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Research Article

An Enhanced Energy Efficient Management in OFDM-Massive MIMO for Cognitive Wireless Body Area Network (C-WBAN)

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Abstract

The cognitive networks make use of cutting edge technology to solve various problems related to signal degradation. As they are self-managing networks, they face lot of challenges.One such problem is interference which is of serious concern and it needs to be reduced to increase the performance of the network at low bit error rate(BER). WBAN is the network of individual connected nodes which are independently bound on the human body in the form of sensors, actuators, etc that need to be configured with dynamic power adjustment and provide high quality of services. The network needs efficient analysis using the adaptive beam forming process. This paper proposes an enhanced cognitive-based Massive MIMO with adaptive beam forming approach. WBAN (EC-WBAN) is simulated using MATLAB to evaluate performance metrics namely, BER, energy consumption, packet delivery rate and collision probability.

Keywords: WBAN, Cognitive Radio Systems, Adaptive beam forming, Massive MIMO

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1. INTRODUCTION

The WBANs generally contain sensors set with restrictions on an energy source that comprises of the wireless transmitter and receivers that is attached to the human body. These devices and circuits are positioned around the human body, and they can regulate observations of the human physique. Instruments in WBAN operate in a wireless medium to interchange their information. The presence of the human body could disturb the transmission among devices. This should be correctly measured to design efficient WBAN systems and algorithms [1].

Moreover, the requirement for effective power saving shall be addressed over power control schemes and processes as frequent battery replacement for embedded sensors is difficult and expensive. WBAN comprises of PHY and MAC layers only while the conventional networks are provided with network, transmission and application layers. [7]. So among all layers, the physical layer is the important layer which is having the main WBAN challenges and tasks such as channel encoding, estimation of the channel, modulation process etc., Cooperative sensing achieves high diversity by using the cognitive nodes which receives the data proficiently transported by sensors that work in an organized manner on the human body. There are various published researches. Some of the research have been accomplished on the outcome or estimating power transmission done in cooperative communication in WBAN [16][17].To improve communication performance under the influence of multipath fading, a diversity technique such as Massive Multiple-Input Multiple-Output (MIMO) is the latest interesting wireless access 5G technology. It is an expansion of MIMO technology, which consists of hundreds and even thousands of antennas linked to a base station to enhance spectral efficiency and throughput.The bit information from the huge quantity of smart sensors using conventional multi-access schemes is very impractical as it leads to excessive packet loss, low packet delivery rate, and reduced accuracy. Massive MIMO with enormous beam forming ability can sense information received simultaneously from several sensor nodes with low packet loss and high packet delivery rates and steady connectedness.

In this paper, a cognitive-based adaptive beam forming process is developed and evaluated in terms of minimum energy consumption, low latency, low bit error rate and high throughput of the system which is the novelty of the research. The proposed system can provide effective performance and solutions for problems occurring in the real world scenario [18][19].

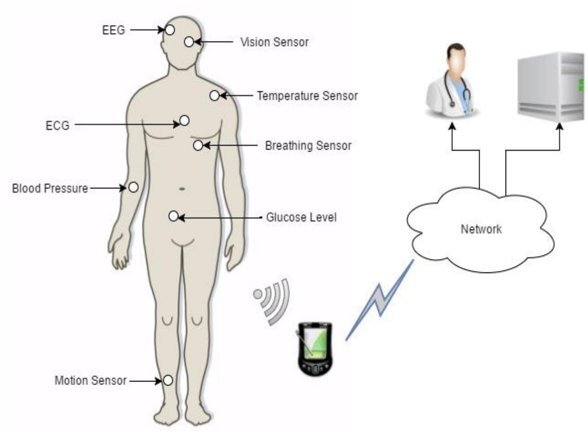

Fig 1: WBAN structure

2. RELATED WORK

In this segment, the WBAN schemes of various authors are analytically reviewed. The presented literature deals with the proposed solutions by various researches to report the issue of consistency and fault-tolerance in the WBAN system. But, many weaknesses are still there which have not been correctly taken, and there are also various drawbacks in the structures such as high energy outflow and BER. Technologies like MIMO are a resourceful approach in a fading atmosphere, but various projections cannot be positioned in such small power sensors. Murtaza Cicioglu et al. [2] have worked on the efficient SDN based architecture in which they have evaluated the performance in terms of the high efficiency of the network, less end delay and also they have performed routing process using the Dijkstra technique through which they have performed the optimized process for high network lifetime. Anil Kumar Sagar et al. [3] have worked on the data routing process for transmitting information to the supernode which acts as a head node for them. It will work as a controller and manage the signals for the inner operations and analyze the sensor nodes deviation and if it occurs then it will move to the rest. Consequently, the supportive methodology is an effective substitute to provide a simulated MIMO atmosphere for WBAN [9], [10]. Furthermore, one of the projected structures used the fault detection approach, which accomplishes communication of information grounded on the neighbor node but is not an effective solution to the high failure level of the controlling area.

