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Using MANET in IoT Healthcare Applications: A Survey

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Abstract: Internet of Things (IoT) is an innovative technology and an efficient solution that facilitates the real-time interconnection within physical devices through heterogeneous networks. Wireless Sensor Networks (WSN) and Mobile ad-hoc networks (MANETs) play significant roles in IoT-based systems. The interactions between WSN and the IoT create innovative MANET-IoT systems that result in several design challenges. MANET-based IoT systems are being used in several application domains. Nowadays, MANET-IoT healthcare applications have become a trend due to the novel COVID-19 pandemic. In this paper, we discuss the possible approaches of routing frameworks to achieve the optimum Quality of Service(QoS) in the MANET-IoT healthcare domain. The presented analysis highlights the advantages and disadvantages of each approach and discusses the impact of the findings on network design. The paper presents an in-depth review of using MANET-IoT in healthcare applications and explores the MANET-IoT healthcare system architecture with its related sensors to help designers better understand the possible options.

Keywords: Mobile Ad Hoc Networks (MANET), Wireless Sensors Network (WSN), Internet of Things (IoT), Healthcare Sensors, Personal Area Network (PAN), Body Area Network (BAN)

1. Introduction

Wireless technology offers high networking flexibility that enables users to access their information remotely. In ad-hoc networks, nodes are wirelessly interconnected without administration nor infrastructure support [1]. The IoT is an innovative technology that promotes the interaction of things with the wide world over various networks and communication technologies. There are 50 billion wirelessly connected devices and four billion sensors in the marketplace. Some specialists expect that these numbers will become trillions within the next decade. The more connected machines, the more generated data, therefore the more routing traffic. The cooperation between MANET and the IoT re-opens new channels of the requirement of services in smart environments. One of the most motivating factors that pushed us to focus on the healthcare system is the COVID-19. This pandemic widely utilizes several sensors, act as input devices such as the blood oxygen sensor, heart rate sensor, temperature sensor, and blood pressure sensors. On the other hand, multiple medical equipment act as output devices or actuators, such as respiratory systems and auto-injector systems.

The world is in a war against coronavirus. All the people and medical societies are working hard to face the new challenges. MANETs, IoT, ES, and clouding are cooperated to observe and control the novel virus and reduce its impacts. The improvements in healthcare-IoT frameworks and sensor technologies explore innovative solutions to assist people to live with Covid-19. The need for a proper routing protocol is crucial to conserve the resources and overcome the challenges. One of the critical factors in MANET-IoT systems is the nodes' energy. Since the IoT systems rely on mobile ad-hoc routing protocols, routing should discover the power-optimized, shortest path for efficient communication. Several challenges face the WSNs, such as bounded resources and limited energy. The need to conserve nodes' energy has grown to increase nodes and network lifetime. Different MANETs' energy-aware routing techniques and relevant surveys have been presented such as in [2], [3], [4], [5], [6], and [7]. Many authors concern the routing Quality of Service (QoS) and performance evaluation issues such as in [8], [9], [10], [11], [12], [13], and [14]. Moreover, the IoT applications in various domains using MANET have been presented in [15], [16], [17], [18], [19], [20], [21], and [22]. The QoS and the Quality of Experience (QoE) issues presented in [23], [24], [25], and [26]. Different

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proposed routing techniques based on bio-inspired approaches and Genetic Algorithm (GA) such as in [27], [28], and [29]. On the other hand, the Embedded Systems (ES) and the hardware influence on the IoT and Real-Time Communication (RTC) have been presented in [30], [31], [32], [33], and [15]. Moreover, numerous surveys have been exhibited on ad-hoc routing such as in [2], [34], [35], [36], [37], [38], [39], and [40]. Energy is considered the spirit and the main drive of the IoT systems. Accordingly, improving routing techniques intends to achieve efficient energy conservation and reach significant power optimization.

In this paper, we exhibit the state-of-the-art MANET-IoT systems, particularly in the healthcare domain as an application of the MANET-IoT systems. The study includes several comparative analyses of the different approaches. The rest of this paper is organized as follows. In section 2, We present a comprehensive survey of MANET-IoT applications. Section 3 shows the healthcare routing approaches. In section 4, we analyze the relevant sensors. We present a discussion to see the bigger picture of the MANET-IoT healthcare applications in Section 5. Finally, in Section 6, we summarize the main findings.

achieved through a diversity of devices running under different patterns [41], [42].

Fig. 1 shows the MANET-IoT-Cloud framework. The MANETs' node is a part of a smart device. This device can be stand-alone or connected to the internet. The IoT device and can communicate with other smart devices even without the internet. These communications are among different applications in various fields. The things can be input devices, such as sensors, or can be output devices, such as actuators. Moreover, a smart node, sensor, or actuator is a component in an ES that can communicate wirelessly with others through different wireless communications, such as WIFI, Bluetooth, ZigBee. WSNs and MANETs have been considered one of the highest features of IoT [32], [35], and [41]. Expanding portable devices and wireless communication development present more value to ad-hoc networks that promote significant applications such as industrial, commercial, Martial, and individual sectors. MANET beneficially enables users to share and reach information regardless of their location. Several studies have been done to improve the MANET-IoT applications in different fields, such as agriculture [42], healthcare [20], animal farms [43], and transportation systems [44]. Mobility, energy consumption,

