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Improving the Lifetime of an Out-Patient Implanted Medical Device Using a Novel Flower Pollination-Based Optimization Algorithm in WBAN Systems

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Abstract: The new inventions in health care devices have led to a considerable increase in the human lifespan. Miniaturized bio-sensing elements and dedicated wireless communication bands have led to the development of a new arena called Wireless Body Area Network (WBAN) (IEEE 802.11.6). These Implantable Medical Devices (IMDs) are used for monitoring a chronic patient's medical condition as well as therapeutic and life-saving functions. The aim of this study is to improve the dynamic channel selection algorithm for an increased Out Patient-Body Network Controller (OP-BNC) medical device during visits to the hospital. There is a fixed number of licensed spectra allocated to the In Patient-Body Network Controller (IP-BNC) and Out-Patient Body Network Controller (OP-BNC). When there is an increase in the OP-BNC, there is an availability of idle spectrum in the IP-BNC. An existing rank-based algorithm is used in the allocation of idle spectrum to the increased OP-BNC. This ranking method takes more time for the processing and selection of an idle channel to the registered user. To avoid it, we proposed an EFPOC model to select from the free idle channels of the IP-BNC licensed spectrum. We also discussed the algorithm complexity of the proposed Enhanced Flower Pollination-based Optimized Channel selection (EFPOC) algorithm and obtained a complexity of O(n^2), which is a significant improvement over the existing algorithm rank-based algorithm complexity. Our experimental result shows that the proposed EFPOC algorithm improves the Tier-2 systems lifetime by 46.47%. Then, to prove that the proposed model is time efficient in channel selection, a simulated experimented is conducted. When selecting a number of channels from a Look-Up Table (LUT), the proposed EFPOC method takes 25% less time than the existing algorithms.

Keywords: cognitive radio; WBAN; UWB; CRC; BNC

1. Introduction

The development of Wireless Body Area Network (WBAN) technology made the sensing and communication of various medical and non-medical signal applications easier, as shown in Figure 1. The authors [1] have initiated the need for an inexpensive monitoring device and a secure communication system for monitoring at the doctor's end. Devices such as wearable Electro Cardi Gram (ECG), Electromyography (EMG), Electroencephalography (EEG), Blood Pressure (BP), Oxygen Saturation (SpO2), and temperature monitor the subject and collect the data. This vital information is communicated through an open wireless channel to the doctor's programming device on demand or on a daily basis. The communication of these signals is made through dedicated frequencies such as Wireless Medical Telemetry Services (WMTS), unlicensed Industrial Scientific and Medical (ISM) Band, Ultra-Wide Band, and Medical Implanted Communication services (MICS) band for bio-medical signal transmission. These Implantable Medical Devices (IMDs) are invasive to the human body, requiring a miniature structure. The Body Network Controller (BNC) consists of a wireless module, a small processor, and a miniature battery. Therefore, it becomes mandatory to design with a light weight security algorithm to protect the data and device from an attacker. The IMD placed in the human body is connected to another reliable node or to an IMD programmer through a wireless telemetry interface. The wireless communication between devices is not an authenticated channel, and information transmitted is unencrypted. This Physiological Value (PV) has more valuable information, and when hacked during communication, it can result in false treatment, leading to life-threatening situations. Security issues of data privacy and device authentication are discussed with the energy constrains of the device.

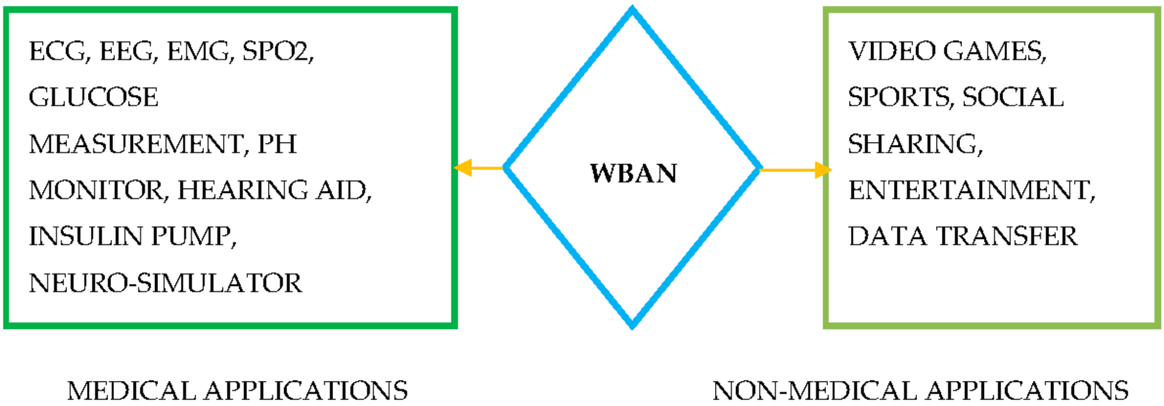

Figure 1. Wireless Body Area Network (WBAN) Applications.

To address the spectrum scarcity, the next-generation promising wireless technology has evolved, which is known as Cognitive Radio (CR). The CR technology has two band users: Primary Users (PUs) and Secondary Users (SUs). Whenever the licensed PUs are idle, the SUs can access the underutilized licensed (PUs) spectrum opportunistically [2]. In the working spectrum, PUs has first priority to access the channels ahead of SUs. In order to efficiently improve the spectrum usage, the SUs utilizes both licensed and unlicensed bands. The health-care sector (or Hospital) is the best example of how CR techniques can be engaged to improve the utility, scalability, and robustness of IMDs. The WBAN standardization working group (IEEE 802.15.6) had drafted a document requiring the Physical (PHY) and Medium Access Control (MAC) layer characteristics for WBAN applications [3,4]. The wide range of power with the data rate of a WBAN is shown below in Figure 2. In order to reduce or eliminate the Electro Magnetic Interferences (EMI) to the Medical Devices (MDs), the CR can be applied to reduce the interference.

Reducing the EMI effect to the WBAN devices can considerably improve the level of Quality of Service (QoS) and precision of the MDs. Table 1 gives the medical and non-medical devices available in the market with their operating range [5–7].