Other than this, the dispersed and clustering-based methodologies with the cooperation of the sensing devices give effectual results in fault-tolerance and consistency. In the network failures, consistency in the system is improved. The originality of the proposed study is sensor-based support in WBAN to increase fault acceptance and dependability, which additionally improves the QoS in critical structure. Zone et al. [11], [12], projected an efficient architecture for WBAN systems. This QoS-based arrangement has an asymmetric design, in which the processing is accomplished at an aggregator used to provide efficient resources while limited power is required on sensors. In this arrangement, an effectual resource scheduling methodology is used, which reduces channel deficiency. Though, the main drawback of this outline is that due to heavy load processing, the access node gets overloaded, which interrupts the critical information in the system, causing consistency reduction. Guowei Wu et al., in [13], proposed an efficient fault tolerance model in WBAN systems. In their research work, the bandwidth gets reserved before starting the transmission. The scheme decreases channel damages and assures the dependability of the information in the set-up, and a fault-tolerance precedence system is created which is the real-time scenario. The main influences of the planned pattern are lower end-delay, low losses of the transmitted packets, and efficient reliability [11], [12]. Yet, one of the key restrictions of this structure is that the fault data is not updated at once while performing real-time processes. Similarly, Abdu Rahim et al., [14], proposed a cooperative sensing scheme for WBANs which is an energy-efficient approach. In their research, BER is observed throughout data transmission. Additionally, their approach gives better outcomes than current structures. The prominent powers of this structure deal with the efficient BER evaluation, efficient patient mobility regulation, and low cost, low energy depletion. S Movassaghi et al. [15] worked on the fault management processes in the cooperative environment. More definitely the problem that each transmits node finishes decoding of the acknowledged information from all sensing devices and then re-coding and sending of the base station is required. The whole information is decoded and acknowledged the actual data. Furthermore, with increasing relay nodes, high BER of the data will be transferred to the sink nodes or the base station which makes this solution less energy efficient and is also affecting the latency of the packets in the network. However, the author presented cooperative communication arrangements to decrease network delay. But, it requires more handling of each relay which can affect the critical services reliabilities.

3. PROPOSED WORK

The proposed work relates to the reduction of interference and fadings in the channel and reduces the energy consumptions of the cognitive-based WBAN systems. The WBAN systems are having certain challenges in terms of energy efficiencies, reliabilities, and latencies. So the proposed work makes use of a novel state-of-the-art approach using cognitive-based massive MIMO and adaptive beamforming. The novel approach is achieving low BER, high packet delivery, and low packet losses and end delay.

