An Overview on Wireless Body Area Networks

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***ABSTRACT*---Wireless body Area Network is the interconnection of multiple nodes that are located in or around the surface of the body which is capable of wireless communication. Wireless body Area Network involves various monitoring application environment, warfare, agriculture, military and health care. The sensor nodes are usually light weight, low cost, low power consuming intelligence devices which are capable of sensing, computing, communicating with each other wirelessly. This review gives a clear overview about the functions of WBAN. The main operation of protocols, transmitter and receiver of IEEE 802.15.6 are deeply examined and studied in this work. This survey paper provides quick summary about the sensor design, applications, power efficiency, energy conservation, communication protocols and security issues in WBAN.**

Key words--- Body Area Network; Transmitter; Receiver; Data management; Authentication and Protocols.

I. INTRODUCTION

Wireless body Area Network is the interconnection of multiple nodes that are located in or around the surface of the body which is capable of wireless communication. Body Area Network consists of sensors and actuators for recording and monitoring bio-signals. These functions help us to estimate the patients' health. BAN has a controlling entity called base station, which collects and process bio signals for BAN. All the sensor nodes in the BAN, communicate the signals to the base station at regular intervals. The BAN has a gateway node used to connect sensor nodes to remote location (i.e., hospital, internet).

The main operation of sensors includes sensing, sampling, processing and communication. Fig.1 depicts the communication of data from sensor to doctor. Sensor acquires parameters such as glucose level, ECG, EMG, EEG signals and blood pressure. The sensing nodes send data to base station where it is processed and then send to PDA. PDA (Personal digital Assistant) is a mobile which act as a gateway between sensor and internet and also used as storage for the collected data. These data would be sent to the doctor through the internet (WLAN/WIFI). During emergency, Base station would send an alarm to sensor nodes. The data will be collected from sensor nodes and sent to doctor, nurse and ambulance.

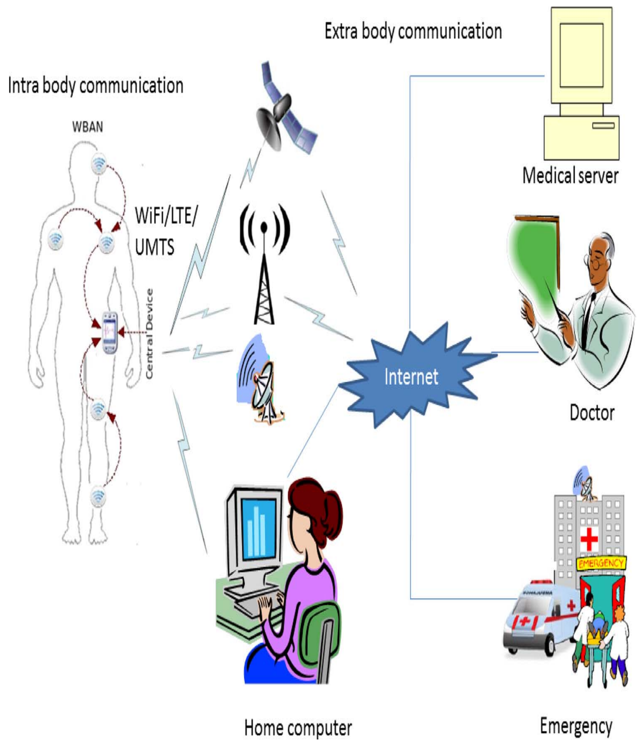

Fig.1. System model
Source: http://file.scirp.org/

Many researchers are working towards WBAN. Author [1] extensively reviewed the applications, research challenges, function and technical requirement of BAN, antenna design, energy efficiency and latest standards in WBAN. Researchers [2] discusses about system architecture, address allocation, routing channel modeling, PHY layer, MAC layer, security, application. It would help the researchers for developing an efficient WBAN.