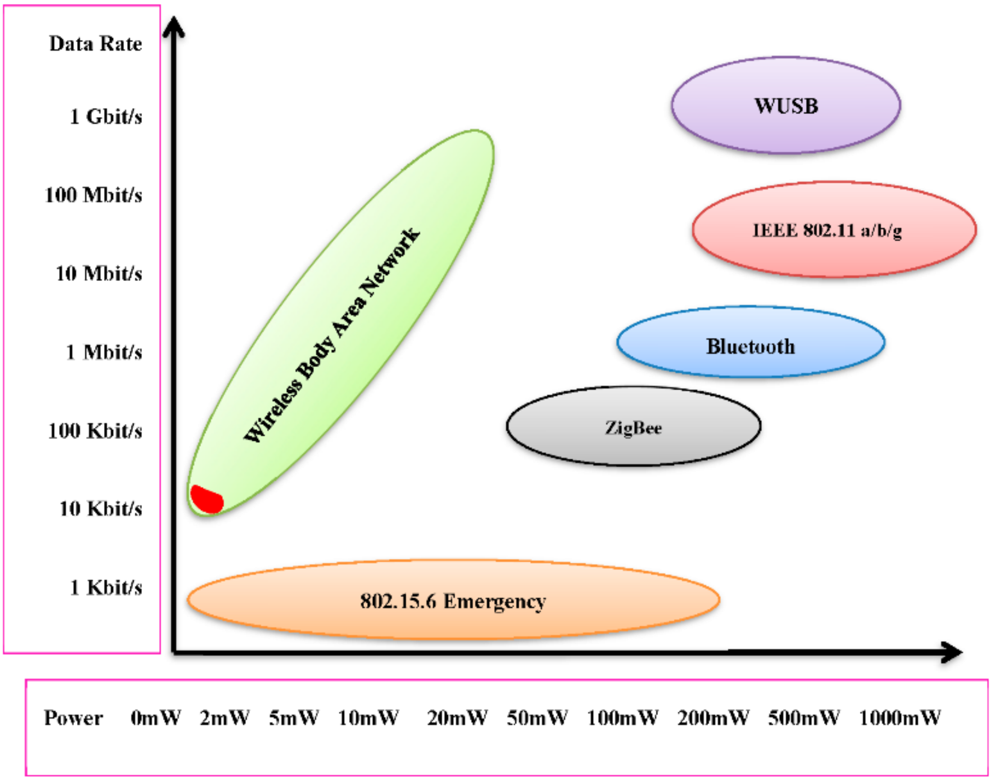

Figure 2. Data Rate vs. Power.

Table 1. WBAN Application Operating Range [8].

WBAN Applications	Signals	Data Range	Frequency (Hz)	Accuracy (bits)	Data Rate
Medical/Health	Glucose Concentration	0–20 mM	40	12	480 bps
	Blood Flow	1–300 mL/s	40	12	480 bps
	ECG	0.5–4 mV	500	12	6 Kbps
	Respiratory Rate	2–50 breaths/min	20	12	520 bps
	Pulse Rate	0–150 BPM	4	12	48 bps
	Blood Pressure	10–400 mm Hg	100	12	1.2 Kbps
	Blood pH	6.8–7.8 pH	4	12	48 bps
	Body Temperature	32–40 °C	0.2	12	2.4 bps

Irrespective of the different spectrum regulatory limitations across the world, several bands designated for medical applications are available on a license band [2]. The United States and Europe have regulated the spectrum that can be used by Ultra-Wide Band (UWB) on a license-exempt basis. The band made available in the United States corresponds to 3.1–10.6 GHz, whereas in Europe, two spectrum sections have been defined, 3.4–4.8 GHz and 6–8.5 GHz, as shown in detail in Figure 3.

The Enhanced Flower Pollination-based Optimized Channel selection (EFPOC) algorithm is assigned with the following modulation techniques between the node and BNC with impulse radio UWB frequency. The proposed environment is considered at the hospital, and it has obtained a limited number of licensed bands (due to higher in cost) for accessing the patient's BNC from collecting the physiological data from the IMD to the hospital server. The number of users of the In Patient-Body Network Controller (IP-BNC) is pre-determined, and a fixed number of licensed channels is assigned to the IP-BNC. The rest of the licensed channels are assigned to the OP-BNC. During the peak visiting hours of the hospital, when the number of OP-BNC users increases, the scarcity for the licensed PU channels increases, as the server has to fetch the data from the OP-BNC for a secure communication. This situation is managed by using the unlicensed SU channel. These unlicensed bands are used by the OP-BNC MDs, which are unsafe to communicate the Physiological Signal (PS) of the patients with IMDs. The problem that arises over here is that all the OP-BNCs must be assigned a licensed frequency in order to protect the data and device from attackers without the need for extra bandwidth. This problem is solved by lending the licensed spectrum of PUs (when idle) to the IP-BNC with an optimized algorithm without affecting the communication of the IP IMDs. The existing node selection algorithms are used in the selection of unused PU channels dedicated for the IP-BNC channel. In this algorithm, the idle PUs are listed and a Look-Up Table (LUT) is created, and these idle PU channels are assigned to the OP-IMD to protect the medical information [9]. In this methodology, two problems are identified: Firstly, the rank-based channel selection algorithm is applied; here, the ranking is done based on the value of Bit Error Rate (BER). When the BER value is constantly low, due to repeated use of the same channel, a busy situation is created always. When the intended PU comes back for the channel, this busy mode creates a collusion, resulting in a loss of data. Secondly, the ranking-based dynamic channel selection algorithm increases the execution time by calculating the BER for each channel that is idle and adds to the LUT, allowing it for the ranking process there and affecting the overall system performance. These two problems motivated us to develop a novel optimization-based dynamic channel selection algorithm called the EFPOC algorithm, which is an ideal dynamic spectrum selection algorithm. Assigning the idle PU spectrum in the existing LUT with BER calculation in the dynamic channel selection is very time consuming. The EFPOC dynamic channel selection algorithm is an optimized algorithm, creating its importance by reducing the channel selection time supported with the algorithm complexity. With the EFPOC algorithm, the process overhead and time is reduced. As the BER calculation is processed only after the channel allocation, the BER calculating time for all the idle channels during the entry at the LUT is completely eliminated by the EFPOC algorithm. The paper is divided into six sections. Section 2 consists of a literature survey of cognitive radio with WBAN. In Section 3, the UWB with WBAN suitability is discussed. In Section 4, CR combined with WBAN is discussed. Section 5 outlines the proposed random channel selection intelligence for CR in BNC for the WBAN system, and finally, in Section 6, the result and conclusion are discussed.

