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The Wireless Body Area Sensor Networks and Routing Strategies: Nomenclature and Review of Literature

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Abstract- *WBASN* devices and the other significant condition like the coexistence of the systems among varied other wireless networks that are constituted in the proximity. In this study, scores of models that has been proposed pertaining to is an effective solution that has been proposed in terms of improving the solutions and there are varied benefits that have been achieved from the usage of *WBASN* solutions in communication, healthcare domain. From the review of stats on rising number of wireless devices and solutions that are coming up which is embraced by the people as wearable devices, implants for medical diagnostic solutions, etc. reflect upon the growing demand for effective models.

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The Wireless Body Area Sensor Networks and Routing Strategies: Nomenclature and Review of Literature

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Abstract- $WBASN$ is an effective solution that has been proposed in terms of improving the solutions and there are varied benefits that have been achieved from the usage of $WBASN$ solutions in communication, healthcare domain. From the review of stats on rising number of wireless devices and solutions that are coming up which is embraced by the people as wearable devices, implants for medical diagnostic solutions, etc. reflect upon the growing demand for effective models. However, the challenge is about effective performance of such solutions with optimal efficiency. Due to certain intrinsic factors like numerous standards that are available, and also due to the necessity for identifying the best solutions that are based on application requirements. Some of the key issues that have to be considered in the process of $WBASN$ are about the impacts that are taking place from the wireless medium, the lifetime of batteries in the $WBASN$ devices and the other significant condition like the coexistence of the systems among varied other wireless networks that are constituted in the proximity. In this study, scores of models that has been proposed pertaining to MAC protocols for $WBASN$ solutions has been reviewed to understand the efficacy of the existing systems, and a scope for process improvement has been explored for conducting in detail research and developing a solution.

Keywords: ieee 802.15.6, medium access control, physical layer, routing, wireless body area networks, wireless sensor networks, energy-efficiency.

I. Introduction

$WBASN$, a Wireless Body Area Sensor Network comprises numerous factors like the low-power, either invasive or non-invasive, miniaturized, lightweight devices that has wireless communication features which operates in close proximity to human body. For instances, the wearable devices and other such devices that can be placed in or around the body comprises some kind of wireless sensor nodes that can monitor the bodily functions and characteristics based on certain environment, and parameters.

There are numerous devices and solutions that have emerged in the market on the basis of $WBASN$ that enable new applications; however, in terms of effective performance of such devices, there are numerous constraints that are envisaged in the process, which emphasize the need for contemporary solutions and protocols that could support in more effective implementation.

In terms of diversity that is envisaged in the applications right from the medical diagnostic and monitoring solutions to smart solutions for gaming, entertainment, communication and in varied domains, the scope of applications is on rise, however, the challenge is about the technical requirements in terms of wide variation that is taking place in the form of expected performance metrics, throughput or delay that is taking place, the levels of flexible architecture, and the protocols that are essential for successful functioning of the system.

Among the key communication standards that are adapted in the process of such devices, the reference standards are: $IEEE802.15.4$ [1], $IEEE802.15.6$ [2], and Bluetooth Low Energy [3]. $IEEE802.15.4$ (published in 2006), which emphasizes more about physical (PHY) and also the Medium Access Controls (MAC) layers which has short-range wireless communications that are devised for supporting in effective features like low power consumption, low bit rate networks and of low cost solutions.

The $IEEE802.15.6$ (published in 2012), is categorically designed for wireless communications in the vicinity of, or from inside or to a human body insertion. The $BTLE$ (Bluetooth Low Energy) model published in year 2010, has the ultra-low power consumption configuration for adaptation of bluetooth technology, and also in terms of targeting varied range of applications that are cost effective and the ones that has ultra-low power consumption configuration models, that are powered by button-cell batteries, and wireless sensors. Due to certain intrinsic factors like numerous standards that are available, and also due to the necessity for identifying the best solutions that are based on application requirements.

Some of the key issues that have to be considered in the process of $WBASN$ are about the

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impacts that are taking place from the wireless medium, the lifetime of batteries in the $WBASN$ devices and the other significant condition like the coexistence of the systems among varied other wireless networks that are constituted in the proximity.

The impact on radio wave propagation due to the human body presence is imperative, thus resulting in need for effective design of protocols and the peculiar radio channels. Also, the need for long battery lifetime has to be addressed using varied levels of energy efficient solutions as frequent replacement of batteries is a herculean task. The other critical factor that has to be taken in to consideration is about the outage occurrence which is resulting from the coexistence among the other wireless networks that are operating in similar frequency band. Majority of standard solutions for $WBASN$ shall operate in the way of license-free Industrial Scientific and Medical $(ISIM)$ band which is centered at 2.45 GHz and such factors leads to co-existence of the solutions with other networks that are operating in same band. (e.g., $WiFi\ IEEE802.11$).

In the proposed paper, the emphasis is on reviewing the taxonomy and the review of literature pertaining to recent developments in the kind of benchmarking routing protocols, MAC oriented protocols, pros and cons envisaged in terms of $WBASNs$ (Wireless Body Area Networks). In the process, the focus is upon initially outlining the properties which are very crucial for handling the $WBASN$ designs. Also identifying several sources contribute towards improving the QoS, qualitative comparisons of the protocol models shall be taken up in the process.

II. Nomenclature of The WBASN

Wireless Body Area Networks always could interact with the other existing range of wireless solutions like ZigBee, Bluetooth, $WSNs$, and $WLAN$ (Wireless Local Area Network), video surveillance solutions, Wireless Personal Area Network $(WPAN)$ and many other cellular networks. There are significant developments that are taking place in the advanced consumer electronic systems which are far more effective in terms of performance and features, for improving the quality of life [4].

In the $WBASN$ solutions, a paradigm shift is expected in how the solutions shall be adapted in the healthcare solutions, and with the rising trends of internet revolution, demand for such solutions are much higher. [5]. $WBASNs$ are very much effective in terms of facilitating information and communication technology solutions. [5]; Some of the significant functions like monitoring, processing information, sampling, relaying of vital signs communications, real-time feedback system are some of the critical functions that are carried out without any kind of interruptions or discomforts. [5] [6] [7].

