Review:
Optimization algorithms in Wireless Body Area Networks

Dalal Abdulmohsin Hammood1,2, Hasliza A Rahim1, Ahmed Alkhayyat3, R. Badlishah Ahmad4
1Bioelectromagnetics Research Group (BioEM), School of Computer and Communication Engineering, Universiti Malaysia Perlis (UniMAP), Kampus Pauh Putra, 02600, Arau, Perlis, Malaysia
2Electrical Engineering Technical College-Department of Computer Technical Engineering/Middle Technical University (MTU), Al Doura 10022, Baghdad, Iraq
3Department of Computer Technical Engineering, College of Technical Engineering, the Islamic University, 54001 Najaf, Iraq
4School of Computer and Communication Engineering, Universiti Malaysia Perlis (UniMAP), Kampus Pauh Putra, 02600, Arau, Perlis, Malaysia

Abstract. Wireless body area network is abbreviated as WBAN. This kind has been originated after the getting of wireless sensor network developing to a certain kind of being matured. That has been likely owing to the huge advance directing to usable wireless comfortable scientific knowledge as well as electronic componental parts that can be tiny. Definitely, such research has obtained important attention nowadays owing to its practical uses which mainly can be in the direction of the sector of health care. Nowadays, a small sensor can be put on the body of humans for recording different mental parameters and this sensor is able to send collected information towards another device in order to get more important behaviours taken. Thus, that is utilized to diagnose illnesses as well as improving dangerous problems alert systems in health field. In this paper, various wireless body area network protocols and algorithms are viewed to optimize QoS in WBAN to improve network lifetime. Such as energy-efficient, duty cycle, power consumption, end to end delay using optimization algorithms.

Keywords: WBAN, optimization, duty cycle, energy efficient, network lifetime, health care monitoring.

1. Introduction

Wireless body area network (WBAN) consists of extremely low power, needs no outside support, smart and not heavy and can be borne by the body sensors, intended to function on, around and in the body of humans [1]. Such a thing is made specifically to be of use medically in these days extended to different aspects such as contingency managing, army, athletics, show business, electronic devices for consumers, and it is still expanding [1][2][3][4][5][6].

With a more contemporary name, WBASN connects with various kinds of gadgets as well as networks for enabling observing process that can be executed from a distance. An important area of application of WBASN can be the observing system for healthcare [7][8][9][10]. Figure 1 shows one of the examples scenario of a system like that [8].

Figure 1: The network of wireless body area sensor, healthcare field
Sensors expansions yielded wireless mobile gadgets to spread in these days, leading the network of wireless sensors centered on humans to be a very interesting subject for researches. Body Sensor Networks (BSNs) have been a number of groups of easy to be programmed motes connecting with a domestic private gadget, and appeared as a radical application of scientific knowledge in a lot of fields related to healthcare, physical health, smart cities, and a lot of other necessary (IoT) practical use [9][10][11][12]. The mentioned wireless body area network (WBAN) is related to that physical conditions that somebody exists in [13][14][15]. Owing to its specifications of practical applying as well as the ability of being mobile [16][17][18], WBAN has got successful applications in a lot of domains, like healthcare, entertaining, as well as the army [11][19][20][21][22][23]. Zimmerman in 1996 raised the principle of a WBAN first, and thenceforth a lot of researches have been printed, concentrating on utilizing the wireless sensor network with the low power type for collecting effective sign [24][25][26][27].

The last two decades has seen unprecedented development in the field of Computational Intelligence with the advent of the GPU and the introduction of several powerful optimization algorithms that make little or no assumption about the nature of the problem. [28]

An optimization algorithm is a procedure which is executed iteratively by comparing various solutions till an optimum or a satisfactory solution is found. With the advent of computers, optimization has become a part of computer-aided design activities. There are two distinct types of optimization algorithms widely used today [28].

We can find many studies released to improve the efficiency of energy, power consumption and the needs of QoS for a WBAN using optimization. This work presents a review paper for optimization methods in WBAN which improve life time networks in terms of duty cycle, and QoS requirements for WBAN, such as: genetic algorithms, Fuzzy, Game theory, cross layer, Smart and Intelligence, and dynamic adaptive.