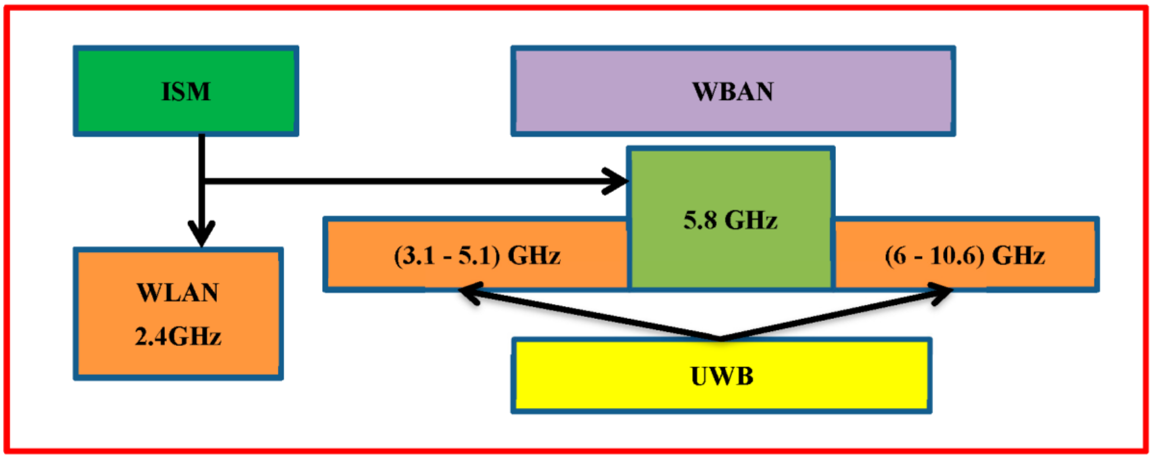

Figure 3. WBAN and Ultra-Wide Band (UWB) Spectrum.

2. Literature Survey

The multi-tier WBAN architecture had introduced many challenges in allocating the frequency, including the time required for calculating and allocating frequency. CR when combined with WBAN in a hospital environment has a large potential to solve the channel interference and spectrum insufficiency problem during allocation to the MDs. This work discusses some of the alternative implementations of CR in allocating the spectrum to the OP-BNC over a hospital environment during increased BNC users and provides a better solution for the dynamic channel allocation. In the channel allocation work, [8] proposed how CR is more efficient and safely used in the transmission of a WBAN signal.

A Multiband Orthogonal Frequency-Division Multiplexing (MB-OFDM) UWB for communication with the OP-BNC is considered as a more efficient spectrum allocation method, but they have not proposed any idea for CR in the Data link layer. The work [10] explored the usage of CR over the existing various types of communication frequency and proved that the existing bands are not the most efficient of the CR through its results. The work [11] proposed an energy-efficient WBAN system for channel selection in CR, where a Particle Swarm Optimization algorithm is proposed in the channel selection. In this model, they had improved the model and increased the lifetime of the system in Tier-2 communication. The model had not proposed any particular on the routing protocol. The disadvantages in the models in the literature outlined above motivated our proposed EFCOP algorithm.

In the work proposed by [12], the global routing protocol that uses the Dijkstra algorithm is applied in WBAN. In this design, balancing the energy consumption across the network substantially increased the network lifetime of the devices. This also increases the energy per bit transmitter by the system. The network maintenance is reduced, and as a balanced energy consumption mode is used, all the batteries are served at the same time at less frequent times. The result of the proposed model is an average increase in network lifetime of up to 40% and an average increase of 0.4 db in energy per bit. In the proposed work, no reference work on global routing in WBAN is proposed with any reference in the parameter settings, and also, there is not much discussion on the latency. Other than this, the proposed work adds value to the WBAN working environment.

Another work proposed [13] an optimal design for WBAN with a data routing and relay positioning problem to increase the network lifetime. The author combined a linear programming model and an energy-aware WBAN model that minimized the energy consumed and installation cost. The work also discussed both cost and energy issues, producing a novel effective model. This model is based on relay nodes, optimal relay nodes, and optimal traffic routing. This work has a combination of two models, and it is a novel approach solution for energy saving. It is a relatively good working model with all its parameter settings. In the proposed work [14], the author proposed an original optimization algorithm that exploits linear relations to guide randomized variables that are implemented in real time. It had been deployed with 30 nodes and operated with a minimum distance of 0.3 m with calculation of its path loss. The system is made to run at various data rates, and the output is measured from it. The proposed work also addressed the traffic uncertainty in the design of WBAN with a single path routing. It is a fast solution algorithm with better quality and lower gaps. This model utilizes the Ant Colony Optimization (ACO), which is a metaheurestic inspired algorithm for the improvement in the energy efficiency of the system. Through the implementation of the ACO in the proposed model, a faster process is also obtained in the given process. A software agent-based disease analysis and machine learning-based data analysis are implemented. Another proposed [15] system constantly scans the applications that are deployed in the cloud (Server application) and checks for vulnerabilities as part of the continuous integration and continuous deployment process. The author [16] proposed a model to identify the risks automatically using Natural Language Processing. This method reduces the human involvement and saved time rather than other approaches. In [17], the Intelligent Searching Approach (ISA) and Agent-oriented Approach (AoA) are replaced by Intelligent Artificial Agents. It acts similar to a human and even dynamically decides in any situations. These agents are used to analyze the medical forums, and the results or findings derived are more accurate than those of other approaches.

3. UWB Wireless Technologies

Irrespective of the different licensed bands and several spectrum regulatory laws across the world, new spectrum regulations are designated for the MDs applications. The UWB offered in the United States agrees to 3.1–10.6 GHz. Europe has two spectrums: 3.4–4.8 GHz and 6–8.5 GHz. The EFPOC algorithm is assigned with the following modulation techniques between the node and BNC with Impulse radio UWB and later with the BNC to the AP that is controlled by the server system is assigned to use a MB-OFDM.