Adapting the process of $WBASN$ shall support in effective adaption of one's physiological parameters and also in terms of offering effective mobility and flexibility for the users. The features of offering data from large time intervals, in specific to the natural environment, doctors shall have much better information to patient's status [8]. But the challenge is about the practical implementation, and acceptability of such solutions.

Such challenges lead to various issues pertaining to design and implementation related factors, as the key objectives for such system are about minimum delay, maximum throughput, network lifetime, and also in terms of reducing unnecessary communication pertaining to energy consumption. (e.g. control frame overhead, idle listening and frame collisions).

Also, the user oriented requirements of for the adoption of $WBASN$ are about certain factors like the privacy, value of such systems, ease of implanting or ease of using, and the safety conditions [5] [9].

a) Types of Nodes in a WBAN

A device that has communication scope and ability is considered as a node in $WBASN$. Nodes can be categorized in to three groups based on the functionalities, role in the network and implementation. Such classification of nodes in $WBASN$ is categorized in to following solutions.

Personal Devices (PD) – Such device is in charge of gathering information based on sensors and the actuators, and also plays a vital role in handling the interaction with the users. On the basis of such factors, the PD informs the users through an external gateway, focus on displaying information on the device or the actuators. There are many terminologies used for such devices as BCU (Body Control Unit), PDA or body gateway. [8].

Sensor – Sensors that are present in $WBASN$ focus on certain parameters in an individual's body from either internal or external factors. Such nodes gather and respond the data on basis of physical stimuli and only process the necessary data on the basis of response to information. Such sensors could be of various types like physiological sensors or ambient or biokinetics [8] [9]. Some of the profoundly used sensors are $EMG, EEG, ECG,$ Humidity detection sensors, blood glucose detection sensors, Temperature sensors, Plethysomgram sensors, motion sensors etc.

Actuators – Can be defined as a interaction system with the user for receiving data on the basis of sensors [8]. Also, the role of it is to offer feedback to the network by using the acting on sensor data, and plays a

vital role in the ubiquitous healthcare applications [10] As per the standards defined in $IEEE802.15.6$, another set of classification for nodes that are based on $WBASN$ have been depicted with the following factors [11] [12]

- Implant nodes: Such nodes are used as implanting in the body or under the skin.
- Body Surface Nodes are the ones that are usually placed on human body or near the human body
- External Node are the ones that never are in close physical contact to human system

'On the basis of nodes classification in $WBASN$, the role of network could be defined as:

Coordinator node can be defined as a communicator to the external world and the ones by which all the nodes communicate.

End Nodes in $WBASN$ are considered to be limiting performance to the embedded application, but they do not have the features of relaying messages from alternate nodes.

Relay is the intermediate nodes that are used for the process, and every relay node has a parent node, and also a child node, and some kind of relay messages. The essence of such a node is about the way the data is relayed to the other nodes before reaching the PDA. Such relay nodes are also effective in terms of data sensing.

b) Number of Nodes in a WBAN

In [13],[14],[15],[16], numerous solutions has been discussed pertaining to $IEEE$ standards in terms of technical requirements for $WBASN$ and the range focus on few actuators to sensor communicating alongside the portable handsets that are adapted high in numbers. In a typical medical network based $WBASN$ comprises 6 nodes that has scalable configuration for supporting even to the levels of 256 nodes [16].

There are varied ranges of operating range that is discussed in the factors, on the basis of support in the form of 256 nodes for each network within a 6m3 cube [17], [18], [19]. Only a single hub is permitted to focus on $WBASN$ while the number of nodes that are ranging from 0 to n MaxBanSize is defined to be 64 as per $IEEE802.15.6$ standards because of the transmission strategy factors. [20]. The value of this octet ranges between $x00$ and xFF (0-255).

Despite the fact that that there is no limitation to the number of nodes in $WBASN$, still the limitations is related to network in terms of communication protocols , architecture and the techniques of transmission that are adapted in the real-time scenarios. [8]

c) Topology used in $WBASNs$

The $IEEE802.15.6$ has adapted $WBASNs$ for operating either on the basis of one-hop or two-hop star based topology for effective communication by positioning at strategic location [21], [22]. The communication methods that are adapted is based on beacon mode or non-beacon model ones. The transmission takes place based on the beacons for beginning and ending at a super frame for enabling network association and also device synchronization. Carrier Sense Multiple Access with Collision Avoidance $(CSMA/CA)$ is adapted in non-beacon mode as and when essential for the process. [23]. In the case of $WBASN$, the coordinator is termed as sink node, and the ones that have one-hop start topology and for multi-hop architecture, nodes are usually connected to access points on the basis of other nodes. [24].

From the new version of standard protocol developed as per $IEEE$ standards, two hops are adapted in $IEEE\ WBASN$ standards for compliant communication. Also some of the proprietary systems which could adapt more than two hops are also considered in the process. However, the interoperability turns to be a major concern, as there is significant challenge in terms of standard compliant.

d) Communication Architecture of $WBASNs$

Communication Architecture of $WBASNs$ can be classified in to three tiers as:

- Tier-1: Intra-$WBASN$ communication
- Tier-2: Inter-$WBASN$ communication
- Tier-3: Beyond-$WBASN$ communication

Tier-1: depicts inputs on network interaction of the nodes and also the respective transmission ranges around the human body.

Tier-2: works as communication tier between PS and one or more access points (APs). The APs are an integral part of infrastructure that shall be posi- tioned in dynamic environment. Tier-2 communication shall interconnect $WBASNs$ for various networks and the ones that are easily accessed for daily life too. [4]. some of the paradigms that are considered as sub cate-gories for inter-$WBASN$ communication are infrastru- cture based architecture and the ad-hoc based architecture. [4].