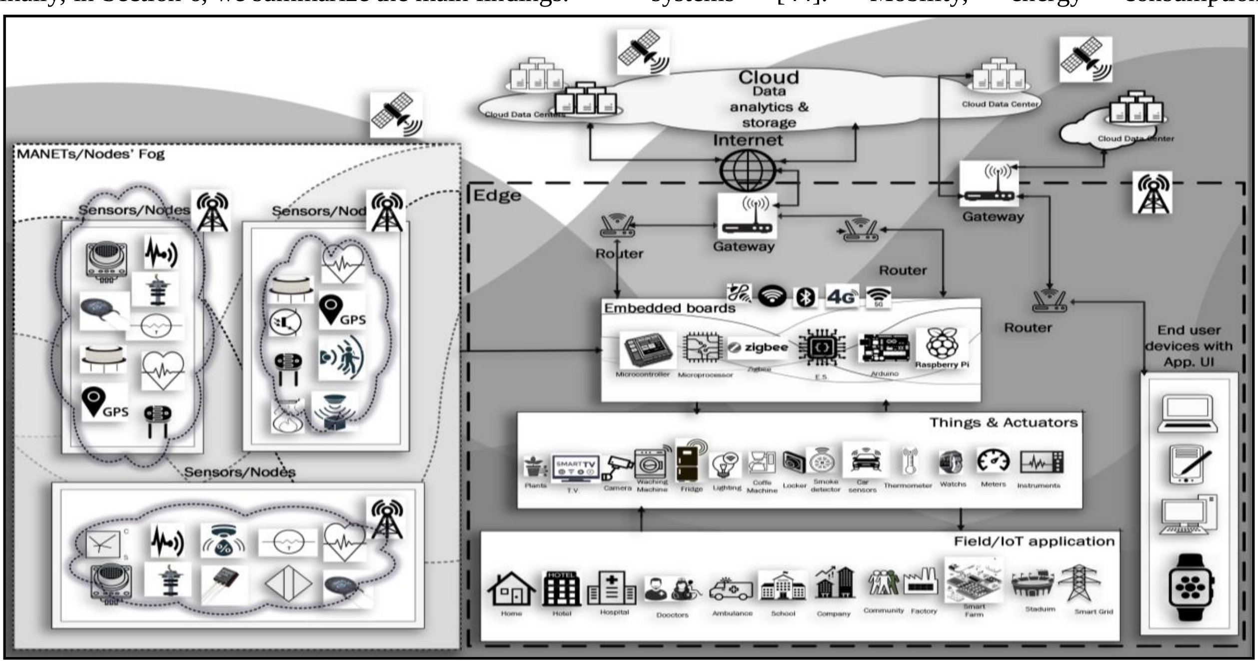

Figure 1. MANET-IoT structure

heterogeneity, fault tolerance, bandwidth, scalability, dynamic topology, connectivity, coverage, processing, security, data integrity, and QoS are the main WSN routing challenges [35].

M. Alrakhami presents a comprehensive survey of the WSN activities in terms of security and energy

2. MANET-IoT Applications

The accelerated development in networks has efficiently developed MANETs and connected everything to the internet. Heterogeneous networks are the agent in the MANET-IoT systems for promoting the most benefits consumption [41]. Cryptographic algorithms consume energy, processing, and memory. M. Alrakhami demonstrated the required characteristics to guarantee security in WSN, such as data integrity confidentiality, authenticity, and availability [41]. One of the most common attacks in WSN is the Denial-Of-Service (DOS) that includes flood attack, amplification attack, exploiting protocol weaknesses, wormhole attack, hello flood attack, and black hole attack [41]. The authors demonstrated the additional common attacks, such as jamming attacks, Sybil attacks, message modification, and node capture with compromised nodes [41]. Also, WSN requires message signature, Intrusion Detection System (IDS), trust management system, security, and power management. Challenges in conserving power and security of WSN are complicated if the sensor is located in hard-to-reach environments and difficult to replace the battery or sensor [41].

M. Rohani et al. present a study of WSN development of environmental applications [46]. Several wireless technologies are valuable for WSN design, such as ZigBee, Wi-Fi, General Packet Radio Service (GPRS), and Global System for Mobile (GSM). Infra-Red (IR), WSN, mobile, and satellite are wireless communication models [46]. IR communication is valuable in a short distance with a line of sight, where wireless network communication is advantageous in Wireless Local Area Network (WLAN) and other types of wireless networks. Mobile communication is serviceable for GSM [46]. Satellite communication is an artificial satellite that relays and amplifies signals between a transmitter and a receiver. ZigBee is suitable in a Personal Area Network (PAN) that can be expandable up to1.6KM wide, works effectively in a low signal, with little bandwidth, high noise conditions, and low power consumption [46].

T. Alam proposed a mobile MANET model using cloud computing for providing secure IoT communication [49]. The proposed model consists of three phases: managing information receiving from millions of sensors, managing network resources in a large-scale network, and managing sensors that create the same type of data [49]. The proposed system uses the hidden Markov model in the 2-dimensional plane zone. Smart devices can move and search for other devices using a transition matrix and identify the signals using the Viterbi algorithm in the 2D plane. The gradient model finds the devices and shares the information among the smart devices [49]. The system is power-efficient and suitable in Machine to Machine (M2M) communication [49].

D. Kumari et al. in [44] presented agricultural applications based on wireless technology and introduced the OPENIoT platform to achieve the efficient benefits of the agricultural applications. The authors concluded that the main three parts of the IoT-based agricultural production system are relational analysis, statistical analysis, and IoT services. The OPENIoT platform has sensor middle-ware that collects, filters, combines data from several sensors, and holding a user interface with Do-It-Yourself tools [44].

A. Sharif et al. present a survey of Intelligent Transportation Systems (ITS) technology that includes every component of the vehicle framework, such as vehicles, streets, and individuals [46]. ITS represent an efficient framework to improve the automobiles stream performance and to manage alerts on the roads. A. Sharif et al. study traffic congestion by using IoT, wireless gates, ad-hoc networks, and vehicle sensor systems (VSN) [46]. Each vehicle contains a unique MAC to can trace a car [46]. IEEE 802.11p presents MAC that is allocated dynamically with a duplicate detection of MAC address [46]. The vehicular systems are regularly connected with the internet through Wireless Local Area Networks (WLAN) [46]. Devices in IoT and ad-hoc networks are combined to make a hybrid network for traffic management [46].

T. Alam et al. proposed a framework in the current MANET communication employing the cloud in the IoT framework [48]. Further, the model covers security, reliability, and vulnerability issue of communication. [48]. The proposed framework applies the Hidden Markov Model (HMM) in a 2Dimensional plan area to determine the neighborhood devices within the range [48]. T. Alam et al. developed a transition matrix to find all the smart devices [48]. The results analysis proves the efficiency of the model

B. Wietrzyk et al. have proposed an architecture called Energy Efficient Route Discovery (EERD) to optimize energy consumption for the animal farming domain [45]. The proposed system can observe animals regardless of their location or their status. Users may access the animals' data through a smartphone via wireless communication [45]. EERD optimizes energy efficiency by identification of animal movement patterns and by the controlled degradation of data traffic. EERD reduces and balances energy consumption in low traffic- high mobility situations. Moreover, EERD decreases consumed energy on route discovery by the convenient PCDI broadcasting [45]. The proposed protocol provides better energy optimization than the other compared routing protocols such as DSR and ESDSR. MANET-IoT structure concerns include encryption, cryptographic authentication, and intrusion detection and management costs [45].