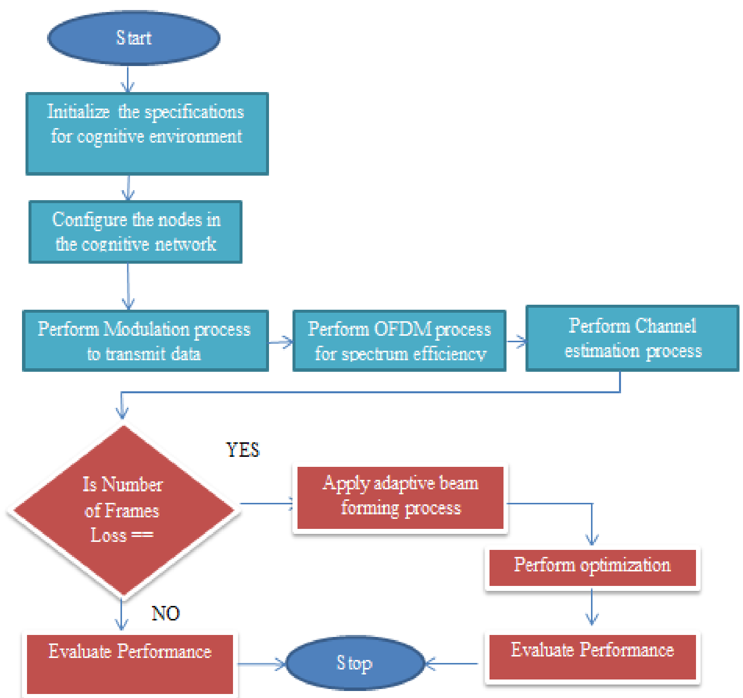

Fig 3: Proposed Flow

3.1 Proposed Enhanced Cognitive-Based Massive MIMO with Adaptive Beam Forming Approach for WBAN (EC-WBAN) algorithm.

Step 1: Initialize Specifications X(n) such that $\mathrm{X(n)} = x1, x2, x3 \ldots x(n)$ where x(1) is the no. of bits per symbol, x(2) = no. of bits process per second, x(3) = constellation size.

Step 2: Generate data to transmit bits such that $\mathrm{T(x)} = \{\, T1, T2, T3 \ldots T(n)\}$

Step 3: Generate cognitive environment by deploying cognitive nodes such that

$$\mathrm{N(x)} = \{\, N1, N2, N3 \ldots N\}$$

For i=1 to N

$$\mathrm{S(n)} = F\{S(x) \qquad (1)$$

End For

Where S{n} is the spectrum sensing

Step 4: Generate the transmission process and arrange it in the array such that

$$\mathrm{G(x)} = [Rx(i), N(x)] \qquad (2)$$

Where Rx is the bits generation in the array and N(x) is the length of the array.

Step 5: Perform modulation of the data to have a high amplitude of the data such as

$$\mathrm{Mod(x)} = QAM[Mod(T(x))] \qquad (3)$$

For QAM modulation

$$\mathrm{Q(x)} = A(n)g(t)\cos[2\pi fxt + \Theta]$$

$$\mathrm{QAM(t)} = P(x, q)/\log(m)$$

Where M is the modulation order and P(x) is the symbol probability

Step 6: Generate the encoded data and convert it serial to parallel conversion process to perform interleaving. For trellis encoding process:

$$\mathrm{y(x)} = \sum_{k=0}^{n} h(\mathrm{x})x^k a^{n-k} \qquad (4)$$

$$\mathrm{M} = \max\{\mathrm{y(x)}\}$$

Where m is the maximum polynomial degree length and k = m+1 is the constraint length.

Then perform convolution encoding

$$G1 = \{x1, 2, x3\} \quad G2 = \{y1, y2, y3\} \quad G3 = \{z1, z2, z3\}$$

$$CovEnc \rightarrow n1 = m1 + m0 + m - 1$$

$$CovEnc \rightarrow n2 = m0 + m - 1$$

$$CovEnc \rightarrow n3 = m1 + m - 1$$

$$Enc = ConEnc\,\{y(x)\} \qquad (5)$$

Where n1, n2, n3 = no. of the symbols and

G1, G1, G3 = polynomial generators, and m is the modulo-2

Step 7: Perform IFFT such that

$$Fn\,\{IFFT\} = IFFT\,\{Enc\} \qquad (6)$$

Step 8: Performing Channelling of the modulation process using OFDM systems to estimate the magnitude of the channel.

Step 9: Inverse $IFFT \rightarrow FFT\,\{X\}$ and evaluate the OFDM subcarrier.

Step 10: Implement a Massive MIMO process such that

$S(M) = \{M1, M2, M3, \ldots .\, Mn)$ Where M € rea(X) (7)

For i=1 to S(M)

X = S(r)

Y = T(x)

ChData = MassiveMIMO{x, y, T(x), S(x), P(g)}

S(x) is spatial correlations

P(g) is the path gains

EndFor

Function MassiveMIMO{

$$C(x) = \sum_{k=1}^{nmin} \frac{\log\big(1 + \mathrm{P(i)} \times \mathrm{W(i)}\big)}{\mathrm{N}}$$

$$P(i) = (mean(x) - N/W)$$

} (8)

Where mean(x) is the power constraint and W (i) is the Eigen channel bits.

Step 11: Perform channel estimation using evaluation of the least mean square errors and perform the adaptive beam forming such that

$$AB(x) = \{R\ lms, Tx, Sx, Pd\ and\ Pg\} \qquad (9)$$

Step 12: Evaluate the performance and repeat steps 7 to 11 until BER near to zero and signal length complete in terms of the transmissions.