2. WBAN architecture of communicating

The figure below clarifies the architecture of communicating for the system of WBASNs' observing. As we can see, there are sensors put on the body. Those sensors are able to be a record of brain activity (EEG), a record of a person’s heartbeat (ECG), the recording of the electrical activity of muscle tissue (EMG), or a sensor for measuring blood pressure. The information collected by such a sensor can be forwarded to the close personal server (PS), that is called the base station (BS) or the sink. All information recorded like that in the sink can be then transferred to the external world that might have a physician, a dispensary or any kind of medicinal database for more data processing and diagnosis of illnesses.

Figure 2 WBASN communication architecture
The operations of communicating achieved in an architecture of a WBASN as shown in the figure above can be parted into 3 tiers: (1) Tier 1—communications of intra-BASN, (2) Tier 2—communications of inter-BASN, and (3) Tier 3—communications of beyond-BASN [29]. It ought to be noticed in this field that as someone in the scenario moves, his body might move throughout that period.

Tier-1: Communications of intra-BASN

Here, communication could be wire or wireless. The kind of communicating has been proposed by[3]. In the intra-BAN one, it can only be among the sink and the sensors [30]. The extent of communicating here can be about two meters around and in a body that has got critical importance since a sensor can mainly be put in that extent. That is why the communicating mode can be of a short-range style. ZigBee [31] and Bluetooth [32] can be utilized as a communication technology in this field. The sensor observes the mental situations, and after that sends the notes to the PS/sink, that is situated here too. The sink's job in this case can be processing the collected information and transmitting it to Tier-2 [33][34][29].

Tier-2: Communications of inter-BASN

Here, the communicating missions put among a single or multiple access points (APs) and the sink. Basic physical and organizational structures could be there that spread APs or in any other scenario, the APs can be put in a long term active physical condition, thus they might have the ability to deal with emergencies. This trier's job, the state of being interconnected among various kinds of networks that can be accessed in an easy way; for example, phone calls (or, might be the Net) to a BASN. Any wireless technology such as 3G/4G, ZigBee, Cellular, wireless local area network (WLAN), as well as Bluetooth have the ability to be utilized for the trier above [33][34][29].

Tier-3: Communications of beyond-BASN

Beyond-BASN communication was established for being utilized in a metropolitan area network (MAN). The medicinal sensor can be linked to the Net or any kind of networks utilized for delivering the collected information to the receiver, giving healthcare staff the ability to reach the data related to the medical/health situations. The receiver can be a physician or a medical assistant [29]. The collected information can as well be saved in the patient's structured set of data. That leads this set to be a significant section of Tier-3. In this database, the patient's profile can be saved accompanied with his medicinal background. In the tier, the physician is able to be noted as well by messages that the ill’s situation is deteriorating (as a condition arises like that) and accompanied with the records of the database, urgent acting can be performed prior the patient arrives at the hospital [33][34]. Medicinal atmosphere as well as the database could be the most significant elements of Tier-3 as those have got the medicinal background and user's profile. Hence, physicians or ill people could be noted of an urgent condition by the Net or via a short message service (SMS). Besides, Tier-3 permits saving all important facts of patients that could be utilized to treat [29] Anyway, relying on the application, the sink in Tier-1 could utilize general packet radio service (GPRS)/3G/ 4G on behalf of communication to APs. You notice in Figure 4, as the physical condition beyond the real WBASN can be regarded, the similar facility can be expanded to imagine a physical condition that might link a lot of gadgets for increasing the facilities of electronic health-care and gives the ability to remote health-care for distant sick people. That big seeing can be named Internet of Medical Things (IoMT) [35]. A WBASN is able to represent the IoMT's backbone; anyway, as we regard a WBASN's perimeter (with Tier-2 and main section enclosed to Tier-1), that can be the principal scope for such work, the things that are beyond a WBASN (i.e. anything beyond Tier-2) will be beyond the scope of the process of a WBASN. Thus, skillful ways and mechanisms can be hired for the beyond-WBASN physical condition and suitable techniques might be chosen for different things such as covering, data transmission speed, safeness, particularity, and skillfulness of energy. It is able to be stated that parts such as a sensor, a mobile, an actuator, a watch, tags of radio-frequency identification (RFID), or other gadgets ought to be able to have an effect on and have communication with each other to achieve their mutual targets.
3. Literature Review of Optimization algorithms in WBAN