Tier-3: Beyond-$WBASN$ Communication is about usage of metropolitan areas, and a gateway like the PDA can be adapted for bridging gap between Tier-2 and the Tier-3. Database is one of the most effective components for Tier-3, and tier-3 usually restores necessary information from a patient, which is used for treatment.

e) Layers of Wbans

Predominantly the PHY and MAC layers are the ones that are proposed as per the approved standards of $802.15x$, as they not have any network, or the application layer transport and hence the call for

other parties to focus upon them. In $IEEE802.15.6$ $(WBASN)$ working group has defined new PHY and MAC control layers with low complexity, reduced cost of operations and also in terms of offering ultra-low power and short range of wireless communication around human body. The introduction of logical node management and the hub management entity models were also developed to address such solutions.

i. *Physical Layer*

The activation and deactivation in the case of CCA (Clear Channel Assessment) and radio transceivers and data transmission is the accountability of PHY layers in $IEEE802.15.6$, for any kind of current channel data reception and transmission. Also, the choice of physical layer is more dependent on the levels of target applications that are established as implant in the body or in the off-body locations. Usually the PHY layer comprises a procedure for transformation of a PSDU (physical layer service data unit) towards PPDU (a physical layer protocol data unit). $IEEE802.15.6$ Specified varied layers of physical layers as HBC and the UWB (Ultra-Wide Band)

While $NB\ PHY$ plays a vital role in terms of data transmission or reception, deactivation or activation for Clear Channel Assessment (CCA) in a current channel. Using differential 8-phase shift keying $(D8PSK)$, and Differential Quadrature Phase-shift keying $(DQPSK)$ modulation techniques the requisite solutions are handled by the process.

$HBC\ PHY$ has supported with Electrostatic Field Communication (EFC) requirements that support in modulation and start frame delimiter (SFD), which are specified data pattern generated and sent before the packet header and payload. SFD Sequence shall be transmitted once while the preamble sequence is sent four times to ensure packet synchronization.

The UWB physical layer shall be used for communication amidst of on-body devices and the off-body devices. The physical header focuses on information from the scrambler seed, length of payload and also on the basis of rate of $PSDU$. Also, the receiver focuses on information in PHR for decoding $PSDU$.

In UBB PHY there are two frequency bands that exist like the high band and low band, which are divided in to two channels as bandwidth of 499.2 MHz. One of the channels is considered to be mandatory channel comprising support by UWB devices.

ii. *MAC Layer*

The $IEEE802.15.6$ working group defines a MAC layer on top of the PHY layer adapted for controlling the channel access, using the hub, which chooses the beacon periods of equal length for binding the super frame. Offsets in the beacon periods are also shifted by Hub, and the beacons are usually sent during each beacon period, if not prohibited by any kind regulations by $MICS$ band. [25].

The coordinator for the channel access coordination is evaluated on the basis of three access modes:

- Beacon Mode with Beacon Period Super-frame Boundaries
- Non-Beacon Mode with Super-Frame boundaries
- Non-Beacon Mode without super-frame boundaries

In each period of super frame, there are three categories of access mechanisms as

- Scheduled Access and Variants
- Unscheduled and Improvised Access
- Random Access Mechanism

f) Routing in $WBASN$

There are numerous routing protocols that has been developed for Ad Hoc Networks [26] and $WSNs$ [27]. Also the $WBASNs$ shall be similar to $MANETs$ which in terms focus on moving topology comprising group-based movement rather than any kind of node-based movement [28]. $WBASNs$ Comprising regular energy issues that are faced for power transmission when compared to traditional sensor for Ad Hoc networks, which are on the basis of node replacements categorically for implanting nodes, which depict more regulated energy factors. Also, in the case of $WBASN$ there are more changes in terms of topology and also in terms of higher moving speed, despite of static or low mobility scenarios [28]. Due to certain factors like the aforementioned factors and specific $WBASN$ challenges, the routing protocols that are designed for $MANET$ and $WSNs$ shall not be effective to $WBASNs$ [29].

g) Challenges of Routing in $WBASNs$

Some of the significant challenges in terms of routing for $WBASNs$ are:

i. *Physical Layer Challenges*

PHY layer of protocols are developed for minimizing the power consumption without compromising on reliability, but the crux is that current models of wireless technologies are having high peak current and also supports in minimizing the average current that is drawn by duty cycling of radio between active and sleep modes. [9]. Also, the interference is also the other major setback in $WBASN$ systems, despite of the developments that are taking place in terms of improving the co-existence. Also, the value of employing transmits power control for minimizing the interference and focusing on $WBASN$ node battery

lifetime has to be given importance. Off-body interference resulting from collision withexternal sensors is also a challenge envisaged in the process [30].

ii. *MAC Layer Challenges*

The mechanisms that are constituted in $IEEE802.15.6$ is not designed based upon complete MAC protocols and only the basis requirements towards addressing the interoperability issues are addressed in such factors, by developing message exchange protocols and packet formats, in terms of further research questions. Reliability which is a major factor in terms of design is also the other key challenge that has to be addressed in the process. In the instances where the reliability is not achieving from one-hop star topology, the relays are adapted for achieving the outcome. [31]. Also, $WBASNs$ require specific QoS requirements that are to be adhered by the MAC proposal [4].

h) Transport (QoS) Challenges

The QoS requirements of the applications in $WBASNs$ have to be addressed with any performance dwindling and without any kind of complexities in place. Also, in real-time, some of the $WBASNs$ are significantly impacted in terms of loss and relay, and the issue of limited memory impacts to great extent the outcome that is expected from the process. At times, the QoS features like the bandwidth, reliability and the delay in the process could impact in terms of performance of the system. In order to achieve a lower level of packet loss, the transmit power have to be increased which shall result in increased levels of relative power consumption.

III. Contemporary Affirmation of Benchmarking Routing Strategies in WBASN

Both in the $WSNs$ [32] and also in $MANETs$ [33], the routing protocol systems have been extensively reviewed in the earlier times, and it is imperative that significant standards in terms of $BANs$ have some impact in terms of constraints on the design for the routing protocol, which also results in significant challenges in terms of routing performance. In the implementation of $WSNs$ the energy efficient routing protocols are more sensitive in terms of data in terms of memory access, processing of data and other such kind of measurements. [34].