4. RESULT & DISCUSSION

The proposed simulation is done in the MATLAB environment in which the medical data is processed in the cognitive-based OFDM environment and is considered as a Massive MIMO process. The size of Massive MIMO is 8×8 at the transmission and receiving side which improves the coverage area, network capacity, and user experience. Then the adaptive beam forming is performed and then the performance of the proposed approach is evaluated in terms of high packet deliveries, low bit error rates, and low packet losses which are discussed below. Simulation experiments shave been conducted for different specifications as given in Table 1 using Massive-MIMO system.

Table 1: Simulation Criterion

Criterions	Specifications
Bandwidth	10^3 bits per second
Modulation order	16
MIMO Size	64 ×64
No. of CR	4
Constellation Size (CS)	16
No. of symbols	Log_2(CS)
Normalized SNR	0-14 (dB)
No. of subcarriers(K)	128

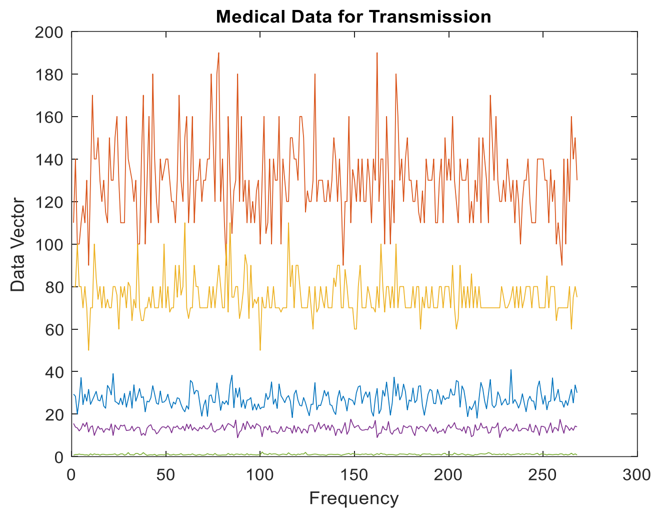

Fig 4: Medical Data

Fig 4 shows the medical data uploaded signal as traffic which will be evaluated through the cognitive environment. The medical data is our main concern because the whole process is taken under a cognitive-based WBAN network where it is assumed that the sensor is attached to the patient's body and it transmits signals to the centralized system to diagnose the patient's data. The transmitted data can be the body mass, blood pressure, heart rate intervals, haemoglobin, and protein values of the patient.

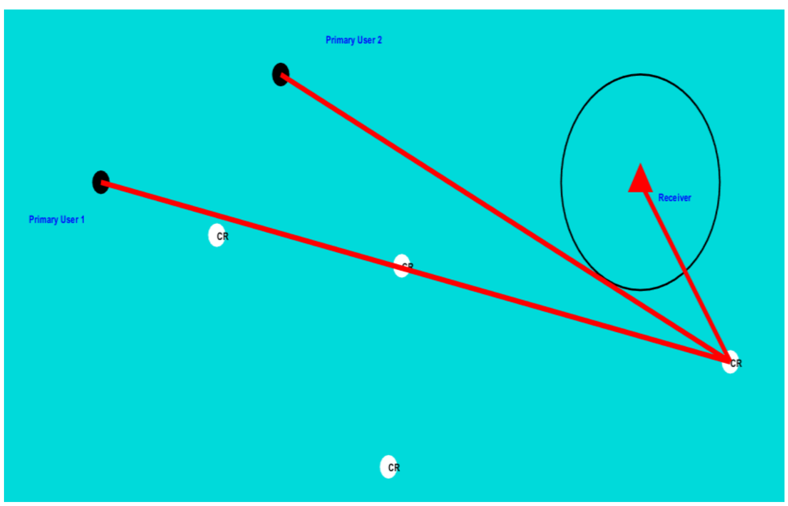

Fig 5: WBAN-Cognitive Network

Fig 5 shows the cognitive network in which the users are deployed and the spectrum sensing process is taking place. This whole process is done through a medium which is a cognitive radio and acts as a radio spectrum sensing node. The radio spectrum is evaluated for the efficient bandwidth utilization to send the packets or traffic to the receiver side or the destination node.

Bandwidth utilization is a serious issue in the communication channels which is efficiently handled by the cognitive environment to have low packet losses and fewer failures of the network.