Many scientists [3] surveyed recent technologies and design challenges in WBAN. They also discussed about main application, technologies, standards, issues in design of WBAN. In this paper [4] authors discussed the technologies, applications, sensor / actuator devices, radio system, interconnection of WBAN, data rate, power consumption and network coverage. Similarly authors [5] also discussed about various Intra Body Communication (IBC) design, IBC coupling

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methods, various IBC models. They are suitable for short range communication with low power. They have found research challenges in IBC are motion, transmission quality, increasing data rates and long term usage.

This review highlights the past, present and future trends in WBAN. Section I deals the introduction on WBAN .Section II discusses the principles of operation, Section III describes the application of WBAN. Section IV explains about the protocols used in WBAN. Section V describes the security issues faced in WBAN. Section VI discusses the performance evaluation of WBAN. Section VII covers miscellaneous information on WBAN. Section VIII concludes the paper.

II. PRINCIPLE OF OPERATION

The working principle of wireless body area networks is depicted in Fig. 2.

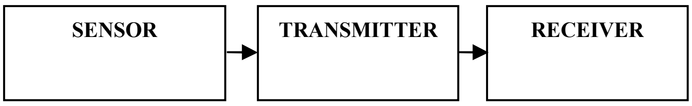

Fig.2. Block diagram

Sensor detects the input signals based on physical change due to reaction. A transducer converts the input into electric signal and amplifies the electric signal to process it using the processor. The processed signal is displayed finally. Transducer is used to convert one form of energy into other such as movement, electrical signals, radiant energy, thermal or magnetic energy. Actuator is a component in the sensor which is used to control the whole system by a control signal.

In the transmitter, carrier frequency is less and then the signal is modulated using high modulation techniques. In the receiver side, low noise amplifier is used to remove noise. The signal is demodulated using demodulator and filtered out to obtain to original signal.

In wireless body area networks, sensor nodes are placed in or around the body of the person to capture signals which is used to measure parameters such as blood pressure, temperature, ECG, EEG and EMG. So sensor node should be placed inappropriate position.

In a work [6] authors have introduced a model for positioning multiple nodes in WBAN based on spatial sparsity, FFT (Fast Fourier Transform) in circular grid. They have tracked the movement of patients and sent to central database server. They have increased the resolution and accuracy with reduction in computation complexity. Similarly author [7] introduced Swarm optimization algorithm which is used to find optimal position of sensor nodes. The path with lowest SAR (Specific Absorption Rate) is selected from path between Hubs nodes. The packet transmission is improved and reduces the EMF radiation. Few researchers [8] estimated channel between Hub and nodes based on path gain and fade depth metrics. They have found out waist are not suitable for location of hub. Best location for placement of hub is left temple. They have also introduced spider plot for evaluation. A scientist [9] introduced a game theoretic approach which is used for relay selection based on node, it has to select its next hop and transmit power. It improves power consumption in transmitter and reduces delay. In their work [10] they have found out location of nodes along the patient body based on vertical arrangement and pressure in the node without anchor and beacons. It improves accelerometer based fall detection performance. Authors [11] have used Indoor free passive localization (DFPL) to record the variance in signal based on RSSI (Received Signal Strength Indicator) and using this variance to find out location of node without any electronic devices.

A. Transmitter

The working principle of Transmitter in wireless body area networks is depicted in Fig. 3.

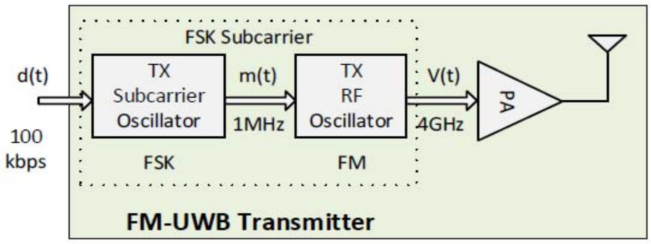

Fig. 3.Transmitter
Source: http://www.mdpi.com/

A transmitter is a device which sends information or data in the form of electromagnetic waves over the wired or wireless channel to the desired destination(receiver).The transmitter operation involves encoding, modulation and amplification. Encoding involves conversion of data into bits.