TABLE I. MANET-IOT

Reference	Contribution	Findings
H. Saha et al. [15]	A hardware approach for routing improvement by using Arduino and ZigBee.	EMFBOD in a benign environment is almost comparable to the existing protocols, but in a malicious environment, it is better in terms of PDF and end-to-end delay, the NRL is average, a trade-off is recommended
P. Lakshmi et al. [32]	A study the embedded systems and IoT devices.	The paper discussed the ES architecture in general, Types of embedded boards, explained the importance of ES to IoT.
J. Al-Karaki et al. [35]	A comprehensive WSN routing protocols survey.	A detailed classification of the WSN from different aspects, WSN challenges, and various routing protocols advantages.
M. Alrakhami et al. [41]	A detailed study of WSN security.	Comprehensive study in WSN, Attacks and security issues including energy consumption in the last few years.
S. Danielet al. [43]	Introduced a model to evaluate the remaining battery energy in the WSN.	In a prediction-based approach using an exponential moving average, the number of messages sent is less than in other schemes, it accommodates variations in the environment, and the error between the remaining energy information reported in the monitoring node and the actual residual energy in each node is minimized. A tradeoff has to be performed between the accuracy of the remaining energy information in the monitoring node and the consumed amount.
D. Kumari et al. [44]	A study of the using the OPENIoT platform and IoT in agricultural applications based on wireless technology.	The Phenonet-OPENIoT platform enables experts to recover data, conduct an action on it, and evaluate it efficiently.
B. Wietrzyk et al. [45,18]	A proposed MANET framework EERD for animal farms based on the following metrics: degradation of data traffic, energy efficiency, and packet loss, the model has been evaluated by utilizing a field quantitative and qualitative experiments.	The framework improves energy utilization than the other compared routing protocols such as DSR, and ESDSR. Reasonable security precautions are processing and traffic costly that raise management costs.
A. Sharif et al. [46]	A survey of the Intelligent Transportation Systems and VANET.	An important study of ITS technology that supports researchers to regard these technologies related to smart city-based traffic management.
M. Rohani et al. [47]	A WSN environmental survey.	WSN development, technologies, topologies, and network design.
T. Alam [48]	A model for using 5G In Cloud-MANET systems considering the Efficiency and Power consumption metrics, the model has been evaluated using 3 Samsung mobile phones and Amazon Web Services.	The proposed model can enhance the efficiency and speed of communication in the cloud and MANET.
T. Alam et al. [49]	Introducing a proposed IoT Framework using cloud computing in the MANET simulated by Samsung mobiles through 3G AND 4G networks.	The results are efficient and easy implemented in the IoT framework, provides better usability, enables the users successful operations through their smart devices, and offers better security.
C. Chibelushi et al. [50]	A proposed MANET framework for the IDM of IoT, including BYOD.	The proposed framework reduces the transmitted information volume within the network, improves the granularity of information before sending it and enables each user identity to appear in more than one Profile table.
H. Saha et al. [51]	Routing improvement using Arduino and ZigBee technology.	EMFBOD shows similar results to the other existing protocols in a harmless environment. In a malicious environment, The model presents more reliability and better PDF. The proposed technique shows better end-to-end delay, and the NRL is average.
H. Mohammad, et al. [52]	A study of the OLSR, AODV, and DSR routing protocols' impact on WBAN considering the wireless LAN throughput, wireless LAN Delay, wireless LAN load, total packet dropped, and the route discovery Time using the OPNET modeler 14.5.	AODV and DSR have less throughput and loads than OLSR, while OLSR increases the network load. DSR has less packet dropped than AODV but it needs more time for route discovery, it is better to use In high mobility networks, using OLSR indoor and AODV in the outdoor conditions are preferable.
M. Garcia et al. [53]	A study of MANET underwater behaviors and applications.	The acoustic waves are appropriate to the aquatic environment. energy consumption, capacity, and network reliability are significant factors for the proper QoS, reactive protocols are common utilized in underwater networks.

M. Garcia et al. presented a comprehensive study of the underwater Ad-hoc communications networks [53]. Underwater communication uses three methods for sending information. These methods are electromagnetic waves, Acoustic Waves, optical signals. EM waves are faster than acoustic waves and can operate in higher frequency applications. The optical signals have two drawbacks, the hung bits that cause light dispersion, and the optical signals are absorbed quickly. Acoustic communication is a widely utilized technique in underwater environments. The acoustic waves are suitable for the aquatic environment. Moreover, reactive protocols such as DSR and AODV are common utilized in underwater networks [53].

S. Daniel et al. proposed a model to evaluate the remaining battery energy in the WSN [43]. The node's residual energy data is stored in a particular node, called the monitoring node that could be utilized to determine the consumption rate to enhance the network lifetime. The model uses the Exponential Moving Average (EMA) to predicts the upcoming energy consumption of each node based on energy reduction history. Every node sends the expected power consumption rate to the monitoring node. A node sends an update to the monitoring node only if the difference of earlier predicted and actual consumption rate is higher than the predefined threshold values [43]. The results analysis shows that the proposed approach decreases the number of sent messages compared to other schemes by 30% [43]. The simulation results confirm that the proposed model minimizes the variation between the predicted and actual remaining energy information. On the other hand, the energy cost of monitoring has increased [43].

Table I introduces a comprehensive comparison of the different MANET studies and that have been presented in the literature review.

From the previous review and the comparative table, we found that all the researches mainly aim to achieve power optimization. In [15], [32], [51], the authors utilized hardware to realize the QoS objectives. In [41], [48], [49], [50], the authors concerned with security. The papers [49], [48], [54] concern with the IoT-cloud.

3. MANET Health-Care Applications

IoT and MANET are widely applicable in several domains, including healthcare. Technology transfers the routines of medical checks from a hospital to the patient's home and reduces the need for hospitalization. IoT-MANET application in healthcare is a common purpose to support doctors work efficiently. Real-time monitoring WPAN sensors can efficiently support several medical cases such as like heart attacks, air quality, temperature monitoring, asthma attacks, etc. [54], [55], [56]. The smart medical device can collect medical data and transfer information to a physician using smartphones through several wireless protocols such as Bluetooth, Wi-Fi, and ZigBee.

On the other hand, the sent amount of data is massive and hard to be stored and managed unless the availability of the cloud [20]. Furthermore, modern healthcare delivers the necessary healthcare analytic for efficient management. Solutions in healthcare can spontaneously monitor the different cases, check them, and detect the illnesses by utilizing several types of wearable or not wearable sensors. Promoted projects and applications of ad-hoc networks in the sector of advanced healthcare have been improved to assist elders, patients, handicapped, and pregnant as well as resources optimization, transportation minimizing, saving time, and avoidance of queues in hospitals [21], [57].

C. Chibelushi et al. in [50] proposed a new MANET framework to support IoT Identification Management (IDM) and realize the identification of healthcare and medical things. The authors consider medical applications using the Bring Your Own Device (BYOD) principle that pushes healthcare applications to work without infrastructures [50]. The new proposed framework is modular and user-centered, where Each module operates either on its own or in conjunction with the identity module that consists of the Device ID, IP, and User ID. The User ID consists of the Device ID and user type [50]. The existing devices need to be incorporated to share data with another device within another e-Health. Due to the nature of the e-Health applications, it is essential separate between individual data and other data by providing a dynamic mechanism of tracking the identity of things and users to improve usability and security. A sandboxing technique is applied to guard users 'data when sharing a device [50]. The proposed framework allows the use of the information granularity module to reduce the transmitted information. C. Chibelushi et al. suggest an algorithm for improving the granularity of information before sending it and enables each user to appear in more than one profile table [50].