3.1. Impulse Radio UWB

Impulse Radio UWB (IR-UWB) technology has remained as a solution in the IEEE 802.15.6 standard [18]. It includes low-cost, less-complex, and minimum-power WBAN devices. The standard has two major divisions with the PHY layer and MAC sublayer supported by UWB: IR-UWB for communication of a short or long pulse per symbol burst with short pulses per symbol for committed to achieve a higher QoS and Frequency Modulated UWB (FM-UWB) elevated for reliable performance and small power consumption modules, particularly in MD.

3.2. Multiband Orthogonal Frequency-Division Multiplexing UWB

For most of the static medical devices, ECMA-368 is a high-data rate wireless UWB PHY and MAC standard. This standard customs MB-OFDM and the spectrum are divided into 14 bands, each with a bandwidth of 528 MHz [19]. The data are modulated and communicated with an OFDM scheme, while a narrowly spaced and overlying carrier are generated and called sub-bands. Sub-bands include a guard band, data, pilot, and null carriers. There are a maximum of 100 sub-bands comprised of 12 pilot subcarriers. This carrier frequency is divided equally for the IP-BNC and OP-BNC devices in the hospital. Next, we see how the CR is modified for the WBAN environment.

4. Cognitive Radio Combined with WBAN

A WBAN comprises a 3-Tier architecture, in which Tier-1 is an intra-WBAN communications, as referred in Figure 2. It consists of different types of medical sensor; all the individual sensors measure the vital signal, process it, and then combine it and communicate it to the BNC [20]. The Cognitive Radio Controller (CRC) is a central unit that controls the communication parameters of BNC for sensor device communication. The 3.1–10.6 GHz UWB spectrum is divided into 14 sub-bands of 528 MHz; then, the UWB from 3.1 to 4.8 GHz is divided into three sub-bands of 3232, 3960, and 4488 MHz for Tier-1 communications. The spectrum monitoring system is based on the spectrum used for the selection of the broadcast channel from the three sub-bands. The broadcast channel is stored in the memory of the BNC and in the medical sensor. The data transmission uses the sub-band for its communication. For Tier-2 communications, the enhanced propagation characteristics of any one of these three sub-bands is chosen. The data transmission by the AP monitors through the UWB spectrum, and broadcast information is obtainable through sub-bands. In Tier-3, the server is connected to the doctor. We analyze all three tiers in detail.

4.1. Tier-1 WBAN Model

In the Tier-1 WBAN model, WBAN sensors communicate with the BNC, which communicates with the Tier-2 WBAN model. Due to the extremely low Effective Isotropic Radiated Power (EIRP), the UWB naturally has a noise-like structure. This increases its advantages such as invisibility during searching, inability to be jammed, and it can be applied to a simple transceiver, eliminating the implementation use of an encryption algorithm. Wearable sensors with a lower amount of power dissipation are attained through the use of an IR-UWB radio for communication in Tier-1. Three sub-bands—3232, 3960, and 4488 MHz—are chosen for Tier-1 communications. The battery charge must be drained linearly; the CR channel assignment process must not consume much power and drain the BNC battery. If the BNC is often drained, it needs to be charged frequently, affecting the communication with the sensors. Thus, for frequency allocation, if most of its power is drained, it cannot be used in an energy constraint device, thus affecting directly the communication with the sensor and reducing the life of it. Thus, CR is not suited for a resource-constrained IMD sensor communication for Tier-1 communication.

4.2. Tier-2 WBAN Model

In the Tier-2 WBAN model, the BNC communicates with AP. The AP is connected to inventory systems and the patient database through the network. The AP can be configured by a server. The AP acts as a communication platform within the Tier-1 and Tier-3 WBAN architecture. The implemented model communicates in a single hop and can support either a centralized or distributed topology. As the WBAN processing capability is still not developed, the AP controls the CR functionalities. The allocated MB-OFDM UWB technology is active over a range of 10 m and presently achieves rates from 53.3 to 480 Mb/s. The MB-OFDM is simply a channel division and modulation technique; in the EFPOC algorithm, a Network Simulator-2 (NS2) stimulation setup with a maximum of 100 sub-carriers can be used.

These carriers are used as idle channels in the IP-BNC and used by the increased OP-BNC when the numbers of out-patients are increased. The hospital scenario with IP-BNC and OP-BNC is shown in Figure 4, with an ECMA-368 interface. The EFPOC algorithm supports an MB-OFDM UWB transceiver and IR-UWB transceiver with On–Off Keying (OOK) modulation. The Tier-2 information communication can be made through other higher frequencies also [21].

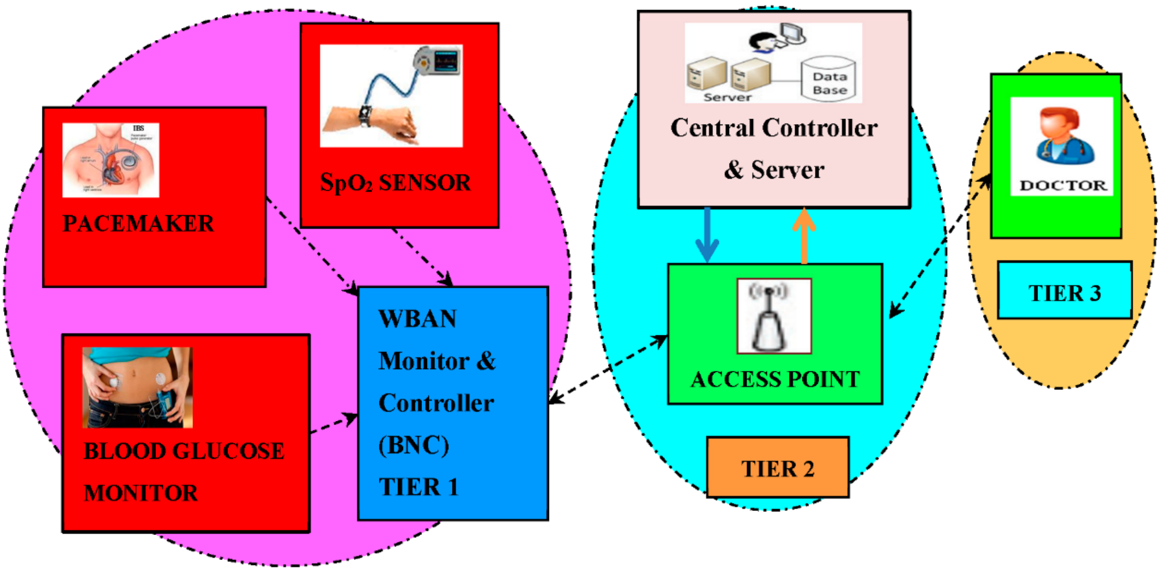

Figure 4. Three-Tier WBAN architecture.