While WSN nodes are homogenous, the BAN nodes are heterogeneous and also have wide range scope in terms of data rate and available energy [35], the mobility might also vary. [34] [35]. Also, BAN routing must take in to account the variations in the body, impact of radiation on tissue heating and limited energy resources, in terms of adapting available resources for further reducing the intervals for batter charging, enhancing network lifespan and also for developing quality system. Despite the fact that the characteristics of $BANs$ are to an extent similar to $MANETs$ and $WSNs$, still the unique difference could be attributed to contemporary solutions that are essential in terms of routing protocols.

a) Temperature based Routing

Magnetic and electric fields are generated from the radio signals that are generated using wireless communication solutions. The high level of radiation emitting and the exposure to such levels of radiation, results in increased temperature levels in the human body. [36], which could impact to health implications. [37].

In the temperature oriented routing algorithms that are provided, the emphasis is on reducing the hot-spots. The levels of heating and radiation absorption in the body are some of the significant factors considered in the design of such routing protocols. $TARA$ (Thermal Aware Routing Algorithm) [36] is one of the effective models that has been proposed which works on addressing the temperature issues, however, the issue of reliability and packet loss rations, along with low network life time are some of the key issues in the model, which has been overcome in the other model proposed as Least Temperature Routing Algorithm (LTR) [38] and Adaptive Least Temperature Routing $(ALTR)$ [38]. But one of the challenges is about how the temperature of each need to understand the other node level temperature is one of the major drawbacks for the solution [8].

HPR [37] is another biomedical based sensor network routing algorithm proposed with the objective of reducing impact of delay-sensitive issues and the ones that work towards reducing the average packet delay and also in terms of avoiding hotspot formation. Also HPR chose the routes that constitute minimum hops from sender node levels to the destination nodes and Thermal-Aware Shortest Hop Routing $(TSHR)$ also provides similar kind of solutions., but the challenge with such models are about lifetime and reliability. Movassaghi et al. [39], have provided a detailed comparison amongst the routing protocols proposed thus far for $(WBASNs)$.

b) Cluster-based Routing

Among the contemporary routing protocols, the cluster based routing protocols that are adapted in WBANs divide the nodes in to varied clusters and for every cluster developed; cluster-head for each of the cluster is assigned. Using the cluster heads the data transmission from sensor to sink is carried out. Prime objective of such routing protocols are to focus on

reducing the number of direct transmissions that are taking place from the sensors to the base station. Also, the overhead and the delay related to cluster selection are considered to be key drawbacks for such protocols.

In [40], adapting a data generating protocol using "Anybody" has been proposed for reducing the quantum of direct transmissions in to base station. In the proposed model, LEACH [41] is used as fundamental model which focus on spreading energy dissipation at frequent intervals using the cluster-heads. Such data is used for gathering information and sending to the base station using the cluster heads. In the LEACH model, it is presumed that all nodes are in the sending range of the base station, but in the proposed model, the issue is addressed by changing the cluster-head selection and developing a robust network comprising of cluster-heads. But one of the key limitations is that the energy efficiency issues are not considered in the model. One of the other issues in the LEACH protocol is about Hybrid Indirect Transmissions (HIT) [42[which is resulting in improving energy efficiency, that is not considered in the process.

Culpepper et al [43], [44] discussed another effective model of data generating protocol which focus on reducing the number of direct transmissions towards the base station, and by using multi-hop indirect transmissions for a cluster and also for multiple clusters that are adjacent. The analysis of HIT and HITm has depicted some kind of network delay despite of high energy efficiency and network life time. It is imperative that HIT needs more effective communication energy while handling dense networks and the issues of reliability and conflicting interaction in the route is not addressed. [34].

c) Probabilistic Routing

There are other alternative routing protocols like the probable of cost factor in to account and work towards developing a route that is carried out with minimum cost, but such protocols require numerous transmissions for updating link-state information, which could be a constraint in terms of implementing blanket range of protocols.

Movassaghiet.al [45] proposed Energy Efficient Thermal and Power Aware routing $(ETPA)$ which has offered an effective solution for the proposed factors of relative costing solutions. Also, some of the other intrinsic aspects like the high depletion time which could result in lasting communication within the nodes are also considered in $WBASNs$.

PSR routing framework proposed by Liang et.al [46], $PRPLC$ [47] that is proposed in terms of Link Likelihood Factor (LLF) were also certain models along with contemporary solutions like $DVRPLC$ [48] is the other set of models that has been proposed in terms of addressing the probabilistic factors in the conditions.

d) Cross Layer Routing

Cross layover routing protocols can be stated as the ones that focus on challenges in the network layer and with the other layers. Despite the fact that such protocols have low energy consumption, still the issues could be more about high path loss and also impact on body motion. Some of the significant models like $WASP$ (Wireless Autonomous Spanning Tree Protocol) which is proposed in [49] focus addressing the issues of by focusing on $WASP$ cycles for effective distribution manner, for offering medium access coordination and also in terms of improving traffic routing.

The Controlling Access with Distributed Slot Assignment protocol $(CICADA)$ [50] is also another low energy cross layer routing protocol categorically designed for $WBASNs$ that are based on multi-hop $TDMS$ scheduling.

Timezone Coordinated Sleeping Mechanism $(TICOSS)$ [51] adjusts all nodes as Full Functional Devices (FDD) and enhances the $IEEE802.15.4$ standard by configuring the shortest path route to the $WBASN$ coordinator, preserving energy and minimizing hidden terminal collisions through V-scheduling (due to V-shape communication flow), which doubles the operational lifetime of $IEEE802.15.4$ for high traffic scenarios and extending $IEEE802.15.4$ to support mobility.