S. Kumar et al. have proposed a model of a wireless patient monitoring system for the management of heart attacks in remote low facilities areas [33]. It is hard to maintain wireless mobile communication in remote areas that restrict doctors and facilities from medicating in several cases. The proposed approach is dedicated to inaccessible areas. The system consists of three divisions: data acquisition, data processing, and data communication architectures [33]. The Data processing unit consists of an ATMEL-At-mega16 microcontroller to transmit the obtained data from the Data acquisition unit to the computer via serial port for data analysis. Accordingly, the Data transmission unit sends the analyzed data to the medical data center through wired or wireless communication techniques [33]. In the data processing phase, the processor sends specific mobile short messages via the GSM module. The nodes have a wide heterogeneity in their capabilities and may join or leave the network as well as random mobility topology. The utilized algorithm for routing is the Bellman-Ford Algorithm that determines the single-source shortest path in a weighted graph routing algorithm. The authors have evaluated the proposed model by using four intermediate nodes, where the model has considered that the distance between the nodes is the cost metric [33]. The results show that the device is continuously monitoring the heart rate, sending messages, and calling the doctor when the heart rate goes beyond the predefined limits [33].

S. Abid et al. proposed the Dynamic Energy Efficient Routing Protocol (DEERP) framework. DEERP provides better performance than other existing medical routing protocols [20]. The proposed DEERP framework combines two proactive and reactive routing protocols to achieve better performance [20]. The Proposed approach analyzes the three states of the nodes: idle mode, transmitting (TX) mode, and receiving (RX) mode. DEERP selects a single state as idle mode and determines which routing technique realizes the best performance. The approach considers three functions: SRP (Select Routing Protocol) that decides the most suitable protocol for idle mode from RPSC (Routing Protocol Selection Criteria) table, the same for the SRP for the TX mode, and SRP for Rx mode. Consequently, two or three routing protocols are selected to achieve the best performance [20]. The authors present a simulation using the NS2. The results analysis shows that the model enhances energy efficiency and consumes less energy in Idle, TX, and RX modes than other approaches.

H. Mohammad, et al. have analyzed the well-known MANET routing protocols in Body Area Networks (BANs) for a long-term health monitoring system of the elderly [52]. The proposed network consists of two fundamental parts: the MANET model and the Universal Mobile Telecommunications System (UMTS) model [52]. The system performance has been evaluated compared to AODV, DSR, and OLSR routing protocols. The considered performance Metrics are throughput, Delay, load, total packet dropped, and route discovery Time [52]. The system has been simulated by using the OPNET. The simulation results analysis shows that AODV and DSR have less throughput than OLSR, where OLSR increases the network load. Moreover, DSR has less packet dropped than AODV but needs more time for route discovery. Consequently, it is better to use OLSR indoor because it decreases delays due to its proactive nature, where it is preferable to use AODV in the outdoor-high mobility networks [52].

MANETs progress has provided advantages to different users such as elders and patients [58]. MANET is successful for short-range communication and real-world applications due to its various features. K. Ramanpre et al. demonstrated several simulation tools for examining the routing protocols and realizing ad-hoc networks in the healthcare domain. Several solutions have been proposed against likely attacks, such as intrusion detection systems, to manage security [58]. The application in e-healthcare is obtainable by applying MANET technologies and using the easy-to-build architectures to assist patients, medical staff, and hospital management systems [58]. The microcontroller-based remote patient monitoring system has a positive impact on healthcare. Smartphones present facilities in the healthcare domain, such as smart and intelligent patients' visiting [58].

T. Saba et al. proposed a secured and Energy-Efficient Framework using the Internet of Medical Things (IoMT) for e-healthcare (SEF-IoMT). The model optimizes the energy consumption of the medical sensors and secures the network from malicious nodes [21]. The proposed architecture decreases the routing overhead and supports both privacy and data integrity [21]. The framework consists of 3-tier: The IoMT, the subgraphs, the sensitive medical information [21]. The IoMT is interconnected as a graph using the Kruskal algorithm. The sub-graphs are obtained by cost estimating to enhances the routing overheads and energy consumption. Sensitive medical information is secured from any undesirable threats.
T. Saba et al. have stated some assumptions, such as all sensor nodes are GPS equipped to know neighbors and data reach doctors through the in-between interconnected things [21]. The proposed framework has a secure algorithm that forwards patient data by a Cipher Block Chaining (CBC) algorithm. Additionally, the model uses digital authentication for data validation [21]. The throughput, packet loss rate, end-to-end delay, and energy consumption are the proposed performance metrics to evaluate the proposed framework [21]. The results analysis show that the proposed framework improves energy consumption, throughput, packets loss rate, end-to-end delay, and link violation compared to other models [21].

A. Ahad et al. presented a study of the 5G supported smart healthcare solutions [22]. The 5G networks support smart healthcare applications in IoT and facilitate advanced diagnostic in real-time [22]. A. Ahad et al. studied the 5G smart healthcare in various aspects in terms of the taxonomy, communications technologies, network types, services, applications, requirements, and characteristics [22]. A. Ahad et al. demonstrated multiple applications with different prospects and compared short and long-range communication technologies [22].

K. Jaiswal et al. proposed a paradigm to automates the patients' significant data gathering and acquisition [57]. The main benefit of the proposed model is reducing the latency and conserving the bandwidth. The proposed model performs the processing at the gateway by employing the Raspberry pi. The proposed model applies virtualization for patients' information local storage and distribution across the cloud and generating emergency warning messages. The structural view of the proposed monitoring system includes fundamental components, such as a sensing network, IoT-Cloud, and the edge device that performs the data cleaning, data storage, data analysis, emergency warning, and GUI [57]. The model is designed using Raspberry pi and 6LoWPAN for sensors' data acquisition and using an e-health sensor. The MQTT protocol was applied to distribute the warning message to different stakeholders [57]. The Raspberry pi works as the network gateway and discovers the potential cases by comparing the sensors' obtained values with threshold values [57]. The 6LoWPAN node for reading and passing different medical sensors data. The model uses the Docker container as a quarantined site application processing. The model has been experimentally examined in transferring data to healthcare team through Gmail by applying the and MQTT protocol [57]. The results show that most of the recommended models are not realize all the IoT features.