3.1 Genetic algorithms

This kind of algorithms can be called a search algorithm. It uses metaphors as being a problem of optimization place physical conditions and a workable solving can be regarded as an individual living in those physical conditions [36][37]. This kind of algorithms can be built on the theory of evolution by Darwin. 49 years ago, Holland first suggested this kind of algorithms to solve the problem [38]. In this algorithm, an individual can be considered as binary digits or of another group of symbols taken out of a finite group. Since the memory in a PC can be made of a bits’ array, we can store anything in a PC and encode by a string of bits of enough length. Every encoded individual in a population is able to be shown as a representing, with reference to a suitable encoding for a certain solving to the issue. For those algorithms for finding an ultimate possible solving, it would be important to achieve specific processes over those individuals [39]. Figure 3 shows the algorithm of genetic algorithm [36][37]

![Figure 3 Cycle of genetic algorithm](image)

The algorithm starts with unitization for population size according on problem. Fitness value is evaluated to represent the best solution. There three operators to update fitness value. They are selection, mutation, and mating. The algorithms is stopped after evaluation of fitness value [36][37].

In [40] two protocols are proposed: Extended-OCER (E-OCER) and Optimized Cost Effective and Energy Efficient Routing protocol (OCER). In OCER, we can apply the optimization utilizing Genetic Algorithm (GA) to the cost function of the multi-objective type with remaining energy, connection accuracy and loss of path as parameters to select the best possible route from a coordinator of a given body to the sink. Space among any 2 motes can be decreased via the application of the approach of the multi-hop type. E-OCER expands OCER's work via regarding the communication of inter-BAN. OCER performing can be matched with other routing protocols of the existing energy aware via regarding various parameters. A matching of E-OCER performing with OCER can be established for studying the affecting of the communications of the on-body sensors on the consuming of energy and the amount of work of the network that is done. Also, the paper supplies a total model of energy for calculating the overall network energy consuming. Besides the radio transmitting and receiving energy, other main energy consuming resources namely, transit and processing energy, sensing of sensors and transmitting/receiving off/on energy were considered too. In [41] mote classifying algorithms are suggested that associates the classifier ANFIS based motes, the trusted and untrusted ones detecting and classifying system can be suggested to develop the skillfulness of the a WBAN network. That suggested system goes on with feature extracting and the modules of classifying. The trust feature can be taken from a mote and this taken feature can be optimized utilizing an algorithm of the genetic type. The WBAN network performing can be taken to pieces in terms of the classifying rate, the ratio of packet delivery as well as latency.
3.2 Fuzzy algorithm

Fuzzy logic algorithm helps to solve a problem after considering all available data. Then it takes the best possible decision for the given the input. The FL method imitates the way of decision making in a human which consider all the possibilities between digital values T and F. As shown in figure 4, the input is represented as crisp input with fuzzifier it and intelligence which represents the rules of algorithm, thereby crisp output that represent the bet solution[54].

![Figure 4 fuzzy algorithm](image)

In fuzzification's step number one, the crisp inputs can be turned into their values of corresponding linguistic type, that can be exemplified during the utilizing of fuzzy groups [42]. Every fuzzy group can relate to a function of membership which depicts the path where all crisp inputs are related with the fuzzy group separately [43][44]. The model of fuzzy utilized 3 linguistic idioms (high, medium, low) for partitioning the variable of inputs. For defining every idiom separately, various functions of membership like Gaussian, S, and Z functions can be utilized [43].