$BIOCOMM$ [52] is another cross layer routing protocol designed with the fundamental as interaction of the MAC and network layer in biomedical sensor networks to optimize overall network performance. This interaction is achieved through a Cross-layer Messaging Interface (CMI) via which the MAC layer sends its status information to the network layer and vice-versa.

e) Qos based Routing

Among the varied levels of routing protocols that are discuss QoS based routing protocols are some of the key models. There are numerous methods that has been proposed based on power efficiency model and also taking in to account varied range of metrics and parameters that could support in effective process of routing. A novel QoS related routing protocol $(LOCALMOR)$ is proposed in [53] for improving the biomedical applications for sensor networks.

It is imperative from the review of solutions that the key issue that is envisaged in the routing path is predominantly related to path routing, and geographic routing issues. Despite the fact that majority of such constraints has been addressed in the process of $RL - QRP$ algorithm, the impact in terms of

independent distributed reinforcement learning model $(IndRL)$ approach for QoS route calculations have to focus on sensor nodes, but the challenge with the proposed solutions are about lack of scope for global optimization in the large scale network conditions.

IV. MAC Protocols

Varied sources contribute to the energy inefficiency in the system, and collisions are one of the major factors that are leading to the energy inefficiency. Collisions result as a part of two or more sensor nodes attempting for data packets transmission in simultaneous manner. There are many over emission issues that result from the issues like prolonged transmission of message whilst the destination node not being comfortable in terms of accepting such transmission. Time Division Multiple Access $(TDMA)$ and the Clear Channel Assessment (CCA) models are some of the solutions that are developed, towards addressing such conditions of emission related implications.

There are wide ranges of Energy protocols that are adapted in terms of focusing on essential behavior of protocols, wherever possible. Contention-based MAC like the Carrier Sense Multiple Access/ Collision Avoidance $(CSMA/CA)$ protocols nodes competes for the channel to transmit data. $CSMA$ based MAC protocols defined in some of the related models [54] [55] [56] [57] [58] are very effective solutions, and the node defers for the transmission for making it idle. $CSMA/CA$ has the issues of protocol reliability Some of the critical models like the $TDMA$ related contention-free MAC protocols [59]-[62] are considered to be very effective and energy-efficient MAC protocols, but the stipulated standards of $WBASN$ are turning out to be some of the limitation for the model.

In the recent past, there are many MAC protocols that have been published for $WBASN$ solutions. $CDMA, FDMA, BSNs$ and many other such models has been proposed for successful implementation. [63]- [68]. In the table-1 comparative analysis of MAC protocols for $WBASN$ has been provided.

Table 1: CSMA based MAC Protocols

Protocols	MAC Approach/ Basic Operation	Time Synchronization Requirement	Benefits	Limitations	Views
S-MAC [54]	CSMA/Scheduling	No	High latency, simplicity, and scope for preventing sleep schedules related overhead issues	Scope of collisions if the packet is not destined for listening nodes and also issues of Low throughput Low throughput,	Effective for routine traffic application solutions.
T-MAC [55]	CSMA/Scheduling	No	Using Burst for packets dispatch resulting in under variable load.	Issues of sleep mode	Responsive to changes in the traffic conditions
B-MAC [56]	CSMA/Scheduling	No	Simplicity, good packet delivery rate, high throughput, low overhead	Scope of increased power consumption and overhearing problems	Effective for normal traffic application models.
P-MAC [57]	CSMA/Listening	No	High throughput	Might be slow in response to changes	Effective for delay sensitive solutions.
D-MAC [58]	CSMA/Scheduling	No	Is efficient model for energy saving and the impact of Good delay in the performance.	Utilization of collision avoidance solutions are poor	Resourceful for low delay applications

WiseMAC	np-CSMA/Listening	No	Adaptive for traffic loads and also in terms of mobility support	Decentralized system might lead to variations in the sleep and wake-up times.	Could be resourceful for Normal traffic applications

The table below indicates the scope of TDMA based MAC protocols that could be adapted for significant development in the solution.

Table 2: TDMA based MAC Protocols

Protocols	Performance Comparison	Time Synchronization Needed	Reasons for Energy-Efficiency	Comments
PACT[59]	TDMA/Passive Clustering	No	Lifetime of network shall be prolonged which is a better solution	High traffic overheads could be a major challenge. Effective for low delay applications
LEACH[60]	TDMA/Clustering	Yes	Distributed protocol performs better scope of system.	Additional overhead essential for dynamic clustering.
				WBAN coordinator shall work as cluster-head
FLAMA[61]	TDMA/Scheduling	Yes	Less delay, increased reliability and effective energy savings	Support issues for multi-channels synchronization. Resourceful for normal traffic conditions.
HEED[62]	TDMA/Clustering	Yes	Low overhead conditions, and increased lifetime	Optimal set of cluster heads shall be a constraint. WBAN coordinator shall work as cluster-head
Omeni[69]	Zigbee, Bluetooth and IEEE 802.11	NO	Centrally controlled system resulting in better energy consumption	Resourceful for Applications like ECG Machines and other similar monitoring solutions.
MedMAC [70]	IEEE 802.15.4 MAC	NO	Increased energy efficiency using dynamical adjustments for QoS requirements	Effective for low rate and medium Data rate and Medical applications
Marinkovic [71]	Protocols described in[69], [72]	YES	Reduced power consumption	Short bursts of data could be sent easily
BodyMAC [73]	IEEE 802.15.4 MAC	YES	Improved node energy efficiency.	Resourceful for periodic data sensing and event reporting

V. Conclusion

Wireless Body Area Networks are turning out to be very significant development and globally with the kind of demand for wearable devices and also the way wireless devices and solutions are being adapted in terms of medical, healthcare diagnostics and also in the process of communication, the *WBASN* related routing protocols has gained significant importance. Alongside

the positive developments, even the challenges and complexities in terms of handling such solutions are also rising to great extent. Right from ensuring that the *PHY* and *MAC* do not have impact from external factors to increasing the efficiency and performance, rising the standards of co-existence that is taking place in the system, there are various factors that has to be taken in to consideration.