Authors [12] have designed low power transmitter with low power consumption which supports WBAN requirements. However they can apply only for short range communication. Similarly scientists [13] have designed an analytic model for wave propagation in WBAN. They calculated path gain vs path length and location. The path gain depends on frequency and location. Few researchers [14] used ZCD (Zero Correlation Duration) to avoid MAI (Multiple Access Interference). BER (Bite Error Rate) is improved in ZCD compared to Pseudo noise code (PN). Authors [15] investigated the characteristics of UWB and draw backs of UWB such as path loss, power delay and he tested the above in indoor environment. The research is useful in designing high speed UWB. Few authors [16] have estimated channel between half wavelength dipoles. Cross layer design is used for consuming energy. Path loss and time domain characteristics of channel are also estimated. In another work [17] authors have controlled transmission power to increases the life time of sensor nodes and link reliability. It increases the life time by 9.86 %. It reduces packet loss by 30.2 %.In this paper [18] authors studied about modulation schemes and the channel is estimated for UWB impulses radio WBAN system. Path loss and delay spread created due to waveform distortion. BER is analyzed based on waveform distortion. Few researchers [19] controlled the transmission power using ATPC. Gain estimation algorithm used for on body to on body propagation channel. From RSSI output power of transmitter is known, and then beacon power is used to calculate the gain.

Authors [20] have used Differential modulation with varying frequency techniques for node operation. BFSK (Binary frequency shift Keying) used for varying frequency reduces circuit complexity, BER, phase noise, interface effect and energy wastage. Similarly authors [21] have used various numerical methods to measure UWB signal propagation and results are compared. This model can reduce computational effect in future. Few scientists [22] introduced compressed sensing theory used to evaluate multipath fading channel. They have obtained 20% reduction for path loss, 10% bit error rate, signal amplitude increased by 25% as the distance between transmitter and receiver increases. Authors [23] introduced Carbon Nano Tubes (CNT) used for data transmission lines. They have measured data collected, and its electrical properties. They are suitable for micro wave applications and easily accepted by biological tissues. However in [24] scientist used a Switch combining with transmitter power control technique for control the transmitter power over a fixed transmitter and reduces switching rate. They have increased the network life time, radio communication and reliability. In this paper [25] authors used optical wireless communication (OWC) which involves in reduction of electromagnetic pollution for health monitoring. Code division multiple access (CDMA) is used for spreading the codes. Few scientists [26] introduced Cross layer reliable retransmission scheme which is used to detect failed frames and retransmit it. It reduces loss rate and average transmission time and increases the power consumption. It also reduces chances of failed transmission.

B. Receiver

The working principle of Receiver in wireless body area networks is depicted in Fig .4.

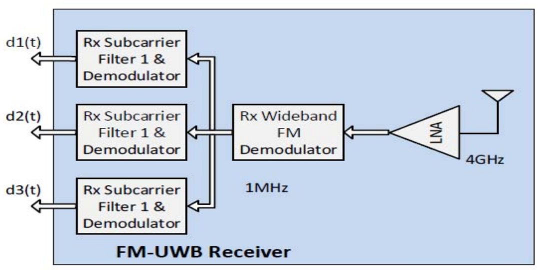

Fig.4. receiver
Source: http://www.mdpi.com/

A communication receiver is a device used to receive the information or data from the transmitter .