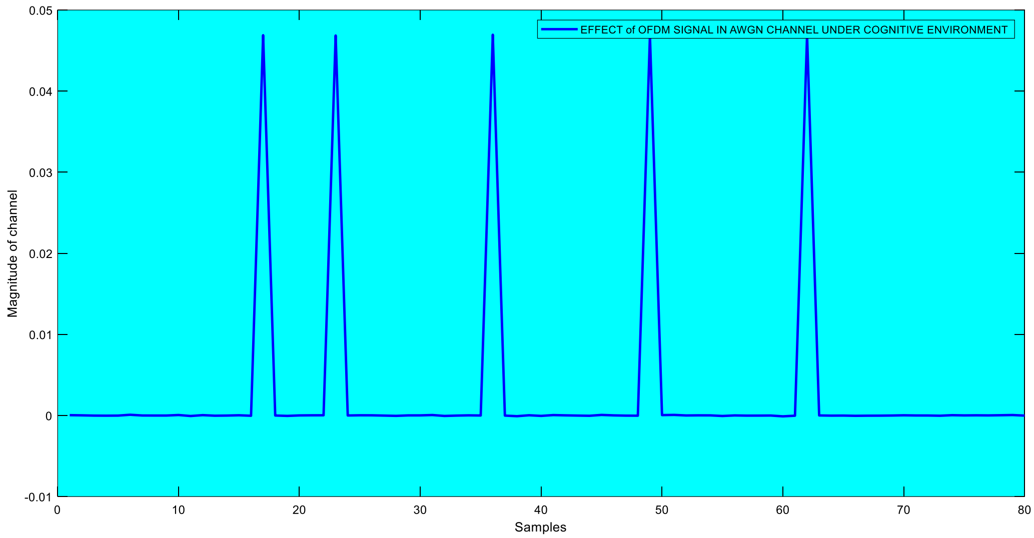

Fig 6: Channel Magnitude

Fig. 6 shows channel magnitude in the cognitive-based WBAN environment.Channel amplitude is the signal coefficient through which tells the rate of change of signal concerning the frequency or time intervals where peaks of the signals can be measured. Channel magnitude is the measure of the output spectrum of the network. If the magnitude is low then it will be difficult for a medium as a channel to transmit signal at large distances. The performance of the signal is always measured on a certain magnitude and phase of the spectrum. The evaluation is done in the presence of the AWGN channel because it is necessary to check the proposed work performance in the noisy environment which can produce a highly distorted environment and is responsible to reduce the spectrum efficiency and also increases the BER. The distortion of the magnitude of the signal always has a high impact in degrading the system performance in terms of the receiving data at the base station or sink node.

The channel magnitude(CM) is evaluated as

$CM = 10log10((I\{p\} \times SI)/(Np/Nb))$______________________________(10)

Where I{p} = Input Signal Power, SI = symbol interval, Nb = Noise bandwidth, Np = Noise Power

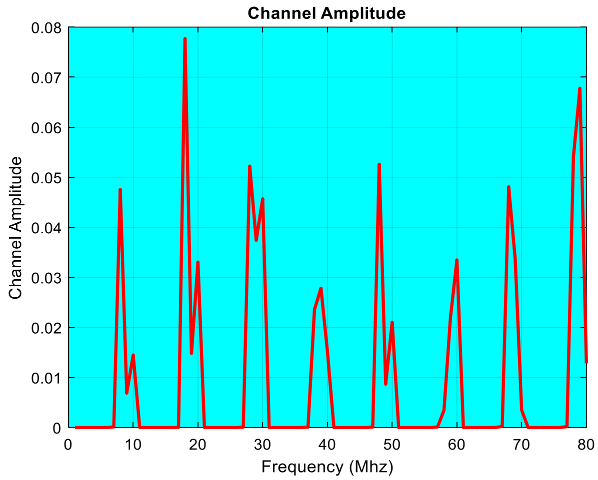

Fig 7: Channel Amplitude

Fig. 7 shows the amplitude of the cognitive channel using massive MIMO realization which is the carrier representation that is further divided into subcarriers. The channel amplitude is orthogonal and is used as the large distance-based modulating transmission. If the orthogonality among the carrier signal decreases then the overlapping of the signal takes place which will give rise to the distorted environments.