TABLE II. MANET-Healthcare Applications

Reference	Contribution	Findings
K. Ramanpreet et al. [58]	An inclusive study of MANET applications in healthcare area.	Presented an introduction to the MANET and considered the healthcare applications of MANETs rather than other possible fields in which MANET can be applied.
A. Ahad et al. [22]	A detailed study of 5G smart health-care solutions including several related aspects.	Declaration for multiple applications with different prospects. comparing short and long-range communication technologies. The study supports the researchers in the smart health-care field .
S. Abid et al. [20]	DEERP framework for medical field routing enhancement in terms of remaining energy, energy consumption, energy efficiency and performance metrics improvements.	The model enhances energy efficiency and performance. DEERP framework consumes least energy in Idle, TX, and RX at the extreme remaining energy as compared to other protocols.
T. Saba et al. [21]	SEF-IoMT system for healthcare routing performance improvements in terms of throughput, packet loss rate, end to end delay, and energy consumption.	The SEFIOMT is energy-efficient, more secure, and better network delay.
C. Chibelushi et al. [50]	A proposed MANET framework for the IDM of IoT, including BYOD.	The proposed framework reduces the transmitted information volume, improves the granularity of information before sending and enables each user identity to appear in more than one Profile table.
S. Kumar et al. [33]	Introducing a prototype of a wireless patient monitoring system considering the distance between the nodes metric using a hardware experiment and NesC programming.	The results show that the device is continuously monitoring the heart rate, sending messages, and calling the doctor successfully, a better range of routing nodes can be used in association with an improved routing algorithm to prolong the MANET's coverage area.
K. Jaiswal et al. [57]	Proposed a paradigm to automates the patients' significant data gathering and acquisition by using Raspberry pi and Docker container for supporting the doctor's medical diagnosis and observations wherever the patient is. The primary benefit of the proposed model is reducing the latency and conserving the bandwidth.	The comparison of the proposed model through different models confirm that most of the recommended models are not realize all the characteristics of the IoT. On the other hand, the proposed model validates all the particularized features.
L. Min et al. [54]	A comprehensive study for the most advanced IoT in healthcare components and applications. The current progress in IoT and cloud computing.	A useful study of the IoT, cloud, and fog computing for healthcare over considering typologies, platforms, structures, and trends.
H. Su et al. [55]	A proposed model called the Movement-Aided Energy-Balance (MAEB) based on the movement and energy information of the neighbor Coordinators.	Base on the latency, energy consumption, packet delivery ratio, and throughput performance metrics to evaluate the protocol, the The proposed model enhances the QoS in terms of the specified performance metrics.
E. Selem et al. [56]	Introduced a Temperature Heterogeneity Energy (THE) routing protocol for IoT healthcare applications that based on choosing the WBAN's parent node	The proposed protocol produces better performance compared to SIMPLE and iMSIMPLE protocols in terms of network lifetime, the number of dead nodes, the total remaining energy, and throughput while maintaining the suitable nodes' temperature with high sensitivity in picking the node's maximum tolerated temperature.

On the other hand, the proposed model validates all the specified characteristics [57].

L. Min et al. have presented a comprehensive study to analyze the most advanced IoT applications in healthcare [54]. The authors have studied the IoT framework for healthcare in terms of typologies, platforms, and structures. The study includes a review of cloud computing and fog computing for healthcare. Multiple healthcare sensors and equipment are available to check and monitor health conditions such as brain electrical signals, body temperature, and oxygen saturation [54]. Nevertheless, IoT technology in healthcare faces numerous challenges. The authors assumed that the IoT in Healthcare Framework (IoTHeF), a combination of physical IoT components, is significant since it supports medical applications via IoT and cloud computing. L. Min et al. have classified the IoTHeF into typology, structure, and platform. IoTHeF topology is the IoT components organization [54]. Within the main structure of IoT and cloud computing integration, several sensor nodes observe, collect, and transmit the data [54]. Short-range communication schemes are regularly utilized among nodes while the signal can transfer several meters. A Low-Power Wide-Area Network (LPWAN) is an important communication class for IoT industrial applications [54]. L. Min et al. have exhibited the two concepts: Ambient Assisted Living (AAL) and the Internet of m-Health-Things (mIoT). The authors have investigated the trends based on Applications. Moreover, the authors have classified the trends based on Bluetooth, Light Fidelity (LIFI), NFC, and RFID technology. Finally, the authors have considered various threats, vulnerabilities, and attacks and summarize appropriate security models to prevent possible security risks [54].

H. Su et al. have proposed a routing protocol called the Movement-Aided Energy-Balance (MAEB) based on the movement and energy information of the neighbor Coordinators [55]. The WBAN data packets are transferred to the Access Gateway (AG) by the Coordinators. The proposed MAEB routing protocol discovers the neighbors. The local Coordinators hold the mobility and energy data of the accessible Coordinators to determines the most proper nodes for data forwarding. The MEAB approach considers the distance, velocity, and residual energy [55]. A beacon-enabled cluster tree topology enables the Coordinator that holds more energy to manage the network. The Coordinator stores, uploads, transfers data to the gateway within other Coordinators by multiple hops. The AG and Coordinators send periodic beacon frames for node synchronization, and the AG sends the data to the healthcare data center. If an administrator is unreachable, the Coordinator buffering the data locally, the route is re-established at his/her returns [55]. Two approaches are used for data transmitting from the Coordinators to the access gateway: by a single-hop or multi-hop delivery [55]. The Coordinators perform the neighbor discovery scheme using a timer to build the neighbor table. A coordinator decides the route by considering signal strength and determining the in-range neighbors [55]. The authors have simulated the MAEB using 100-node and 10-Coordinator compared to PAOLSR, EOLSR, and MMPR protocols in terms of