Authors [27] have done modulation shift keying for transmitter to avoid emissions. Receiver block designed using CMOS analog decoder is used inside the receiver and direct conversion receiver used to obtain low power. The receiver design reduces the link loss, I/F noise and frequency errors. Few researchers [28] used Gaussian on off keying /pulse width modulation for modulation. Detection schemes in receiver reduce the false wake up. Power is consumed by wake up receiver, packet reception and decoding. It provides sensitivity and flexibility when receiver circuit changes. In this paper [29] authors designed a FSK wake up receiver using CMOS technology satisfied WBAN requirements. Body Channel Communication (BCC) used to consume power; (IL-DCO) helps in frequency to envelope conversion and helps in amplifying and demodulation. Successive Approximation Register (SAR) is used to calculate frequency drift. Wake up Receivers (WURX) provides stable reference clock for transceivers. Few researchers [30] introduced wake up receiver with injection-locking ring oscillator (ILRO) which converts weak signal into strong signal was used instead of RF amplifiers for power consumption. PLL based DFSK used for demodulation .BCC provides sensitivity and selectivity, AFC (Auto Frequency Oscillator) which reduces temperature variation and leakage current. Researchers on [31] introduced mutual noise cancellation technique based on passive coupling which act as a differential inductor. Noise canceller works under low power. Scientist [32] used Maximum likelihood detectors for Pulse Position Modulation (PPM) and Transmitted Reference Pulse Amplitude Modulation (TR PAM) was designed. The performance of the receiver is increased and is suitable for non coherent receivers. The parameters power delay profile, path loss, and multi path amplitudes are estimated. However in [33] authors introduced a Soft Decision Decoder (SDD) which provided a gain of 1 db when compared with hard decision decoder (HDD). It reduces test patterns with low voltage circuits. The performance of BER is improved, energy consumption 94%, SNR 5db is achieved. Few researchers [34] used DFSK modulation technique for short range and low power communication. Circuit designed is reduced. BER and phase noise is estimated. Authors [35] used RF envelope detection for low power and short range communication. Direct modulation architecture and CMOS technology is used. System performance is improved by transmitter and receiver design. Few scientists [36] investigated physical layer design of WBAN by using low cost base band transceiver. Digital timing synchronization used for packet synchronization and data recovery. BER and packet error rate is estimated. Authors [37] have done Cooperative diversity for WBAN for monitoring a sleeping person. Two hop transmissions is used to increases the diversity gain.

III. APPLICATIONS

In this paper [38] authors has used the sensor to detect depth of river, pollution, pressure present in river and the method to prevent it from flood. They have used solar power for low power consumption. Scientist [39] measured the respiration rate from RSSI (received signal strength indicator) present in channel state information (CSI). When transmitter power is known RR is measured from RSSI. Similarly authors [40] monitor heart rate and stress level for preventing from dangerous situation by consuming low power. Few researchers [41] differentiate medical and non medical application in WBAN. WBAN products, context aware applications for medical and non medical in both MAC and application layer were studied. However in [42] authors reduced the false alarm based on Haar wavelet decomposition, non-seasonal holt-winter forecasting and hampel filter. This improves system efficiency and reliability.

IV. PROTOCOL

In this paper [43] authors explained about medium access protocol for health care application. The sensor node and sink node act as master- slave architecture. The sensor node collects the information on body temperature, heart rate and activity. They have used single hop and time slot for energy consumption. Clear channel assessment is used to avoid collision based on Listen before Transmit (LBT). Wakeup fall back time is introduced to avoid time slot overlap. Hardware is designed by using system on chip concept. Few researchers [44] designed a Medium access control (MAC) protocol for health care application. It increases the life time of battery without change in reliability and quality of services. Similarly authors [45] introduced a MAC protocol to allocate transmission bandwidth and to support reliable transmission in health care. The protocol reduces the latency energy consumption and packet loss rate. Few scientist [46] designed Energy efficient MAC protocol to monitor EEG and ECG. TDMA techniques and synchronization problems related to it was also discussed and duty cycle calculation. It supports short burst of data, physiological signals. The protocol is using ADF7020RF transceiver. In this paper [47] authors introduced a group mobility protocol to reduce hand off delay and signaling cost. It will reduce the number of control messages, packet loss ratio, and overhead.