4.2.1. Central Controller Architecture

The IP-BNC and OP-BNC are controlled by the CR central controller, which is divided into three stages: the CR Controller (CRC), the server system, and the BNC, as shown in Figure 4. The server controls the CRC, initiates commands to the CRC, and informs the BNC of the allowable transmission power. CRC plays the role of master, while the BNC acts as slaves. This architecture operates in a licensed channel for the IP-BNC and unlicensed channel OP-BNC. Next, we summarize the components in the architecture. This unit is deployed in the local area where all the IMDs patients are monitored and diagnosed for treatment; thus, a dedicated environment and server devices are allocated.

4.2.2. Server System

The entire controls of all the patients with their MDs are registered in the hospital server. The server keeps track of the physical location, inventory register, and priority level. The server will take the necessary action of the IP-BNC control and OP-BNC devices with all control instructions.

4.2.3. Cognitive Radio Controller

For all the MDs, the CRC acts as a master and a central player in allocating the transmission opportunities. It has two distinctive channels that can transmit and receive data simultaneously. The CRC perform two major tasks: first, the CR instructs the client to control its transmission power based on the EMI measurement level to use the underutilized spectrum; secondly, to find the transmission parameters (e.g., SU transmission power) and dynamically adjust it so that the CRC gathers information from the inventory register [22]. The CRC users are of two types and assigned a licensed frequency for IP-BNC and an unlicensed frequency for OP-BNC, which is independent. When the IP-BNC is idle, the CRC will assign these bands to the variable OP-BNC (increasing during peak working hours). In the proposed EFPOC here, the CRC will allocate the idle licensed channels to the increased OP-BNC, avoid the frequency deficiency, and allow the OP-BNC to use a secure communication channel.

4.2.4. Cognitive Radio Users

The MDs using the CR are assigned as slaves, while the CRC will assign the transmission parameters, and the communication openings are assigned by it. The BNC are associated with an in-built wireless interface to communicate with the CRC for data and control instruction.

4.3. Tier-3 WBAN Model

In a Tier-3 WBAN model, the APs communicate with the BNC and server (base stations) [23]. Tier-3 delivers an extensive range of medical communications between doctors, emergency health-care services, caretakers, and the medical database in the hospital.

5. Random Channel Selection Intelligence Algorithm for CR in BNC for the WBAN System

The performance of the CR tuner system depends upon how efficiently and correctly the information about the channel is analyzed. The sensing parameter associated with the CR concert is the sensing capability, where the efficiency corresponds to the ability of any designed algorithm to find the free channel for as long as possible and to utilize the channel in the most efficient way. MB-OFDM UWB systems utilize Power Spectral Density (PSD) data for each sub-band that identifies the MB-OFDM receiver. With this PSD level, it can regulate the presence of co-existing devices. CR is very relevant to the power restriction in WBANs by two vital procedures. The first one is to provide the maximum usage of the unused, licensed PU of an IP-BNC to be supplied for the OP-BNC. The second is the improved dynamic selection of IP-BNC spectrum, thus decreasing the allocation time and fast assignment of the channel to the OP-BNC. For dynamic channel selection, an existing channel ranking scheme is adopted, which is of two types.

The first type is the sub-band PSD data calculation method to find a vacant spectrum, where the measured BER value of the channel is not calculated. The second type is LUT based on the quality of the BER value of the underutilized channels. To get maximum randomness in dynamic channel selection, an optimized EFPOC algorithm is proposed in this work, which obtained an efficient performance and minimum channel selection time [24]. The research had given a solution for the scarcity of the limited band for OP-BNC during increased user visitation to the hospital with an optimum EFPOC algorithm for dynamic channel selection. The hospitals usually maintain a limited number of spectrums due to its high cost and limited amount of availability for providing it to the BNC. The CRC senses the spectrum on a regular basis from the doctor's end and keeps surveillance of the patient's PS on a demand or regular basis. Here, the quantity of the PS can be usually measured from the insulin-pumping device, pacemaker, and neuro-stimulator that are implanted. The IP–BNC will communicate with the AP through its dedicated PU channel given by the hospital. In addition, there will be some limited number of PUs assigned for the OP-BNC during the vising hours for the communication of OP-BNC with the doctor. The OP-BNC will contact with the hospital server to communicate and transfer the PS (i.e., history) prior to the doctor's direct visit as shown in Figure 5.

When the number of OP-IMDs increases, the additional channel supply for the increased OP-IMD is supported by the unlicensed SUs, and this must be must be avoided. The EFPOC algorithm proposes a solution in which, in most cases, the hospital IP-BNC will not occupy the channel, and the usage of the IP-BNC licensed band PUs, which is idle most of the time, can be used. These idle PU spectrums that are identified as idle are listed in an LUT. It can be used in place of the unlicensed SUs during increased

OP-BNCs. This avoids the transmission of vital signs from the patient in the unsecured/unlicensed spectrum. Secondly, this allocation of licensed frequency to the OP-BNC must be highly random from the LUT, and the same frequency of PUs should not be used very often in order to avoid collusion and data loss between the patient and doctor. Thus, an optimized EFPOC channel selection algorithm is proposed to overcome the overloading of the same PU by the CRC [25]. Thus, an immediate reuse of the licensed channel is be avoided, and the energy spent in dynamic channel selection is optimized.