In the proposed paper, the emphasis is on reviewing the taxonomy and the review of literature pertaining to recent developments in the kind of benchmarking routing protocols, *MAC* oriented protocols, pros and cons envisaged in terms of *WBASNs* (Wireless Body Area Networks). In the process, the from the outlining the properties that are very crucial for handling the *WBASN* designs. Many sources contributing towards improving the *QoS*, qualitative comparisons of the protocol models are reviewed in the process, and from the review of literature, it is imperative that despite of numerous models that has evolved, still in terms of improving the operational efficacy, there are potential solutions that could be achieved from the process.

References Références Referencias

1. IEEE 802.15.4 Standard, Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low- Rate Wireless Personal Area Networks (LR-WPANs). Piscataway, New Jersey, 08855-1331: IEEE, 2006. [Online]. Available: http://standards.ieee.org/getieee802/802.15.html
2. "IEEE standard for local and metropolitan area networks part 15.6: Wireless body area networks," IEEE Std 802.15.6-2012, pp. 1 –271, February 2012.
3. Specification of the Bluetooth System version 4.0. Bluetooth SIG, June 2010. [Online]. Available: http://www.bluetooth.com
4. Chen, M., Gonzalez, S., Vasilakos, A., Cao, H., & Leung, V. C. (2011). Body area networks: A survey. Mobile networks and applications, 16(2), 171-193.
5. Otto, C., Milenkovic, A., Sanders, C., & Jovanov, E. (2006). System architecture of a wireless body area sensor network for ubiquitous health monitoring. Journal of mobile multimedia, 1(4), 307-326.
6. Ullah, S., Shen, B., Riazul Islam, S. M., Khan, P., Saleem, S., & Sup Kwak, K. (2009). A study of MAC protocols for WBANs. Sensors, 10(1), 128-145.
7. Kwon, H., & Lee, S. (2009, September). Energy-efficient multi-hop transmission in body area networks. In 2009 IEEE 20th International Symposium on Personal, Indoor and Mobile Radio Communications (pp. 2142-2146). IEEE.
8. Latré, B., Braem, B., Moerman, I., Blondia, C., & Demeester, P. (2011). A survey on wireless body area networks. Wireless Networks, 17(1), 1-18.
9. Hanson, M. A., Powell Jr, H. C., Barth, A. T., Ringgenberg, K., Calhoun, B. H., Aylor, J. H., & Lach, J. (2009). Body area sensor networks: Challenges and opportunities. Computer, 42(1), 58.
10. Wang, S., & Park, J. T. (2010). Modeling and analysis of multi-type failures in wireless body area networks with semi-Markov model. IEEE Communications Letters, 14(1), 6-8.
11. J. Xing and Y. Zhu, "A survey on body area network," in 5th Int. Conf.on Wireless Communications, Networking and Mobile Computing (WiCom '09), pp. 1 –4, Sept. 2009.
12. Yazdandoost, K. Y., & Sayrafian-Pour, K. (2009). Channel model for body area network (BAN). IEEE P802, 15, 08-0780.
13. "IEEE p802.15-07–0867-04-0ban," in 15-10-0245-06-0006, Oct. 2007.
14. "IEEE p802.15.6/d0 draft standard for body area network," IEEE Draft, 2010.
15. Lewis, D. (2010). IEEE P802. 15.6 D04 Draft Trial-Use Standard for Body Area Network. IEEE 802.15 WPAN.
16. "IEEE p802. 15-10 wireless personal area networks,," July, 2011.
17. Zhen, B., Patel, M., Lee, S., Won, E., & Astrin, A. (2008). Tg6 technical requirements document (TRD) IEEE p802. 15-08-0644-09-0006.
18. Zhang, A., Smith, D. B., Miniutti, D., Hanlen, L. W., Rodda, D., & Gilbert, B. (2010, April). Performance of piconet co-existence schemes in wireless body area networks. In 2010 IEEE Wireless Communication and Networking Conference (pp. 1-6). IEEE.
19. L. Hanlen, D. Miniutti, D. B. Smith, D. Rodda, and B. Gilbert, "Cochannel interference in body area networks with indoor measurements at 2.4 GHz: Distance-to-interferer is a poor estimate of received interference power.," IJWIN, vol. 17, no. 3-4, pp. 113–125, 2010.
20. Zasowski, T., Althaus, F., Stager, M., Wittneben, A., & Troster, G. (2003, November). UWB for noninvasive wireless body area networks: channel measurements and results. In Ultra Wideband Systems and Technologies, 2003 IEEE Conference on (pp. 285-289). IEEE.
21. Tachtatzis, C., Di Franco, F., Tracey, D. C., Timmons, N. F., & Morrison, J. (2010, December). An energy analysis of IEEE 802.15. 6 scheduled access modes. In 2010 IEEE Globecom Workshops (pp. 1270-1275). IEEE.
22. Shah, R. C., & Yarvis, M. (2006, September). Characteristics of on-body 802.15. 4 networks. In 2006 2nd IEEE Workshop on Wireless Mesh Networks(pp. 138-139). IEEE.
23. Sukor, M., Ariffin, S., Fisal, N., Yusof, S. S., & Abdallah, A. (2008, May). Performance study of wireless body area network in medical environment. In 2008 Second Asia International Conference on