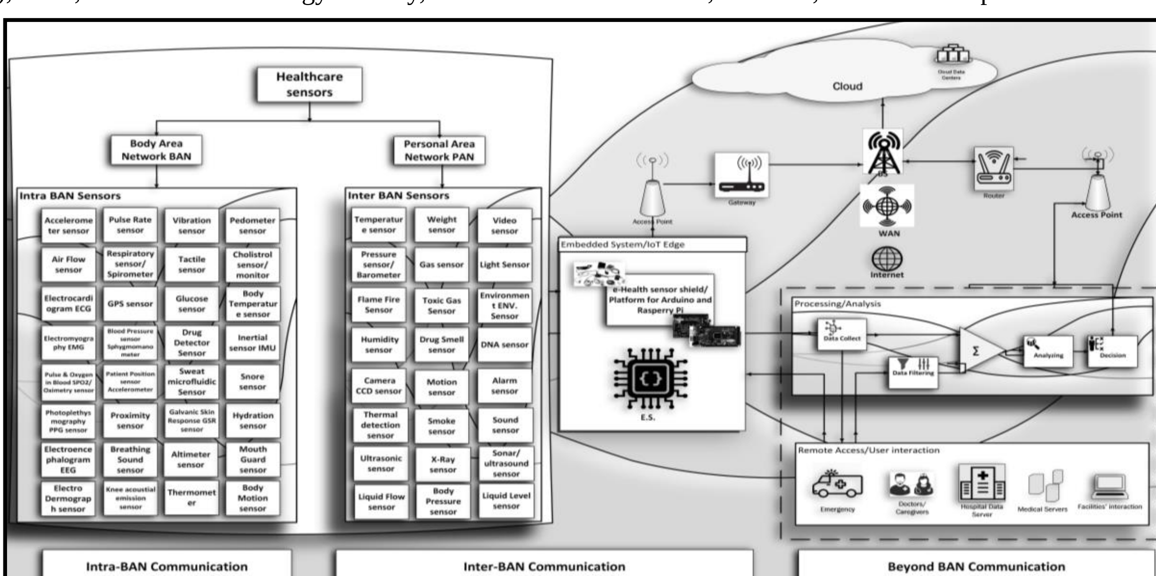

Figure 2. MANET-IoT Health-Care System Architecture

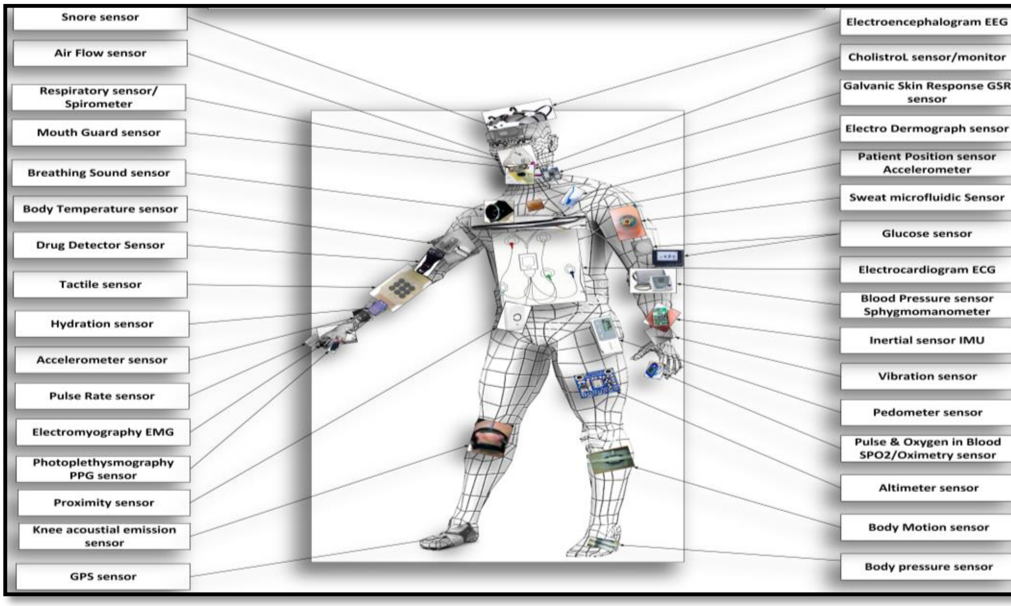

Figure 3. Healthcare WBAN Sensors.

latency, energy consumption, PDR, and throughput. The analysis proves that the more traffic, the more latency. The MAEB presents better performance than other protocols [55]. The results confirm that energy consumption rises gradually by increasing n the traffic load and the energy consumption of the MAEB is decreased compared to the other three protocols. Furthermore, the results show that the packet delivery ratio decreases by increasing the traffic load. Further, MAEB improves both throughput and system QoS [55].

E. Selem et al. have proposed a Temperature Heterogeneity Energy (THE) routing protocol for IoT health-care applications. THE based on choosing the WBAN's parent node (PN) that holds the highest remaining energy, the highest data rate, the smallest distance to the coordinator, and the least sensor's temperature [56]. The nodes continuously transmit the data to the Coordinator Node (CN), which transfers these data to a remote server [56]. The proposed model is an improved form of the iMproved Stable Increased-throughput Multi-Hop Link Efficient routing protocol (iM-SIMPLE) protocol using two added criteria for choosing the PN node particularly, the node's temperature and data rate [56]. The proposed protocol has addressed the thermal conditions of on-body nodes. Threshold

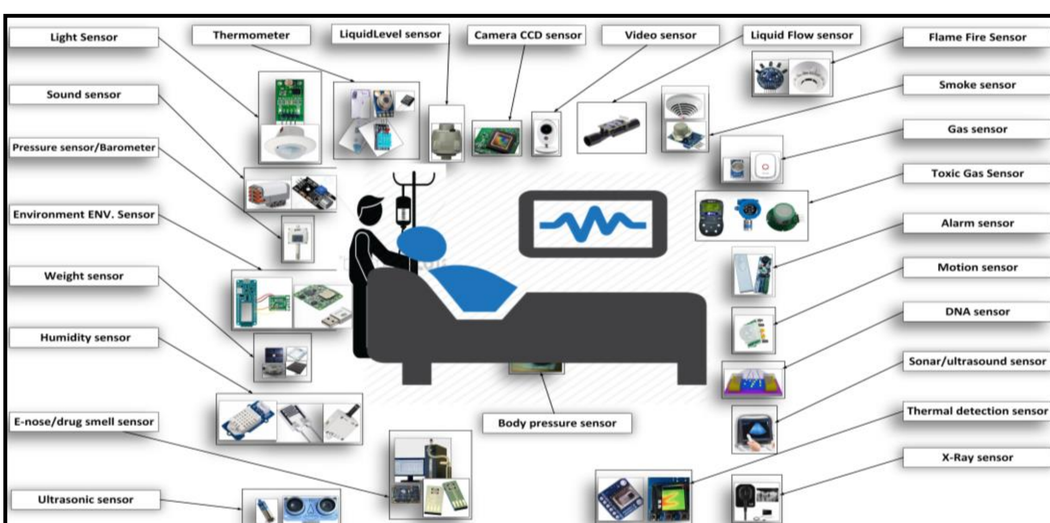

Figure 4. Healthcare WPAN Sensors.

temperatures (TSH) and a High temperature threshold (TTHH) are the limits that control the temperature of the node. If a node temperature hits the threshold of TTHH, a sensor instantly transmits its data to the PN node in case of multi-hops and renouncing the CN in the case of one-hop [56]. The simulation results show that THE presents better performance than the Stably Increased Throughput multi-hop Protocol for Link Efficiency in Wireless Body Area Networks (SIMPLE) and iM-SIMPLE [56].
Table II demonstrates a conclusion of MANET health-care applications that have been presented in the literature survey.
From the above review in healthcare IoT applications, we found In [22], the authors concern using the 5G in healthcare applications. In [21], the authors concerned with improving the PDR, throughput, and energy conserving of the routing. The papers [33], concerned with extending the network coverage area.

4. MANET-IoT Healthcare System Architecture

Fig. 2 depicts the IoT-Healthcare system architecture showing the main three communication tiers: Intra-BAN Communication, Inter-BAN Communication, and Beyond BAN Communication. Sensors in the medical domain can be classified into two classes: the BAN sensors [52], [56] and PAN sensors [15], [60]. These sensors transfer the sensed data through the wireless networks to the doctors to take the proper actions [21], [55].

A. Healthcare System WBAN Sensors

BAN sensors are the nodes that are attached to the patient body to monitor the patient's conditions. Fig. 3 illustrates several Healthcare WBAN Sensors.

B. Healthcare System WPAN sensors

PAN sensors are the nodes which are installed around the patients to observe them and monitor their location, including the environmental conditions, such as room temperature, pressure, humidity, and oxygen. Fig. 4 demonstrates various Healthcare WPAN Sensors.