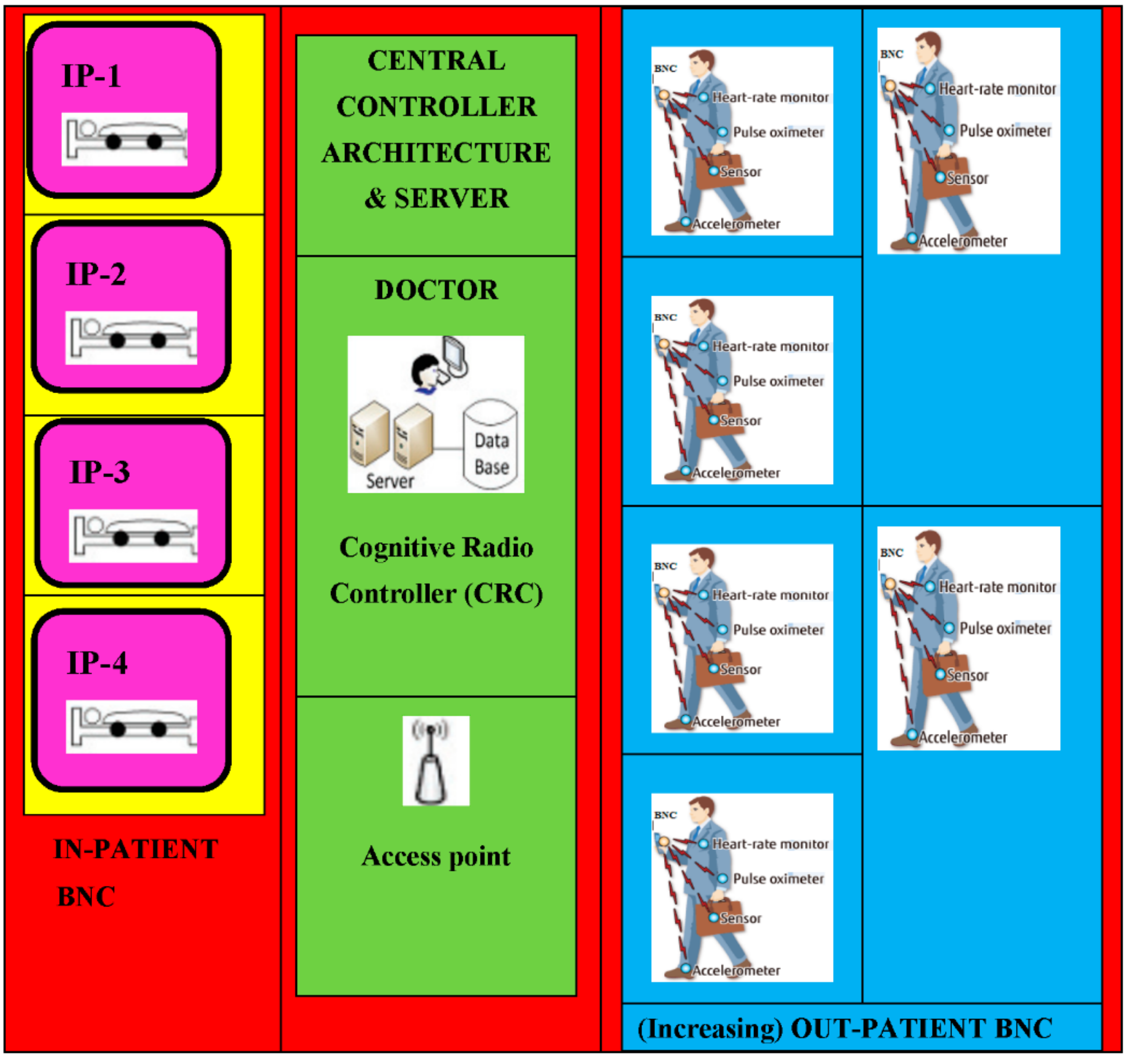

Figure 5. Central Cognitive Controller with an inpatient and out-patient based hospital scenario.

The steps involved in the optimized EFPOC channel selection algorithm are explained briefly by the following steps [26–28].

Step 1: Initializing the parameters, switch probability = P. The initial free channels available with the BNC are set to a count of five (C1, C2, C3, C4, C5).

Step 2: In this step, the fitness function is made to run; the channel with the maximum BER obtained in the previous calculation is obtained from the LUT. The maximum number of times the channel is used by the BNC is counted and stored in a table. The maximum number of times the channel is used is kept as a reference and a decreasing order in the number of usage of licensed channels created. The highest maximum number of times the channel is used is marked as ‘gbest’, and the values are 19, 18, 15, 8, 2 respectively.

Step 3: A random number is arbitrarily chosen from a uniform distribution and compared with the Switch Probability. Then, the condition (rand > SP) decides the threshold and which channel in the search area must undergo either global or local channel selection. In the given example, if the threshold is set as (T = 5), four channels undergo the global channel selection, and one channel undergoes the local channel selection.

Global channel search: During the first iteration, C1, C2, C3, and C5 undergo a global channel search, and C2 channel is first considered for a global search in Equation (1). The next optimum channel to be allocated for the IMD is in another direction toward the current 'gbest' channel.

$$\text{Best chaff point (global Best) Solution } f(z) = \begin{cases} Z_f^{p+1} = Z_f^{p+1},\ Z_f^{p+1} < Z_f^{p} \\ \\ Z_f^{p+1} = Z_f^{p+1},Z_f^{p+1} > Z_f^{p} \end{cases} \quad (1)$$

Local channel search: Only one point undergoes a local point search C4. The local channel search occurs between the threshold channel points close to it. The threshold channel C3 and point C1, another channel, combine to arrive at the free channel. This is the new channel C4, which is quite free for a long time.

Step 4: Steps 1, 2, and 3 are repeated until all the free channels are searched, and a single free channel is selected.

It is understood that the switch probability and fitness of the free channel value make a suitable condition for channel allocation to the OP-IMD by introducing the maximum randomness. In addition, the optimal channel is selected faster from the LUT of free channels due to the minimum convergence and small step of the variables. The EFPOC is best suited for channel selection application, as it explores globally and exploits locally within a single iteration. This process is concurrently performed for all the free channels shown in Figure 6, which is freely available at that time. Once the channel is selected, it is transferred to the OP-IMD immediately for communication with the hospital server. We attain an energy-saving method from a dynamic spectrum selection algorithm and improved the overall performance by simulating the EFPOC.