2006 2nd IEEE Workshop on Wireless Mesh Networks(pp. 138-139). IEEE.
23. Sukor, M., Ariffin, S., Fisal, N., Yusof, S. S., & Abdallah, A. (2008, May). Performance study of wireless body area network in medical environment. In 2008 Second Asia International Conference on Modelling &# x00026; Simulation (AMS) (pp. 202-206). IEEE.
24. Natarajan, A., Motani, M., de Silva, B., Yap, K. K., & Chua, K. C. (2007, June). Investigating network architectures for body sensor networks. In Proceedings of the 1st ACM SIGMOBILE international workshop on Systems and networking support for healthcare and assisted living environments (pp. 19-24). ACM.
25. Kwak, K. S., Ullah, S., & Ullah, N. (2010, November). An overview of IEEE 802.15. 6 standard. In 2010 3rd International Symposium on Applied Sciences in Biomedical and Communication Technologies (ISABEL 2010)(pp. 1-6). IEEE.
26. Abolhasan, M., Wysocki, T., & Dutkiewicz, E. (2004). A review of routing protocols for mobile ad hoc networks. Ad hoc networks, 2(1), 1-22.
27. Akkaya, K., & Younis, M. (2005). A survey on routing protocols for wireless sensor networks. Ad hoc networks, 3(3), 325-349.
28. Cheng, S. H., & Huang, C. Y. (2013). Coloring-based inter-WBAN scheduling for mobile wireless body area networks. IEEE Transactions on parallel and distributed systems, 24(2), 250-259.
29. Ullah, S., Higgins, H., Braem, B., Latre, B., Blondia, C., Moerman, I.,...& Kwak, K. S. (2012). A comprehensive survey of wireless body area networks. Journal of medical systems, 36(3), 1065-1094.
30. Yuce, M. R., & Khan, J. (Eds.). (2011). Wireless body area networks: Technology, implementation, and applications. CRC Press.
31. Boulis, A., Smith, D., Miniutti, D., Libman, L., & Tselishchev, Y. (2012). Challenges in body area networks for healthcare: The MAC. IEEE Communications Magazine, 50(5), 100-106.
32. Akkaya, K., & Younis, M. (2005). A survey on routing protocols for wireless sensor networks. Ad hoc networks, 3(3), 325-349.
33. Abolhasan, M., Wysocki, T., & Dutkiewicz, E. (2004). A review of routing protocols for mobile ad hoc networks. Ad hoc networks, 2(1), 1-22.
34. Ullah, S., Higgins, H., Braem, B., Latre, B., Blondia, C., Moerman, I., ...& Kwak, K. S. (2012). A comprehensive survey of wireless body area networks. Journal of medical systems, 36(3), 1065-1094.
35. Latré, B., Braem, B., Moerman, I., Blondia, C., & Demeester, P. (2011). A survey on wireless body area networks. Wireless Networks, 17(1), 1-18.
36. Tang, Q., Tummala, N., Gupta, S. K., & Schwiebert, L. (2005). Communication scheduling to minimize thermal effects of implanted biosensor networks in homogeneous tissue. IEEE Transactions on Biomedical Engineering, 52(7), 1285-1294.
37. Bag, A., & Bassiouni, M. A. (2007, May). Hotspot preventing routing algorithm for delay-sensitive biomedical sensor networks. In Portable Information Devices, 2007. PORTABLE07. IEEE International Conference on (pp. 1-5). IEEE.
38. Bag, A., & Bassiouni, M. A. (2006, October). Energy efficient thermal aware routing algorithms for embedded biomedical sensor networks. In 2006 IEEE International Conference on Mobile Ad Hoc and Sensor Systems (pp. 604-609). IEEE.
39. Movassaghi, S., Abolhasan, M., & Lipman, J. (2013). A review of routing protocols in wireless body area networks. Journal of Networks, 8(3), 559-575.
40. Watteyne, T., Augé-Blum, I., Dohler, M., & Barthel, D. (2007, June). Anybody: a self-organization protocol for body area networks. In Proceedings of the ICST 2nd international conference on Body area networks (p. 6). ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering).
41. Heinzelman, W. R., Chandrakasan, A., & Balakrishnan, H. (2000, January). Energy-efficient communication protocol for wireless microsensor networks. In System sciences, 2000. Proceedings of the 33rd annual Hawaii international conference on (pp. 10-pp). IEEE.
42. Moh, M., Culpepper, B. J., Dung, L., Moh, T. S., Hamada, T., & Su, C. F. (2005, December). On data gathering protocols for in-body biomedical sensor networks. In GLOBECOM'05. IEEE Global Telecommunications Conference, 2005. (Vol. 5, pp. 6-pp). IEEE.
43. Culpepper, B. J., Dung, L., & Moh, M. (2004). Design and analysis of Hybrid Indirect Transmissions (HIT) for data gathering in wireless micro sensor networks. ACM SIGMOBILE Mobile Computing and Communications Review, 8(1), 61-83.
44. Moh, M., Culpepper, B. J., Dung, L., Moh, T. S., Hamada, T., & Su, C. F. (2005, December). On data gathering protocols for in-body biomedical sensor networks. In GLOBECOM'05. IEEE Global Telecommunications Conference, 2005. (Vol. 5, pp. 6-pp). IEEE.
45. Movassaghi, S., Abolhasan, M., & Lipman, J. (2012, September). Energy efficient thermal and power aware (ETPA) routing in body area networks. In 2012 IEEE 23rd International Symposium on Personal, Indoor and Mobile Radio Communications-(PIMRC) (pp. 1108-1113). IEEE.
46. Liang, X., Li, X., Shen, Q., Lu, R., Lin, X., Shen, X., & Zhuang, W. (2012, March). Exploiting prediction to enable secure and reliable routing in wireless body area networks. In INFOCOM, 2012 Proceedings IEEE (pp. 388-396). IEEE.