The proposed work in [43] treats an assigning scheme of dynamic time slot in network of fog-assisted type for a monitoring system of actual ill people instantly. The computing of Fog can be an expanded copy of the model of cloud computing, that can be appropriate for a trusted, sensitive in delaying and serious situations' application. besides, for improving the network performing, an algorithm of energy-efficient parent selection of the least cost was suggested to the packets of routing data. The slot allocation of dynamic time utilizes fuzzy logic with variables as inputs just as ratio and buffer of energy, and the rate of packet arrival. Dynamic slot allocating removes the waste of time slot, the network excess delaying and imposes a reliability of high level for the network with the highest number channel utilizing. The effectiveness of the suggested scheme can be demonstrated in terms of the ratio of packet delivery, average delaying of end to end, and average consuming of energy as matched with the traditional IEEE 802.15.4 standard and the protocol of the tele-medicine quality. In [45] two algorithms are used to improve energy Consumption and Throughput in WBAN. Genetic Algorithm is utilized for improving the performance of the parameters. The extraneous data is being removed by using Fuzzy logic classifier.
3.3 Cross layer optimization

Cross-layer optimization removes such strict boundaries to allow communication between layers by permitting one layer to access the data of another layer to exchange information and enable interaction. Figure 5 shows the algorithm of cross layer optimization [46].

![Cross-layer optimization diagram](image)

The scheme of CLDO supplies an overall method for configuring WBANs for optimizing the reliability of transmitting, efficiency of energy, and lifetime, it surely fetches a little overhead, that could be briefed: first, CLDO possesses complicated proceedings throughout the initializing of the network, that can be expensive in both time and consuming. Then, the iterations' value in the algorithm of CLDO affects its performing to an important degree, but sometimes the rationality of its setting could not be guaranteed [47].

A scheme of Cross Layer Design Optimal (CLDO) can be suggested in [47] for optimizing the reliability of transmitting at the same time, the efficiency of energy, and lifetime of a WBAN from many layers. First, as it is known that the transmitting power of motes affects the links' reliability in a direct way, the optimized transmitting power of various motes can be concluded, that can raise the skillfulness of energy to the top theoretically under the supposition that needs on delaying and jitter can be executed. Second, an algorithm of relay decision can be suggested for choosing motes of optimized relay. Utilizing that algorithm, motes are going to select relay motes that guarantee some balancing of consuming of network energy, on condition that all motes transfer with optimized transmitting power and the same size of packet. Third, the energy consuming of motes can still be without a balance even with optimized transmitting power owing to their various places in the network's topology. Besides, the size of the packet possesses an effect on final performing metrics too. For that, a method of synthesized cross layer to optimize can be suggested. By using the method above, the transmitting power of motes with more remaining energy is going to be improved as the size of appropriate packet can be estimated for various connections in a network, resulting more developments in the system of WBAN.

In [48] A performing of two cross-layer routing techniques of optimized dynamic type can be researched to mitigate a radio interference crossing a number of existing together wireless body area networks (BANs), built on authentic measuring. At the layer of the network, the most suitable route can be chosen in relation with the information of channel state from the materialistic layer, related to low duty cycle TDMA at the layer of MAC. The techniques of routing (i.e., shortest path routing (SPR), and novel cooperative multipath routing (CMR) creating 3-branch selecting combining) achieve authentic and trustable collected information transmit crossing BANs processing close to the band of 2.4 GHz ISM. An open-access experimental group of data of daily activities can be utilized to analyze the suggested cross-layer optimizing. A cross-layer optimizing can be studies in [49] for the information of the route crossing divided networks of wireless body-to-body, built on authentic experiential measuring. At the layer of the network, the most suitable route can be chosen relating to the information of channel
state (for example, the count of anticipated transmitting, the count of hop) from the materialistic layer. There are 2 kinds of dynamic routing can be applied: cooperative multi-path routing (CMR) and shortest path routing (SPR) related to the combining of the selecting. An open-access experiential group of data creating daily activities can be utilized to analyze and compare the cross-layer optimizing with various protocols of wireless sensor network (i.e., ORPL, LOADng). Insignificant error rate of packet can be accomplished when we apply the techniques of CMR and SPR with a rationally sensitive receiver[49].