(EFPOC: Enhanced Flower Pollination based Optimized Channel Selection Algorithm)

```
For (f = 1, f ≤ n; f ++) do Randomly generated initial free/idle channels of   zi
        For all solutions in the population evaluate the fitness function f (zi)
        The Best fitness is the channel having maximum BER
End for {initialization} Initialize p = 0
While   (p< MNG)
            For (f = 1; f ≤ n; f ++) do (all n channels in the list)
                    Generate a random number rand {rand is a uniform distribution}
            If (rand <S) then
                    Generate a step vector L, (d – dimension)
                    This obeys Lévy distribution
                    Proceed Global channel search Z_f^{p+1} = Z_f^p + ω H(λ)(b_* − Z_f^p)
            else
                    Random choose j and k among all the solutions
                    Draw a parameter ∈, where ∈ [0, 1]
                    Do local channel search Z_f^{p+1} = Z_f^p + ∈(Z_v^p − Z_s^p)
            End if
            End for
        For (f = 1; f ≤ n;f ++)
            Evaluate new channel solution
            Process the fitness function of f (zf) for all solution in the channel list
        End for
            If (Z_f^{p+1} < Z_f^p) then
                Set (Z_f^{p+1} = Z_f^{p+1}) (discard)
            else
                Set (Z_f^{p+1} = Z_f^p) (update)
            End if
        Categorize the solution and keep the best solution   b* identified from the channel list.
        Increment ++p
Output the best solution found.
```

Figure 6. Pseudo code of the proposed Enhanced Flower Pollination-based Optimized Channel selection (EFPOC) algorithm.

6. EFPOC Algorithm Complexity

To estimate the presentation of the EFPOC algorithm, a complexity analysis is made in Table 2. The existing BER is based on the LUT for dynamic channel allocation of channel selection; the price of the LUT is high usually in terms of time and space. The complexity study is done on the EFPOC algorithm while taking the logic expense of operations once implemented in the hardware. It is taken that n represents the number of channel presently being idle in IN-BNC and T is the time engaged in finding the free channels that must be engendered. The algorithmic complexity of the EFPOC algorithm for the channel selection has been calculated, and the complexity obtained is $O(n^2)$. This manages the dynamic channel selection in a rapid manner compared to the existing BER-based ranking system.

Table 2. Algorithm Complexity.

No.	Operation	Complexity	Total
1.	i = 0, S = 0, t = 0, initialize random parameters	0	t*
2.			n*
	while (t < G)//iteration//	1	n*1
	for (I = 1; I < S; i++) //channel size//	S*(1 + n)	Sn + Sn^2
	rand = RNG (0,1)	1	n*1
			Sn^2 + Sn + 2n
3.			n*
	if (rand > p)//global channel search//	1	n*1
	$Z_f^{p+1} = Z_f^p + H\left(b_* - Z_f^p\right)$	3	n*3
	H = (λ Γ(λ) sin(πλ/2)/π)*(1/SZ (1+λ))	3	n*3
			7n
4.			n*
	else//local channel search//		
	ε = RNG (0,1)	1	n*1
	$Z_f^{p+1} = Z_f^p + \epsilon\left(Z_v^p - Z_s^p\right)$	3	n*3
			4n
5.			n*
	for (I = 1; I < S; i++)	S*(1 + n)	Sn + Sn^2
	if ($Z_f^p > Z_f^{p+1}$)	1	n*1
	$b_* = Z_f^p$ //current best//	0	0
			Sn^2 + Sn + n
			n*
6.	**else**		
	($Z_d^p = Z_f^p$), ($Z_f^p = Z_f^{p+1}$) ($Z_f^{p+1} = Z_f^p$), $b_* = Z_f^p$	0 0	0
7.	t++	n	**n**
	Total complexity, O(n):		Sn^2 + Sn + n + n + 4n+ 7n + Sn^2 + Sn + 2n ~2Sn^2 + 2Sn + 15n ~ n^2

The EFPOC algorithm when used in the dynamic channel selection of idle PUs consumes less processing time, thereby enabling the APs to allocate channels to a higher number of OP-BAN in less time [22,23].

7. Simulation Setup

WBANs are smart wireless medical monitoring networks interlaced by wearable and implantable medical devices over the human subject. For the WBAN, device spectrum longevity is a main challenge due to the inadequacy in the availability of dedicated licensed PU channels to the IP-BNC. Thus, we proposed an optimized dynamic channel allocation algorithm. The effective EFPOC channel allocation algorithm deployment strategy to the OP-IMD can influence the network lifetime eminently. Table 3 gives the following simulation setup parameters made in NS2 software [24]. The WBAN transmitter (BNC), receiver (APs), and the energy level are measured for dynamic channel selection. The number of channels in allocation for the idle PUs to the OP-BNC is varied, and their energy levels are obtained. Figure 7 shows the stimulated output of the number of channels scanned and the allocation of idle dynamic channel selection to the increased OP-BNC patients. The ranking method [9] takes nearly 81 ms to scan all the idle channels and allocate them to find the two idle channels to allocate to the patients, where the EFPOC takes 63 ms to scan and allocate the two channels to the required users.

Table 3. Simulated Parameters.

