and code deletion have been suggested.

Access to sensitive information can only be conducted by those who have been granted permission to do so. In this way, patients' privacy is protected. Policies such as role-based access control and criticality-aware access rules are frequently employed for restricting who has access to sensitive data.

You can use PSKA (physiological-signal-based key agreement), which combines signal processing and cryptography, to secure your BAN applications. The human body's physiological signals can be used to automatically synchronise the keys of two devices. There are five major stages to this protocol:

Each device agrees to utilise a physiological signal before any data is exchanged. 2. The physiological signal is turned into a binary string by processing and decoding. 3. The message is encrypted by the sending device with an arbitrary key.

As a last resort, the sender employs the physiological signal's binary string to conceal the secret code. Once the message has been encrypted, it is sent along with the secret key.

The receiver obtains the key by decoding the local binary string. Once the key decryption has been verified, the device checks the integrity of the received data.

A physiological signal isn't required for any further data exchange after the one described above. As a security measure, this protocol makes advantage of physiological signals that are always different from one another. Because of this, an external device that isn't in direct communication with the patient is unable to share data. There is no need for an additional key in the PSKA protocol to provide secure communication between the various devices. Adding, removing, or transferring devices is also possible with this protocol without affecting the network significantly.

BAN applications can benefit from the PSKA protocol's novel security features, but it is not without its drawbacks. The first hurdle to overcome is determining which physiological signal will be used to safeguard data transfer. All of the signals that the human body generates can be used by PSKA. A signal must be processed before it can be used, and this can lead to a variety of problems, as the following paragraphs explain:

Low latency, distinctness, and temporal variance must all be present in the physiological signal before it can be used.

As physiological signals are time-dependent, the key unhiding procedure requires synchronisation between the receiver and the sender in order to be employed effectively.

The human body's topographical distinctiveness must also be taken into account. Different areas of the body appear to have similar trends in physiological signals, although the actual values differ.

Furthermore, physiological signals are time-dependent and erratic. As long as the current number is kept secret, no one outside the system will be able to determine future values. Moreover, the communication devices must be in sync in order to accomplish a safe data transmission.

There are two ways to process physiological signals. In the first, binary streams of time-domain analysis signal values are concatenated. Device synchronisation is a drawback of this strategy. There are two types of frequency-domain analysis: synchronised and non-synchronised. This strategy, however, necessitates complex mathematical changes, which can be prohibitively expensive on machines with limited resources.

The use of homomorphic encryption in the transmission of medical data is an example of how security can be used to the communication of medical information. A four-tiered design for health monitoring systems has also been proposed by certain researchers. Security requirements for each layer of the WBAN are identified and literature on increasing WBAN security and privacy is reviewed. In addition to addressing congestion in sensor networks, studies have been conducted on the use of cross-layer bridges to mix protocols.

7. CURRENT CHALLENGES:

New sensors, communication channels, wireless networks, and smart, secure integrated components for cyberphysical systems are all hot topics right now. Embedded cyberphysical systems and embedded components must be better integrated into each other in order to generate truly networked and collaborative places, according to the European Commission's Horizon 2020 initiative. There are various requirements that these systems must meet, including security and safety, low power and size, use and flexibility.

In order for body area networks to attain the standards required for widespread use, there are still a number of issues and restrictions that need to be worked out. A large number of research groups throughout the world are engaged in the pursuit of solutions that will allow BAN products to be deployed successfully. BANs must contend with signal propagation, interference, and human-computer interaction as their primary issues. There are a number of communication challenges that concern BAN nodes, whether they are on or inside the body.

As the nodes are placed and oriented, the signal strength changes. Some researchers are looking into ways to transfer data between gadgets using the human body.

It becomes an issue when multiple devices or BANs emit at the same time. An oversaturation of the transmission channels generates a significant rise in packet loss. Interference is being addressed by scientists. BAN users can be identified by biometrics (glucose level, blood pressure, and heart rate). Different communication channels are another option, as is the utilisation of multiple devices. As a result of using many channels, packet loss is considerably reduced.

In order to display information or receive commands, any technical solution needs have an intuitive user interface. Users have high expectations when it comes to the ease of use of BAN systems. Most of the time, people who use these devices have no idea how to use the technology. T-shirts incorporating sensor tissue have been developed by certain researchers in an effort to prevent this problem.

8. CONCLUSIONS:

The focus of this paper has been on BAN applications in the healthcare industry, presenting a brief overview of the current state of the art in BAN technology. The purpose of this article was to briefly cover the architecture, network topology, energy sources, applications, and significant problems of these systems.

For example, the IEEE 802.15 standard gives standards for BAN applications and defines distinct levels that these types of solutions must adhere to in order to work. BAN products require a high level of security because the information generated by the applications must only be accessible to those who are authorised to see it. Another important consideration in the development of BAN solutions is the need for long-term sustainability. A long-lasting and environmentally friendly product is the result of good design.

The pros and disadvantages of various types of wearable sensors have also been discussed. Researchers from all around the world who are working on a variety of wearable technology projects have shared their findings. There is a lot of room for innovation when it comes to sensors like these. There has been a comprehensive review of the most recent research on BAN solutions in healthcare by the most prominent researchers. It is the goal of this post to demonstrate the many advantages that BANs provide to an area by referencing numerous publications.

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