Designing and implementing a smart portal for Wireless Body Area Network (WBAN) can be suggested in [50] that searches for exploiting access of authorized Primary User (PU) channels utilizing Cognitive Radio (CR) for facilitating spectral-skilful, cost-skilful and trustable Non-Real Time (NRT) backhaul transmitting of the data of WBAN for observing widespread health-care. Moreover, the stack of protocols eases the managing of sessions and the transmitting of energy-skilful backhaul CR over PU channels that employ a suggested algorithm of Inter-Sensing Time Optimization (ISTO). The analytical expressions of closed form can also be established for estimating the medium used energy, switching likelihood and time, and the cost-skilfulness of BodyCog-BNC. Complete performing analysis makes it clear that the BodyCog-BNC (WBAN portal), supplies a cost-efficient solving for various health-care applications under some proceeding conditions and CR cost systems [50].

3.4 Smart and Intelligence

Smart can be applied to learned inferences, such as making smart business or emotional decisions. Smart is an earned status. When we study and learn, we become smarter in the subject matter. Book smart or street smart, we have to put effort into becoming smarter. Intelligence is something with which you are born. Your IQ is a measurement of your intelligence, and doesn’t change because it is a measure of your ability to learn. This can apply to terms we chronically associate with intelligence, like math, or it can apply to your ability to learn negotiation of emotional issues. In either case, it is inherent, and it simply stems from your genetic makeup. Smart and intelligence are considered in health care system to improve QoS in WBAN [51].

A health observing system permits individuals to nearly observe alters in his effective signs and supplies a feedback for helping to maintain a perfect health condition that can be built on the collected information. If merged into a telemedical order, those orders are able to alert medicinal people as dangerous alters happen in or out a human body. Besides, ill people are able to make use of permanent observing as a section of a diagnosis, able to accomplish the best maintaining of a constant condition, or able to be monitored throughout curing from a sharp case or an operation owing to a permanent hearing. A monitoring system of permanent health is able to apprehend the diurnal and circadian alternations in mental signs [52].

In [52] Health-care Monitoring System, that is anticipated to decrease health-care costs by giving ability to the permanent observing of sick people’s health from distance during their routine in a health-care atmosphere. The applications of health-care built on a Wireless Sensor Network gain a big fame worldwide owing to their qualities such as being flexible, mobile and easy of permeant observing of the sick person in the body and out of it felt as more beneficial. The major concentration of systems like that can be distant observing of a sick person, in and out the room in a hospital and in ICU in the sense of a feature able to be implanted to analyze the sick person’s collected information. Modern improvements in an integrating sensor, systems of communicating, and other fields like computing of cloud and Big Data analyzing supplied the best instruments for developing modern systems to improve energy skillfulness and consuming with the groups of data. Home automation, intelligent sensors, and IoT can be some instances of those technologies that are application based which are going to result more affordable and flexible systems of energy. A common scheduling and problem of admission control that aims to optimize the energy skillfulness of intra- and beyond-WBAN connection can be searched in [63]. Simulating incomes exposes the suggested algorithm is able of, matching with avid scheme, accomplishing about one hundred percent produced amount development in different power consuming expenditures. Furthermore, the suggested algorithm is able to accomplish up to 5.59 power consuming saving for mote matching with another scheduling algorithm.
### 3.5 Dynamic adaptive

A WBAN could be organized as the scale of a human body. It comprises intelligent gadgets that can be of low power, a small replica, hardware restricted, accompanied with or implanted in the human body [53]. Normally, WBAN motes have got finite capacity of energy, restrictions on the small size, processing potentials of a low signal and a capacity of a low saving [54]. Anyway, energy skilfulness is still a significant problem in a WBAN. Figure 5 clears the adaptive algorithm and computes the wake-up interval \( (Iwu) \) based on the contents of the TSR for a specific node [53]. The wake-up interval is updated for the time instant \( (t_{iC1}) \) based on the previous time instant \( (ti) \), and update factors as,

\[
I_{wu}(t_{i+1}) = I_{wu}(t_i) + [\mu(t_i) + e(t_i)] \cdot t_{ref}.
\]  

Figure 6 Adaptive wake-up interval system [53]

Where, \( \mu \) is the output of the weighting average algorithm and \( e \) is the correlation error [53].