Simulation Parameters	Values
Ls	1024 bits
N	15 to 25
L_h	60 bits
T_0	0.9
r	15 Kbps

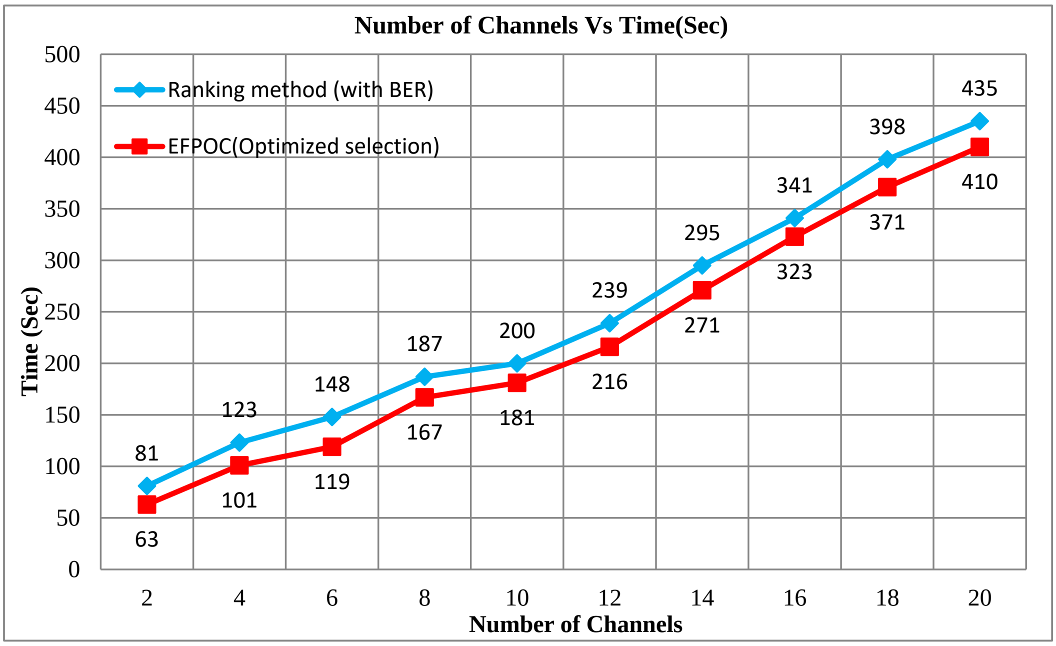

Figure 7. Number of Channels vs. Time (ms).

When the number of channels scanned is increased and the idle channel is linearly increased to twenty numbers, the proposed EFPOC algorithm takes 410 ms, but the existing algorithm takes 435 ms to complete the process of scanning, selecting, and assignment. An overall value of 25% time improvement is achieved by the EFPOC dynamic channel section algorithm The above analysis and calculations are the overall time and the total number of channels evaluated and the simulated results.

The assignment of channels to the increasing OP-BNC is attended by the SUs, and to provide a steady channel, the idle PUs are allocated by the EFPOC algorithm. The results analysis summarizes that when there are two patient nodes, the required time to select an optimized channel from the table takes 63 s. When the nodes are increased to a maximum of 20, the time has increased up to 410 s to select the idle channels for the increased OP-BNC nodes.

Table 4 provides the comparison of the existing algorithm with the proposed EFPOC algorithm for a wide range of nodes from two to sixty. The time for calculating and choosing the best optimum channel is noted. It is observed that there is a linear increase in the time as the node increases. The proposed EFPOC has constantly less channel selection time, representing the improvement in the overall performance of the system and making it an energy-efficient algorithm. One more improvement measure is the rank-based method, which can handle up to 34 nodes in channel selection, whereas the proposed EFPOC algorithm can handle a maximum of 60 nodes, which is a more technical improvement achievement and makes it a more advantageous selection process. The simulation results also indicate the strength of the proposed EFPOC algorithm in Tier-1 device usage for the effective channel allocation strategy by the APs for the CRC within a WBAN environment, thereby indirectly increasing the control signal and reducing the lifetime of the battery. However, the proposed EFPOC algorithm does not require the additional BER calculation and control signal to communicate, thus extending the lifetime of the Tier-1 BNC device. It prolonged the network lifetime of the Tier-1 system by up to 46.47%.

Table 4. Comparison of a simulated value for the number of channels and the time taken to select the channel for the optimized algorithm and an existing algorithm.

No of Increased OP-BNC Node	Ranking Based Method (sec) (with BER)	EFPOC (sec) (Optimized Selection)
2	81	63
6	148	119
10	200	181
16	341	323
20	435	410
26	540	473
30	610	513
34	682	554
40	NA	613
46	NA	673
50	NA	712
56	NA	792
60	NA	855

8. Conclusions

In this work, the existing model, a BER-based LUT, is replaced by the optimized EFPOC algorithm. We detailed the proposed EFPOC algorithm as an optimized channel selection algorithm and also measured its complexity. Simulations have proved that the proposed algorithm has reduced time in dynamic channel selection. In addition, the overhead is also reduced as the BER is calculated only for the selected channels. From this simulation, it has been concluded that the time utilized by the hardware on implementation can be reduced by the proposed EFPOC dynamic spectrum allocation algorithm. It can be seen from the analysis and from the simulation results that idle licensed PU channels can be chosen by the optimized random channel selection algorithm for sending the data to the destination within the best time. The EFPOC proposal is time efficient; we derive the algorithm complexity and arrive to $O(n^2)$. This evidently proves that the proposed algorithm is a faster and time-efficient model. The final simulations of the EFPOC algorithm are calculated and improved the network lifetime of the Tier-1 system by up to 46.47%. The EFPOC algorithm improves the energy optimization and the channel allocation with an overall value of 25% for the channel information and provides the OP-BNC user channel quickly. Still, we work with the computation process of channel allocation and improve the time efficiency with the least computation complexity.

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Abbreviations

EFPOC	Enhanced Flower Pollination based Optimized Channel selection algorithm
CR	Cognitive Radio
PUs	Primary Users
SUs	Secondary Users

MDs	Medical Devices
WBAN	Wireless Body Area Network
PHY	Physical
MAC	Medium Access Control
EMI	Electro Magnetic Interferences
QoS	Quality of Service
IP-BNC	In-Patients-Body Network Controller
OP-BNC	Out-Patient-Body Network Controller
IMDs	Implanted Medical Devices
LUT	Look Up-Table
BER	Bit Error Rate
UWB	Ultra-Wide Band
AP	Access Point
MB-OFDM	Multiband Orthogonal Frequency-Division Multiplexing
IR-UWB	Impulse Radio UWB
FM-UWB	Frequency Modulated UWB
CRC	Cognitive Radio Controller
EIRP	Effective Isotropic Radiated Power
OOK	On-Off Keying
PSD	Power Spectral Density
PS	Physiological Signal
BNC	Body area Network Coordinator
WMTS	Wireless Medical Telemetry Services
MICS	Medical Implanted Communication services
ISA	Intelligent Searching Approach
AoA	Agent oriented Approach

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