47. Quwaider, M., & Biswas, S. (2009, October). Probabilistic routing in on-body sensor networks with postural disconnections. In Proceedings of the 7th ACM international symposium on Mobility management and wireless access (pp. 149-158). ACM.
48. Quwaider, M., & Biswas, S. (2010). DTN routing in body sensor networks with dynamic postural partitioning. Ad Hoc Networks, 8(8), 824-841.
49. Braem, B., Latre, B., Moerman, I., Blondia, C., & Demeester, P. (2006, July). The wireless autonomous spanning tree protocol for multihop wireless body area networks. In 2006 Third Annual International Conference on Mobile and Ubiquitous Systems: Networking & Services (pp. 1-8). IEEE.
50. Braem, B., Latré, B., Blondia, C., Moerman, I., & Demeester, P. (2008, August). Improving reliability in multi-hop body sensor networks. In Sensor Technologies and Applications, 2008. SENSORCOMM'08. Second International Conference on (pp. 342-347). IEEE.
51. Ruzzelli, A. G., Jurdak, R., O'Hare, G. M., & Van Der Stok, P. (2007, June). Energy-efficient multi-hop medical sensor networking. In Proceedings of the 1st ACM SIGMOBILE international workshop on Systems and networking support for healthcare and assisted living environments (pp. 37-42). ACM.
52. Bag, A., & Bassiouni, M. A. (2009). Biocomm–A cross-layer medium access control (MAC) and routing protocol co-design for biomedical sensor networks. International Journal of Parallel, Emergent and Distributed Systems, 24(1), 85-103.
53. Djenouri, D., & Balasingham, I. (2009, September). New QoS and geographical routing in wireless biomedical sensor networks. In 2009 Sixth International Conference on Broadband Communications, Networks, and Systems (pp. 1-8). IEEE.
54. Ye, W., Heidemann, J., & Estrin, D. (2002). An energy-efficient MAC protocol for wireless sensor networks. In INFOCOM 2002. Twenty-First Annual Joint Conference of the IEEE Computer and Communications Societies. Proceedings. IEEE (Vol. 3, pp. 1567-1576). IEEE.
55. Van Dam, T., & Langendoen, K. (2003, November). An adaptive energy-efficient MAC protocol for wireless sensor networks. In Proceedings of the 1st international conference on Embedded networked sensor systems (pp. 171-180). ACM.
56. Polastre, J., Hill, J., & Culler, D. (2004, November). Versatile low power media access for wireless sensor networks. In Proceedings of the 2nd international conference on Embedded networked sensor systems (pp. 95-107). ACM.
57. Khan, N. P., & Boncelet, C. (2006, October). PMAC: Energy efficient medium access control protocol for wireless sensor networks. In MILCOM 2006-2006 IEEE Military Communications conference (pp. 1-5). IEEE.
58. Lu, G., Krishnamachari, B., & Raghavendra, C. S. (2004, April). An adaptive energy-efficient and low-latency MAC for data gathering in wireless sensor networks. In Parallel and Distributed Processing Symposium, 2004. Proceedings. 18th International (p. 224). IEEE.
59. Pei, G., & Chien, C. (2001). Low power TDMA in large wireless sensor networks. In Military Communications Conference, 2001. MILCOM 2001. Commu- nications for Network-Centric Operations: Creating the Information Force. IEEE (Vol. 1, pp. 347-351). IEEE.
60. Heinzelman, W. B., Chandrakasan, A. P., & Balakrishnan, H. (2002). An application-specific protocol architecture for wireless microsensor networks. IEEE Transactions on wireless communications, 1(4), 660-670.
61. Rajendran, V., Garcia-Luna-Aveces, J. J., & Obraczka, K. (2005, November). Energy-efficient, application-aware medium access for sensor networks. In IEEE International Conference on Mobile Adhoc and Sensor Systems Conference, 2005. (pp. 8-pp). IEEE.
62. Younis, O., & Fahmy, S. (2004). HEED: a hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks. IEEE Transactions on mobile computing, 3(4), 366-379.
63. H.M. Li and J.D. Tan. "Heartbeat driven MAC for body sensor networks", In Proc of the 1st ACM SIGMOBILE international workshop on systems and networking support for healthcare and assisted living environments, San Juan, Puerto Rico, pp. 25-30, Jun. 2007.
64. Changle, L. I., Huan-Bang, L. I., & Kohno, R. (2009). Reservation-based dynamic TDMA protocol for medical body area networks. IEICE transactions on communications, 92(2), 387-395.
65. Otal, B., Alonso, L., & Verikoukis, C. (2009). Highly reliable energy-saving MAC for wireless body sensor networks in healthcare systems. IEEE Journal on Selected Areas in Communications, 27(4), 553-565.
66. Su, H., & Zhang, X. (2009). Battery-dynamics driven TDMA MAC protocols for wireless body-area monitoring networks in healthcare applications. IEEE Journal on selected areas in communications, 27(4), 424-434.
67. Li, C., Wang, L., Li, J., Zhen, B., Li, H. B., & Kohno, R. (2009, September). Scalable and robust medium access control protocol in wireless body area networks. In PIMRC (pp. 2127-2131).
68. Li, C., Li, J., Zhen, B., Li, H. B., & Kohno, R. (2010). Hybrid unified-slot access protocol for wireless body area networks. International Journal of Wireless Information Networks, 17(3-4), 150-161.

69. Omeni, O., Wong, A. C. W., Burdett, A. J., & Toumazou, C. (2008). Energy efficient medium access protocol for wireless medical body area sensor networks. IEEE Transactions on biomedical circuits and systems, 2(4), 251-259.
70. Timmons, N. F., & Scanlon, W. G. (2009, May). An adaptive energy efficient MAC protocol for the medical body area network. In Wireless Communication, Vehicular Technology, Information Theory and Aerospace & Electronic Systems Technology, 2009. Wireless VITAE 2009. 1st International Conference on (pp. 587-593). IEEE.
71. Marinkovic, S. J., Popovici, E. M., Spagnol, C., Faul, S., & Marnane, W. P. (2009). Energy-efficient low duty cycle MAC protocol for wireless body area networks. IEEE Transactions on Information Technology in Biomedicine, 13(6), 915-925.
72. Ye, W., Silva, F., & Heidemann, J. (2006, October). Ultra-low duty cycle MAC with scheduled channel polling. In Proceedings of the 4th international conference on Embedded networked sensor systems (pp. 321-334). ACM.
73. Fang, G., & Dutkiewicz, E. (2009, September). BodyMAC: Energy efficient TDMA-based MAC protocol for wireless body area networks. In Communications and Information Technology, 2009. ISCIT 2009. 9th International Symposium on (pp. 1455-1459). IEEE.