In [55] a self-improving approach submitted to self-sufficient and configures the schedule of waking up of the motes in a wireless body area network (WBAN) differently. We can submit a traffic-aware latency-energy-optimized dynamic medium access control protocol. This protocol can be built on an algorithm given to adaptation which permits the motes to adjust their sleep and waking up patterns skillfully in the alternations of dynamic and static traffic. A form of an open-loop feature can be improved by preserving the interval of waking up preceded by the adaptive system of the closed-loop quality that makes. A network average delay, throughput, PDR, associated nodes, packets drop and PAN initialization time are analyzed in [56] by using different combinations of BO and SO values during nodes movement in order to check their impact on the above mentioned two network parameters using brief simulations. Simulation results helps in adjusting the accurate duty cycle to work with better network performance. In [57] the hypothetical energy consuming approach for the coordinator mote of the standard of IEEE 802.15.6 can be tackled, and consequently, a fresh algorithm can be improved for energy consuming. In the conventional approach, the coordinator mote can be fixed for a WBAN’s architecture. With the suggested algorithm the coordinator mote can be chosen in a dynamic way. That algorithm named dynamic HUB (or coordinator) selecting (DHS) can be acted with Riverbed Modeler simulating program with a sample scenario and the performing outcomes could be tested. As a result, the coordinator motes energy consuming level can be decreased and the lifetime of the network of the architecture can be expanded effectively.

### 3.6 Optimization Methods

Optimization Algorithms are the algorithms that are allocating the most perfect solution from an applicable solving. Optimizing issues are able to be parted into 2 categories relying on if the variables permanent or individually separated. An optimizing issue with the individually
separate variables can be known as a discrete optimization. In discrete optimization problems, we look for a thing like an whole number, variation or graph from a group can be counted. Issued with permanent variables have got restricted issues multimodal and problems[58].

In [59] this study illustrates two problems, that is to say spectrum interferences and sharing. Methods for channel and power allocating can be proposed. The former instructs on a strengthening learning technique, where the second one can be built on convex optimizing. Moreover, it has also been suggested a model of arithmetical channel for the communicating links of off-body quality in line with the standard of IEEE 802.15.6. The optimizing approach of the colony of ants to the issue of travelling sales assistant has been applied to WBANs in [60] to specify the shortest path to send an urgent message to the physician by motes; and also a game formulation of static Bayesian with a jumbled strategy has been analyzed for enhancing the lifetime of the network. At whatever time the ill person requires any stringent care or another kind of medicinal problem happens, an urgent message is going to be made by a WBAN and forwarded to the physician’s last resort. In [61] an agent built QoS-aware Routing framework called Multi-agent Markov Probable (MMPQoS) for WBAN is designed. A multiagent framework is proposed with the aim of ensuring desired critical QoS demands along with routing framework. The coordinator agent in MMPQoS framework coordinates the data packets and manages them through traffic monitoring agent. The traffic monitoring agent measures the transition probability and queue length for different state space using Markov Probable QoS-aware queuing model, ensuring end-to-end delay and reliability for critical data packets transmission. The routing agent then constructs the QoS-aware Route table constructor using MAXMIN policy, i.e., obtaining maximum trustworthiness for link with minimum queue length. A number of estimations on feasible channel models for a perfect WBAN can be utilized in [62] regarding different scenarios with various carrier frequencies, bandwidths, movements of the body, and the locations of transceivers, the famous Bayesian Information Criterion can be utilized to test an existed channel group of data versus eleven various models of statistics. Taking the models of channels as the instruments of the commerce, we chose a rate of symbol error as the wanted metric for finding the optimum mote location between the already known choices that outputs in the most trustable performing. Except for the individual motes positioning, the principle of reliability is used in more common problems, producing handy applications beyond a single mote level. In this field, we can introduce the lifetime of the network as the performing indicator that is assessed for any interest scenario. Furthermore, the lifetime of the network might be dealt with as the expense function of an optimizing issue.