The channel amplitude (C_{Amp}) is evaluated as

$$CAmp = 10\log_{10}(SI/ST) + Snr\ (\text{dB})$$ ______________________________(11)

Where SI = Symbol Interval, ST = Sampling Time, Snr = Signal to Noise Ratio

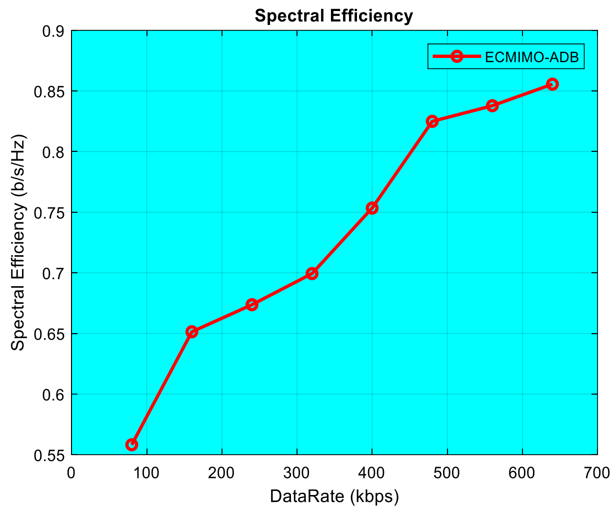

Fig 8: Spectrum Efficiency

Fig. 8 shows the spectrum efficiency of the proposed protocol which shows that the proposed approach is achieving high bandwidth utilization in which Massive MIMO transmissions can be done for high packet deliveries with low packet losses. If the spectrum efficiency decreases then the bandwidth or resource allocations will get reduced and the overload on the cognitive nodes will increase due to which more failures can occur. It can be noticed that the proposed approach is achieving 87% spectrum efficiency which is the desired output.

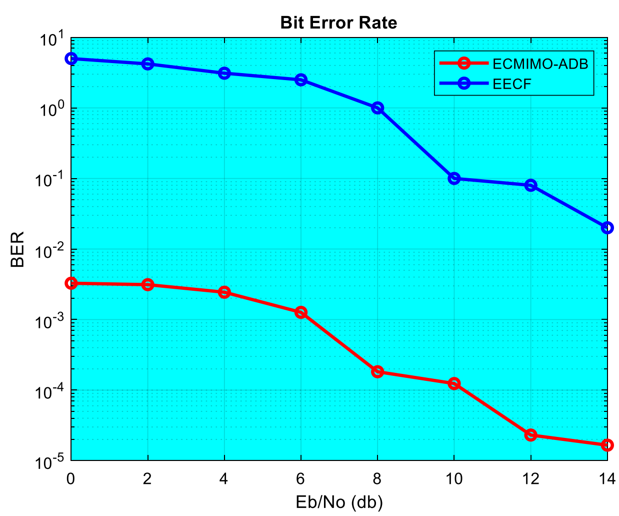

Fig 9: BER Performance

Fig. 9 shows the Bit error performance of the proposed work and it can be seen that low bit losses occurred as per the massive MIMO transmissions. BER is reducing as the E_b/N_0 ratio increases which shows that the proposed approach can achieve low losses of bits if the distortion occurs in the transmissions. The BER must be low for the high throughput of the network. The proposed protocol i.e. ECMIMO-ADB is achieving high performance in terms of low BER in comparison with energy-efficient cooperative fault tolerance BER. As you can see Y-axis the bit errors are reducing with increase in the E_b/N_0 ratio which shows that the noisy interference is reducing and BER also reduces. The throughput of the network increases through which the packet delivery rates increases and losses of the packets decreases.