Author [48] used two hop extension protocols to join two nodes and allow two hop transmissions between nodes. It increases the life time of nodes, decreases the Bit Error Rate (BER) with low power. In their work [49] scientists introduced (QS-PS) Quasi sleep-preempt support protocol which uses TDMA technique. In case of emergency it will wake up whole network and use current slot for transmitting emergency packets. It decreases the delay and consumes energy. In this paper [50] authors designed TAD- MAC traffic aware dynamic MAC protocol to control the traffic based on wakeup interval. This can be applied to other low power MAC Protocol. This consumes low energy due to idle listening, over healing, collision and unnecessary wake up for Beacon transmission. However in [51] authors have introduced Data communication protocol for secure data communication between implanted / wearable sensors and data consumers in WBAN. The encryption and signature are used to provide security. In another work, [52] authors evaluated performance of implant communication. It gets degraded due to polarization, distance and power settings at the base station. The analysis proved that Carrier Sense Multiple Access (CSMA/CA) technique unable to support traffic and correlation requirements in WBAN.

V. SECURITY ISSUES

A. Interference

In this paper [53] authors have used power control algorithm to reduce inter network interference. Here throughput is increased with minimum power consumed. Few researchers [54] eliminated Intra WBAN interference by power control game in cyber physical WBAN system. It improves system utility with low power. In their work [55] researchers introduced Clique Based WBAN Scheduling (CBWS) to group sensors in or out of WBAN to eliminate the interference. Coloring based scheduling method is used to allot time slot for each group. Throughput is increased with minimum power. Similarly few scientists [56] used Random In Complete Coloring (RIC) with low time and high spatial reuse to reduce interference in WBAN which leads to throughput degradation and energy wastage. It is suitable for inter WBAN interference. However in [57], authors used Successive Interference cancellation (SIC) algorithm for UWB and MIMO system. ZCD is used to spread codes in UWB when Multiple Access Interference (MAI) is present in multiple devices. Few researchers [58] used omni directional antennas (monopole) and directional antennas (horn) to reduce inter user interference up to 20db and Carrier to Interference Ratio (CIR) is measured. These antennas can perform random movement in a fixed area. Authors [59] used CW antennas to reduce interference between 2 WBAN. Interference is reduced up to 10db when one WBAN uses CW antenna. If both WBAN use CW antennas interference is reduced up to 3db. Similarly few scientists [60] used Interference Cancellation with Interrupted Transmission (ICIT) algorithm to remove the interference and it is compared with optimum combining (OC) and Weiner Hop (WH) solution. Signal to interference noise ratio (SINR) is improved. In this paper [61] authors used Cross Technology Interference Model (CTIM) to avoid interference based on node mobility. Protocol also designed to reduce the operation of CTIM. Evaluation based on node density and utilization of CS. However in [62] scientist used Adaptive interference schemes for coexisting WBAN based on mobility of nodes, traffic load, signal strength and density of sensors. It improves packet delivery ratio, longer network life time, energy efficient channel assignment, power consumption and increases spatial reuse.

B. Authentication

Authors [63] designed light weight confidential data discovery and dissemination protocol to check disseminated data for maintaining confidentiality. It uses multiple one way key hash chains which provides authentication. Researchers [64] designed a protocol to study mutual authentication and confidential transmission for two tier WBAN. The parameters on end to end delay, throughput, low computation cost are estimated. Hash function and XOR operation is used. Scientist [65] introduced Scalable anonymous certificate less remote authentication protocol for eliminating clients account information. It supports mutual authentication, session key establishment, anonymity, up link ability and non repudiation, forward security, key escrow, resilience, scalability and low power mobiles. Few researchers [66] used Protocol based on Certificate Less Signature (CLS) scheme prevents from forgery, maintain privacy of users and reduces the cost. In their work [67] authors have designed Revocable and scalable certificate less remote authentication protocol which provides efficient revocation and short term key exposure based on binary tree. Encryption scheme and signature scheme provides revocation. It is suitable for large WBAN, non-repudiation, key escrow resistance and anonymity. Similarly few researchers [68] introduced MASK-BAN (movement aided authenticated secret key) which provides authentication for intra BAN communication. Key is generated by max flow algorithm and it reduces false positive rate. However in [69] authors introduced Access control scheme for authorize, authenticate and revoke user to use WBAN was created based on sign encryption scheme. The paper provides confidentiality, integrity, authentication, non-repudiation, public verifiability, cipher text authenticity, low cost and low computation time. Few scientists [70] used Encryption and signature scheme which provides secure data communication between sensor nodes and sink nodes in WBAN based on cipher text policy attribute. Signature used to store data in cipher text format at sink node. It provides authentication, collision resistance, feasible and low power consuming. In this paper [71] authors used Key management protocol which provides data confidentiality and integrity based on cryptography and hash chains. Authentication based on group key generation is used. This reduces computation and complexity. Researchers also have [72] designed physical layer based security based on finger print to provide authentication in health care.