Wireless network communications within the overall WBAN body sensor system is improved in [63] to optimize of transmitter power to conserve energy, performance improvements for WBAN devices under interference, and WBAN security. A most favorable policy of control built on time-ratio and transmitting power allocating in a wireless body area network (WBAN) can be suggested in [64], whereas the cycle of duty can be taken on. To maximize the produced amount of information, the entire cycle of duty can be parted into 2 states: sleep and active states. Through the sleep one, for transmitting information from a sensor, the energy gathered in the sensor has to be greater than a specific threshold. And in the active one, the operation of the transmission of information via the sensor is going to result interfering to energy gathering. For getting to a very rational and convicting optimizing target, it is optimized that the duty-cycle time-ratio of active and sleep states and transmitting power in active state in the same time in a system.

3.7 Game theory
Game theory is one of the branches in applied mathematics and can be used in a wide variety of fields. Game theory is primarily used to predict how rational players will behave in a game and moreover analyze their actual behaviors. Game theory also models all possible situations that players, according to their choices, will receive corresponding payoff, which can reflect whether a strategy is good or not. Well-behaved players are rewarded while misbehaved ones are punished. There are many kinds of games and we list several common examples below [65][66][67]:

- Cooperative and Non-Cooperative Games:
Players in cooperative games can cooperate with each other on a joint strategy. On the contrary, players in non-cooperative games do not cooperate with each other. But, cooperative games are not absolutely advantageous under certain specific conditions. Figure 7 shows a cooperative game, in which Player A and B can communicate and work together in order to defeat Node C.

![Figure 7 Proposed cooperative game model](image)

- Zero-sum and Non-zero-sum Game:
In a zero-sum game, one player's gains are the other plays’ losses. In other words, the gain of Player A can be balanced by the loss of Player B. In a non-zero-sum game, on the contrary, the gain of Player A cannot be balanced by the loss of Player B. Game theory is often used to avoid conflicts and make decisions. By making assessment of all possible situations, game theory helps the system to reach the optimization [65][66][67].

The theory of game can be the search of deciding of rival agents in some disagreements. It comprises a group of analytical instruments that anticipate the result of complicated reciprocal actions between reasonable entities, whereas reason requires a rigid involvement to a strategy built on understood or scaled outcomes [68][69]. In the theory of classical games, players can be presumed to be wholly reasonable, and the instructions of the game, functions of payoff and the players' reasonableness can be used as common sense. Anyway, in the last years, toward this justifying, a lot of concept-related and experimental critiques had been there. Experimental evidence show that the players cannot be perfectly reasonable in a lot of conditions. Those incomes ask for relaxation of the strong presumptions of the theory of classical games about complete reasonableness of players [70].

In [71] an unfamiliar synthetic noise generation strategy built on the theory of games can be suggested to develop the security versus the attacks against privacy in a CWSN. The generation of synthetic noise comprises introducing interfering in the spectrum to cover the actual information. The deciding whether to introduce or not a synthetic noise can be modeled throughout a light uncooperative game made for a network of low sources that stable enhancing of security and energy consuming. In [72] a light-weight and adjusting irregular detecting approach of two levels can be introduced for discarding false alarms resulted by broken mensuration and raise them solely as a sick person appears to be in danger. In the level number one, a game-theoretic mechanism can be introduced where body-worn sensor motes use the space-time attachment between readings to domestically and in an adjusted way discover irregular conditions related to the dynamic context alters of a WBAN. In the second one, it is feasible to apply the distance of Mahalanobis in the Local Processing Unit (LPU) that has got an international view for analyzing involving two or more variable quantities. Our major goal has been to guarantee a trade-off among detecting accuracy, incorrect positive rates, and the performing of a network as regarding the WBAN physical conditions restricts. The suggested approach can be estimated throughout numeral emulations on a real mental group of data.
A flexible game theoretic framework is formulated in [73] to study WBAN coexistence. A detailed mathematical analysis for a 2-player game is provided. As the WBANs' number raises in a game, the complicatedness in utility calculating and emulations raises very much. We suggest an estimating method to model games that involves three players and above.