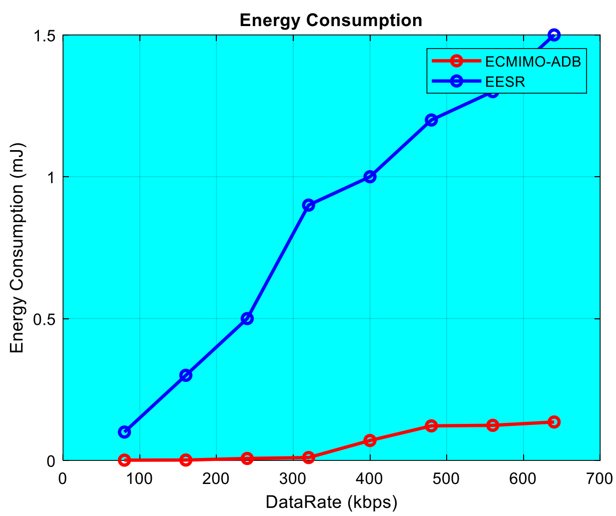

Fig 10: Energy Consumption

Fig. 10 shows the energy consumption of the proposed work which is a significant parameter in the ECMIMO-ADB. It can be seen from the fig. 10 that the energy consumption increases as the data rate increases but it is consuming very little energy even at high data rate transmission environment which shows the robustness of the proposed work. If the energy consumption increases then the cognitive radio node failures increases and should be controlled efficiently. It can be noticed the ECMIMO-ADB is achieving 0.08 mJ in comparison with the EESR(energy-efficient SDN enable routing)protocol

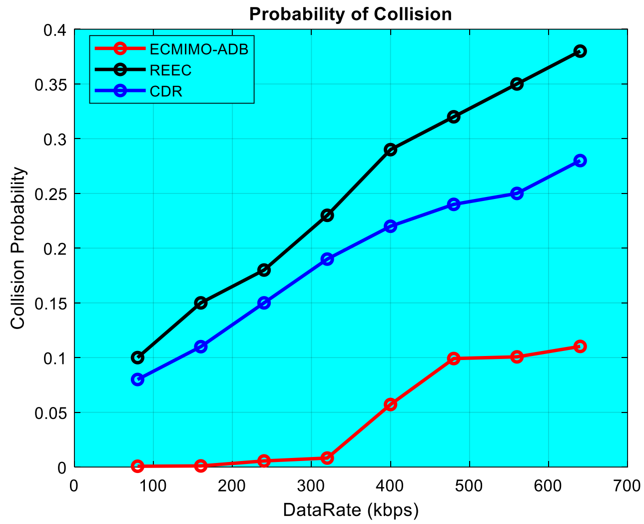

Fig 11: Collision Probability

Fig. 11 shows the collision probability which should be low to indicate the high throughput of the network. If the collision probability increases then there will be high chances of the CR node packets colliding in the transmission environment. The collision probability should not be too high. It should be less as much as possible so that there will be high fault tolerances and low packet losses. It can be seen that the proposed approach is achieving low collision probability than CDR i.e. critical data routing and REEC (Reliable Energy-efficient CDR). The probability of collision significance is to measure the collisions of the cognitive nodes packets in the spectrum. The collision of the packets of the CR nodes occurs when the cognitive nodes attempt to transmit the packets on the same channel in the same time interval. This increases the probability of collision which results in dropping of the packets and increases the chances of the link failures among the primary or secondary users in the network. Hence, more packet losses reduce the throughput of the C-WBAN system.

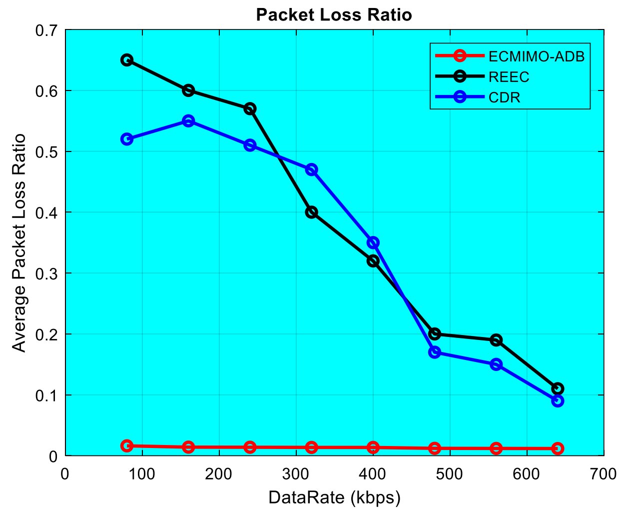

Fig 12: Average Packet loss

Fig. 12 shows the average packet loss in the proposed work which shows that in the proposed work, packet losses are less as compared to the REEC and CDR. The packet losses are completely dependent on the bit error rate performance. If the BER increases then the packet losses also increases which increases the failures of CR nodes in the system and degrades the throughput of the cognitive radio-based WBAN network.