VI. PERFORMANCE

In this paper [73] authors designed a network layer protocol that supports the relay selection in which BCC link act as relay. In case of RF (Radio Frequency) link failure, which acts as link between WBAN and gateway, medium access control (MAC) protocol is used to consume energy and to avoid delay. Md. Few researchers [74] used Body node coordinator placement algorithm (BNC) to place BNC at various position in order to increase network life time with low power. In another work, [75] authors used Energy efficient medium access approach which has set of key frames as a static postures based on key frames BNC will identify node without shadowing effect and select node for transmission. Author [76] used two more receiver antennas at back of the human to avoid varying channel due to movement of the person. These antennas receive data and transmit to BNC. Few scientists [77] studied Modulation schemes and channel is estimated for UWB impulse radio WBAN system. BER is analyzed under waveform distortion due to delay spread and path loss. In this paper [78] authors used Dynamic program algorithm to select the sensor for operation. Scientist [79] estimated channel capacity and BER is measured when channel is under slow and fast fading effects. Channel capacity decreases when complex propagation mechanism is used. To improve QOS, fading should be minimized. Similarly researchers [80] estimated propagation channel using micro strip patch antennas. GFSK modulation was used inside Bluetooth. This can be used in health monitoring. However in [81] authors used QOS aware energy management which consists of three models first model to reduce energy, second model to improve QOS and third model to provide efficient detection. (PEH-QOS) control scheme is used to reduce packet loss and end to end delay. In this paper [82] scientist introduced Low power model based on transmission distance, transmission data rate for on body WBAN is proposed. Transmission power is reduced by optimizing data rate. Thus system performance is improved. Author [83] have done Integration of MCC(Mobile Cloud Computing) with WBAN for transmitting the data with efficient routing, resource allocation, semantic interactions and data security mechanism. However QOS improvement is not obtained. Researchers on [84] used Random room mobility to capture mobility within building. They have estimated packet drop ratio, delay and average energy per node. Traffic and pay load size have impact on pact loss in network. In [85], authors used Multi hop topology formation game (MTFG) for optimization of multi hop based on PHY security with delay management. It improves performance gain.

VII. MISCELLANEOUS

In [86] authors compared performance of various modulation schemes based on energy consumption of packet transformer. Analytical model used for evaluating energy consumption for both un-coded and coded transmission. They have found that differential phase shift keying is energy efficient. Energy consumption is reduced by non coherent frequency shift keying. In this paper [87] authors used Space Time Frequency Coding (STFC) to avoid diversity error in MB OFDM.