C. Interfacing BAN And PAN Nodes With MCU

Connecting a node to a microcontroller (MCU) needs interfacing circuits with filters to eliminate unwanted noise. Also, a sampling circuit to obtain samples from the stream of data to reduce the consumed resources, such as memory, processing, and energy. Generally, the sensor's signal needs to amplify by an operational amplifier. The analog sensor's signal is converted to digital using an A/D converter. Finally, more signal processing is applied to the data if needed to prepare it for the output phase. Fig. 5 depicts the Sensor (Node) data Processing architecture.

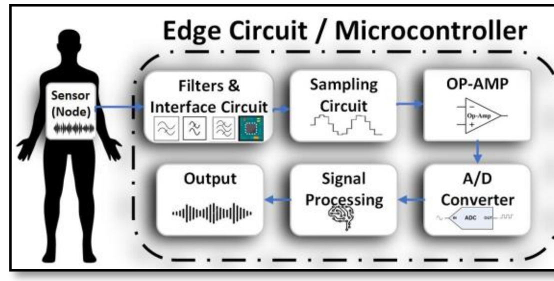

Figure 5. A Sensor(Node) Data Processing.

D. Archetectures of Healthcare Sensors

Sensors are used in electronic medical and non-medical equipment and transform several kinds of requisite signs into electrical signals. Numerous sensors are employing in the healthcare domain, and their applications include biosensors, pregnancy, ultrasound pressure sensors, oxygen concentrators, temperature sensors, ventilators, imaging, and cardiology. Nodes must to be tiny, lightweight, and consume low power. In the next paragraphs, we will introduce brief demonstrations of the most pervasive healthcare sensors.

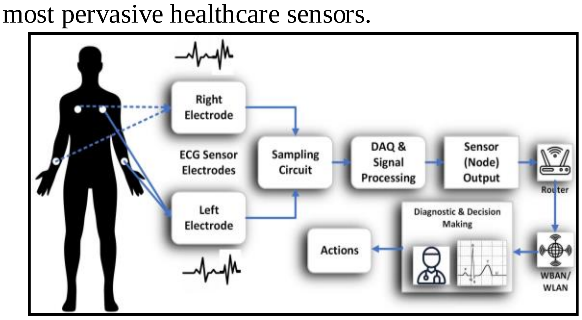

Figure 6. ECG Sensor Node Working Principle.

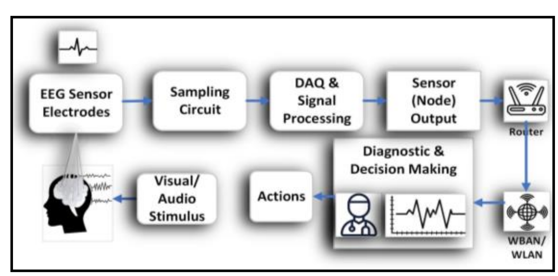

Figure 7. EEG Sensor Node Working Principle.

1) ECG Sensor: An electrocardiogram (ECG or EKG) estimates the electrical signal of the patient's heart to check the different heart conditions. Electrodes are placed on the patient's chest to monitor his heart's electrical signals. The signals are displayed as waves on a linked monitor. An ECG is often used besides other tests to support diagnosis and monitor conditions affecting the heart. Fig. 6 explains the ECG Sensor node working principle and architecture. ECG sensor is utilized to examine indications of a possible heart problem.

2) *EEG Sensor:* Electroencephalography (EEG) sensor tracks, records, and appraises the behavior of electrical brain waves. An EEG senses the possible troubles associated with this behavior. Fig. 7 presents the EEG Sensor node working principle and architecture. Electrodes are wirily connected to the scalp for less than 60 minutes to test the patient. The electrodes conduct the brain's electrical pulses to a PC to be checked and evaluated by specialists.

3) *Blood Pressure Sensor:* The Blood Pressure Sensor measures systolic, diastolic, and mean arterial pressure using the oscillometric method. In the oscillometric method, the cuff is wrapped on the upper arm compresses blood vessels.

4) *EMG Sensor:* EMG Sensor (Electromyography sensor) measures the created minor muscles' signals during their movement. The brain transfers electrical pulses to the muscle through neurons that stimulate the muscle immediately and generating a mechanical change and depolarization which is detected by EMG.

5) *Motion Sensor:* Motion Sensor Monitors alert the caregiver of patient movement. Different types of Motion Sensor Monitors are available to choose from. A motion sensor applies several technologies through several types of motion detection sensors such as passive infrared, PIR, microwave, ultrasonic, and Gesture detector. Passive motion sensors detect infrared energy of the emitted heat from the body.

6) *Temperature Sensor:* The temperature sensor is an electronic device that measures temperature in the human body, environment, and other objects. Several types of temperature sensors are manufactured such as Resistance Temperature Detectors (RTDs), thermistors, infrared sensors, and semiconductor sensors. Fig. 8 depicts the temperature sensor node working principle and architecture. The temperature sensor produces an analog signal due to a varying voltage which is amplified and converted to digital through an ADC chip.

7) *PPG Sensor:* Photo plethysmography (PPG) is an affordable optical measurement approach that usually monitors heart rate and blood pressure. PPG is a technology that utilizes a light source and a photodetector at the skin surface to estimate the volumetric variations of blood circulation. The PPG waveform represents the mechanical activity of the heart. Fig. 9 illustrates the PPG

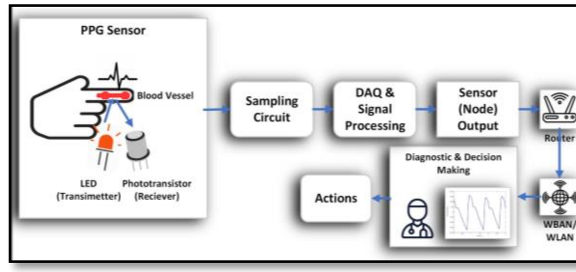

Figure 9. PPG Sensor Node Working Principle.

Sensor node working architecture. When the heart beats, capillaries inflate and compress built on blood volume variations. PPG optical sensor, employing motion-tolerant

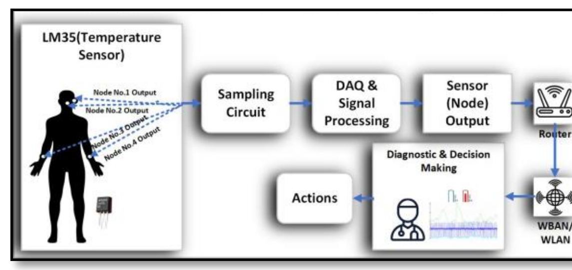

Figure 8. Temperature Sensor Node Working Principle.

technology, transmits light signals that reflect onto the skin to accurately and continuously measure the low blood flow signals.