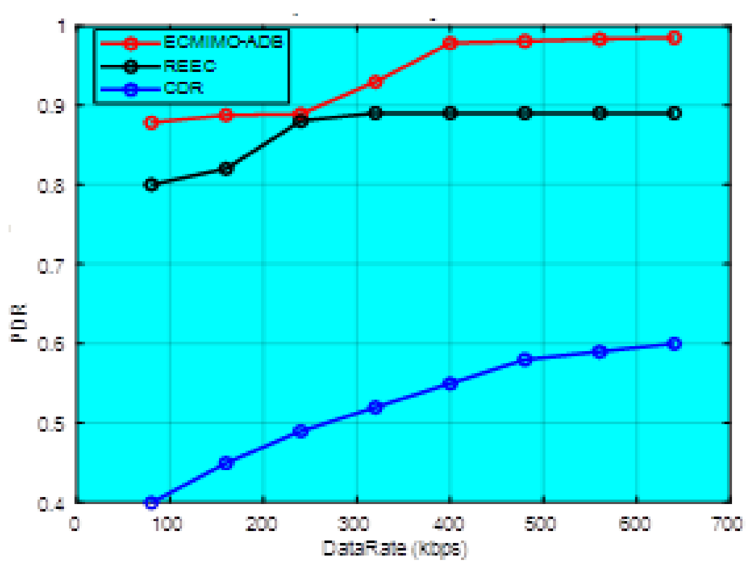

Fig 13: Packet Delivery Rate

Fig. 13 shows the packet delivery rate comparison using data rate because transmission of the packets is completely dependent on the data rates in a channel. If the low data rates are there then the packet transmissions will be slow which cannot make sufficient utilizations of the spectrum in the cognitive networks and it can be noticed that the PDR of ECMIMO-ADB is achieving a high packet delivery rate as the data rate increases which is the desired output. The packet delivery rate considered as the throughput of the network and our proposed protocol is achieving high packet deliveries compared to REEC and CDR protocols.

Table 2: Performance Comparison

Parameter	**ECMIMO-ADB (Proposed)**	**CDR [3]**	**REEC [3]**
PDR	0.96	0.60	0.89
Average Packet Loss	0.007	0.09	0.12
Collision Probability	0.15	0.28	0.37

Table 1 shows the comparison of the proposed work (**ECMIMO-ADB)** with the CDR and REEC approach in which it can be noticed that the proposed work is achieving high PDR which should be high from high packet deliveries. Also, the packet losses are less because the BER is less with high throughput. The collision probability is also a significant parameter in which it can be seen from Table 1 that the proposed protocol is attaining low collision probability which increases the lifetime of the CR nodes to survive long in the network due to CR nodes may be ready to switch their process specifications to modify to channel conditions. If we compare CDR and REEC, the CDR protocol is achieving good performance in terms of packet losses and collision probability but somewhat less in packet delivery rate but both protocols are performing nearly the same for the stability of the WBAN network.

Table 3: Performance Comparison

Parameter	**ECMIMO-ADB (Proposed)**	**EESR [2]**
BER	0.00018	0.01

Energy Consumption (mJ)	0.3	1.5

Table 2 shows the comparison of the proposed work (**ECMIMO-ADB)** with an energy-efficient SDN routing approach in which it can be noticed that the proposed protocol is achieving low BER and low energy consumption than EESR which makes our work energy-efficient protocol. As both performance parameters are very significant in analyzing the network performance, it is very necessary to evaluate these at the receiver to evaluate the reliability of the survival of the CR nodes in the WBAN network.

5. CONCLUSION & FUTURE SCOPE

Health monitoring is a serious issue in the WBAN networks. It is necessary to have high fault tolerance capability in fifth generation wireless networks. In this paper, the cognitive-based WBAN network routing is performed with massive MIMO in collaboration with adaptive beam forming process. The proposed work evaluation is achieved by analysing the performance in terms of bit error rate, energy consumption, packet losses, packet drops, and packet delivery rate assuming different data rates. The proposed work is achieving a high cooperative sensing environment which is used to reduce energy consumption and also reduces the risk of failures which increases the reliability of the WBAN systems. Eventually, the enhanced energy-efficient adaptive protocol is developed to avoid packet drops and gaining high throughput which is proved to an effective solution for WBAN health care monitoring systems.

In the future, the proposed scheme can be further extended for the machine learning and cloud computing scenarios in which the supervised learning of the network can be performed and the BER rates can be further improved. Also, the cloud system can be used for network security and the execution time can be improved in next generation wireless networks**.**

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