Schemes they have used changes modulation, coding rate and constellation power. Similarly few researchers [88] used Spiral antenna in WBAN which operate as endoscopy capsule in implant device. They have evaluated path loss model from various tissues for in body to out body. Specific Absorption Rate (SAR) in homogenous and heterogeneous body is characterized. In one another work [89] authors used Multi Attribute Decision Making (MADM) hand over algorithm to select best network and to provide continuous connectivity satisfies QOS. It involves in reduction of packet overhead, handover and packet loss. However in [90] scientist discussed about body sensor network and it applications such as health care, disability assistance, sports, human activity monitoring. Here cost and time is reduced. In this survey network layer operation is not considered. Authors [91] have done low energy UWB receiver architecture which uses narrow band rejection mechanism in RF front end. Pulses are filtered, correlated and combined to obtain SNR. This system is compared with BER and BPSK modulation scheme. In this paper [92] authors used Distributed Queuing Medium Access Control (DQ-MAC) for the function of network load and packet length. Super frame optimization is used for saving energy. This protocol avoids collision in data transmission and reducing the control over head. In [93] scientist explained a prototype for a telemonitoring system based on BAN which consists of Bluetooth, GPS and Smartphone. The Smartphone uses python software to maintain Bluetooth piconet. This prototype helps in forwarding patients health and location .Few researchers [94] used biometric signal processing methods to provide secure communication in BAN. Wise adaptation and adaptation modulation were also studied. Researcher in [95] evaluated 3-5 GHZ UWB channel for wireless communication. Various LOS and NLOS channel model were measured with various position of transmitter. The frequency and distance of UWB channel is noted. Path loss of NLOS is greater than that of LOS but sensor are operated in low data rate which support NLOS. In the work done by [96] scientists, they evaluated the performance of multiplexing and error control scheme for various channel model in WBAN. Decomposable code is used which has simple structure. Their goal is to optimize QOS by selecting the error correcting code. In [97], authors used Cooperator-assisted WBAN for data collection. Two frame structures are evaluated, TDMA being the first one and second one is hybrid TDMA/CSMA and they have compared both in terms of power consumption. They have found that TDMA/CSMA is energy efficient. Similarly researchers [98] introduced dynamic channel model for WBAN during walking. Due to body movement antenna gain of transmitter and receiver varies and multipath fading created in channel model. Rice distribution is used to evaluate multipath fading and found that by choosing correct diversity location of antenna can increase system performance. Researchers on [99] used two antennas monopole and loop antenna which act as mouth device to control wheel chair or using computer by mimicking. They have identified link loss was low for monopole than loop antenna and fading occurs in the link of mouth-chair due to shadowing and breathing. In this paper [100] author designed model for analyzing behavior of node and to increase reliability of WBAN in case of failures based on semi markov process. Nodes are classified based on sensing and relaying then model is used to identify misbehavior of node.

VIII. CONCLUSION

The main aim of this review is to develop an efficient WBAN by reviewing the literature thoroughly. We tried to identify draw backs of protocol design, transceiver architecture and security issues in WBAN. The following are the conclusions made: Idle listening and over hearing leads to energy wastage. Data reliability isn't handled by MAC protocol. Multiple nodes lead to complexity. Collision occurs, when multiple nodes wish to connect with a hub since they send request at same time. If a large amount of data needs to be sent, time slot per frame becomes difficult. If two hop transmission sensor nodes are used, complexity in design is created and also for every hop, energy is wasted. Sensor nodes using battery power which has limited capacity may have to recharge or replace complexity. If more number of 'wake up' circuits is used, then hardware implementation becomes difficult. Various body postures create reflection, refraction and body shadowing leads to loss of packets. When parallel emergency occurs in same person, collision occurs and priority of sending data has to be decided. Transceiver design should not be complex and it should improve traffic fluctuation and it should consume low power. Hence best modulation techniques and detection techniques should be used. Interference is one of the serious problems. This reduces signal to interference and noise ratio (SINR) leading to packet loss and performance degradation. This packet loss affects reliability in WBAN and may harm patients' health. However interference may cause energy and reduction of throughput. Interference reduces quality of service and creates communication problems. Channel assignment schemes and transceiver power control should be good to avoid interference. Attackers at different location may modify the data at the channel. So it is necessary to provide security to WBAN. Authentication may be provided by efficient key management and encryption techniques. Cryptography algorithm is used to improve security in WBAN. These are major issues in WBAN and these issues have to be sorted out to make Wireless Body Area Network as powerful and efficient.

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WEBLINKS:

Fig. 1. system model
Source: http://file.scirp.org/

Fig. 2. Block diagram

Fig. 3. Transmitter
Source: http://www.mdpi.com/

Fig. 4. Receiver
Source:http://www.mdpi.com/