8) *SPO2 Sensor:* A pulse oximeter is a non-invasively test equipment that measures the oxygen saturation of a person's blood. This device is composed of a red LED and

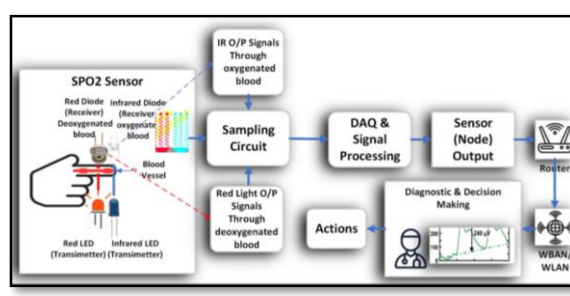

Figure 10. SPO2 Sensor Node Working Principle.

infrared photodetector to send and receive light through a fingertip. It performs this by measuring changes in light absorption in oxygenated or deoxygenated blood. Fig. 10 explains the SPO2 Sensor node working principle. SPO2 measures using a pulse oximeter, which consists of a computerized monitor and probe. The middle finger of the dominant hand is the most likely and accurate SpO2 measurement. For a healthy individual, the normal SpO2 should be between 96 and 100.

9) Accelerometer Sensor: An accelerometer is a sensor to determine the linear acceleration forces working on an object to evaluate the object's position and observe its motility using the piezoelectric effect. These piezo

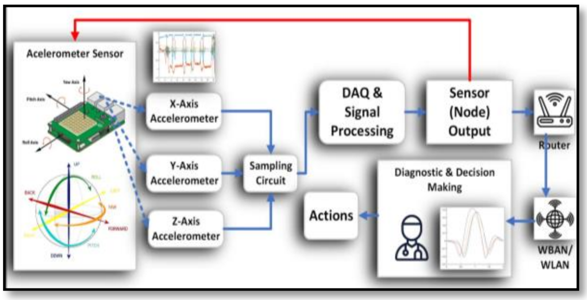

Figure 11. Accelerometer Sensor Node Working Principle.

crystals generate a voltage variation due to the stress, and the accelerometer makes sense of the voltage to find out speed and orientation as shown in fig.11. The accelerometer detects the patients' and doctor's orientation and measures their linear acceleration of movements. An accelerometer measures acceleration, not speed. To obtain speed, we merge the acceleration data over time. Accelerometers need to be oriented precisely to avoid huge errors.

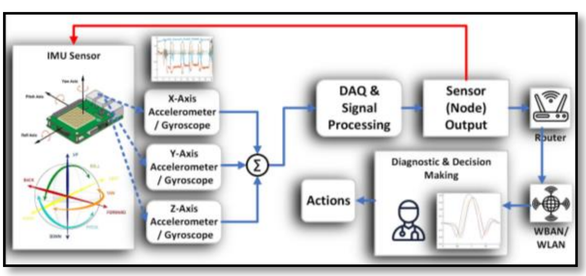

Figure 12. IMU Sensor Node Working Principle.

10) Glucose Sensor: A glucose sensor is an electronic part of a continuous glucose monitoring (CGM) system that is inserted under the skin to measure the patient's glucose levels discreetly and transfer the patient's recorded data remotely. The signal characterizes the amount of sugar in the blood. A small transmitter attaches to the sensor. The graphs' trends and records' history support the doctors in managing patient's glucose levels logically.

11) Inertial IMU Sensor: An inertial sensor can measure the acceleration and angular velocity of a body at the 3-axis based on indirect determining of specific forces. IMUs consist of a 3-axis accelerometer plus a 3-axis gyroscope. IMUs can also include an additional 3-axis magnetometer, which would be considered a 9-axis IMU. Fig. 12 presents the IMU Sensor node working principle.

12) GSR Sensor: Skin conductance or Galvanic skin's Response (GSR) sensor measures sweat gland activity which is correlated to emotional stimulation by measuring the skin electrical conductance which changes with its moisture level. The GSR sensor applies a constant voltage on the two electrodes that are contacted to the skin. GSR senses the electrical variation resultant from changes in sweat gland activity. GSR measures electro-dermal activity by detecting the resistance of the passage of little electric current through the skin.

13) GPS Sensor: The Global Positioning System (GPS) sensor is a receiver that utilizes a satellite to deliver location, speed, and timing data. The GPS receives a signal from each GPS satellite. The satellites transmit the accurate time of the sent signals. With the GPS signals from three satellites and their exact position, the GPS receiver can determine the location in three dimensions (east, north, and altitude). GPS can track the position without an internet connection.

14) Respiratory Rate Sensor: The Respiration Sensor measures breathing rate and related parameters. It is provided with an elastic band. The Respiration sensor is an electronic device that measures respiration airflow from the patient, usually placed over the abdomen, and used in combination with the blood volume pulse sensor. The data is produced as voltage signals and measured using a multi-function DAQ that represents the respiration waveform which is normally at the rate of 12 to 20 breaths/minute for an adult at rest.

5. Discussion

Many challenges face the MANET-IoT systems due to their infrastructure-less construction, the high changeable topology of nodes. In our survey, we exhaustively studied the routing techniques through various approaches. However, many issues have been analyzed, and others are still open. Next, we address some of these issues.

- MANET-IoT healthcare systems challenges represent MANET, IoT, and Cloud issues.
- MANET-IoT in healthcare applications concerns the power consumption optimization, security, throughput, and QoS.
- The research findings prove that GA techniques are efficient and adaptive in routing.

- The hardware approaches are widely utilized, thanks to the evolution of electronics components manufacturing.
- The innovative hardware technologies in wireless such as Wi-Fi, Bluetooth, 5G, and other communication techniques improve the power consumption and enhance the network QoS.
- We can't imagine that a protocol or an approach fits the best performance, but we evaluate the system QoS in terms of specific performance metrics.
- A tradeoff between metrics is required. The performance of an approach is based on the proposed.
- MANET-IoT healthcare systems routing requires discovering a route and considering the route that meets the QoS requirement. The QoS is evaluated in terms of specific proposed metrics such as power consumption, throughput, bandwidth, and security. Therefore, a trade-off is a must.
- Healthcare applications support both doctors and patients, save time, decrease the consumed resources, improve the healthcare issues, and realize the real-time applications successfully.

6. CONCLUSION

MANETs are infrastructure-less networks that face several challenges, such as limited nodes' energy, mobility of the nodes, and network security. Commonly, the nodes are battery-powered. Several developed routing approaches concern with network power optimization issues. We have presented several MANET-IoT models in different domains and analyzed the contribution of each model and the findings. In healthcare MANET-IoT systems, as one of the MANET-IoT domains, we have presented the different utilized routing approaches and represented the advantages of each technique supported with a comparative table. We have outlined the healthcare system architecture and described the usage of the two classes of the utilized sensors: WBAN sensors and WPAN sensors. Also, we have presented and illustrated the WBAN and WPAN sensors' architectures. Despite the successful applications of MANET-IoT, they have several shortcomings. Information security is critical due to nodes expanding in different environments. Challenges in conserving the power and security of WSN are complicated issues and need more future work.

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