**A- non zero game theory**
In [74] proposed an unfamiliar optimized routing protocol (named Game Theoretic Approach for Context Based Routing (GT-ACR)) for OppNets which utilizes the theory of games to select the optimum next-hop for forwarding the packets of data skillfully. In the mentioned protocol, the optimum strategy for selecting the following hop mote can rely on a cooperative game of 2 participants of positive or negative summation does not equal to 0, regarding the information of context, index of encounters, and corresponding mote distance from the last resort as effective features in game framing.

**B- Nash equilibrium game theory**
A stochastic game is proposed in [75] for balancing the tradeoff among network performing and the level of safety as considering the dynamics of the context. The lifetime of the network, the level of security, the throughput of the network and criticality and prioritizing of collected information are improved in this proposed.

**C- Bayesian game theory**
The optimizing approach of the colony of ants to the travelling sales assistants' issue has been applied to a WBAN in [60] to specify the smallest path to send urgent messages to a physician by motes; and a static Bayesian game formulating too with jumbled strategy has been analyzed for enhancing the lifetime of the network. At whatever time the ill person requires any stringent care or another medicinal problem happens, an urgent message is going to be established by a WBAN and forwarded to the physician's position.

The advantages of the previous works are to enhance network life time in WBAN in term of duty cycle, BER, PDR, PER, SNR, Energy efficiency, throughput, power control and E2E delay. But there are still some disadvantages. Such as: A Cooperative communication and duty cycle are not considered in [41] [52] [55] [59] [71] [72] which avoid retransition data between sensors. While in [56] IEEE 802.15.6 is not considered which it is suitable in WBAN. Non cooperative and game theory are not considered in [40] [43] [45] [53] [57] [61] [63] [64] which it is a new optimization algorithms in WBAN. In [68] [74]. The algorithms are relate of WSN not in WBAN. Non- cooperative game theory in term of duty cycle is not considered in [47] [60]. Multiple WBAN’s in [48] not only WBAN. In [49] non cooperative game theory to optimize duty cycle and power consumption are not considered. A comparison of the latest work is also presented in Table 1.
Table 1 Comparison state of art works for optimization

| Author | Proposed | Objective | Metrics | Protocol | Optimization |
|--------|----------|-----------|---------|----------|--------------|
| 2019[71] | CALAA& key agreement scheme | • To provide selective anonymous authentication between nodes in WBAN | • security | Security | A context-aware and lightweight anonymous authentication |
| 2019[72] | Two-level LAADA | • To ensure a tradeoff between detection accuracy, false positive rates, and network performance while considering the WBAN environment constraints | • Accuracy • False positive rates • Energy consumption • Network performance | - | two-level lightweight and adaptive anomaly detection approach. |
| 2016[55] | Optimized TAD-MAC | • To adapt their wake-up and sleep patterns efficiently in static and dynamic traffic variations | • Energy consumption • packet delay • PDR • convergence speed | adaptive algorithm | dynamic traffic variations |
| 2019[56] | LR-WPAN | • To enhance network performance | • Network average delay • Throughput • PDR • Packets drop | Routing | dynamic BO & SO |
| 2019[59] | Optimized QoS using MCM for off-body comm. | • To enhance throughput | • Throughput | IEEE 802.15.6 | reinforcement learning |
| 2017[52] | Smart sensor inside & outside the hospital room and in ICU | • To optimize energy consumption based WBAN | • Security • Energy Consumption | - | Smart Sensors |
| 2017[61] | MMPQoS | • To optimize end-to-end delay | • end-to-end delay | Routing | MMPQoS |
| 2017[40] | OCER & (E-OCER) Using GA | • To select the most optimal route from a given body coordinator to the sink. | • Residual energy • link reliability • path loss | Routing | Genetic Algorithm |
| 2017[63] | APC | • To optimize transmitter power to conserve energy • To improve interference & security. | • transmitter power | IEEE 802.15.6 | APC |
| 2018[41] | GA (SNC) | • To improve the efficiency of the WBAN networks | • classification rate, packet delivery ratio and latency | - | genetic algorithm |
| 2018[57] | DHS | • To develop energy consumption | • power consumption | IEEE 802.15.6 | DHS |
| 2019[64] | Optimized CPBTR&TPA | • To optimize the duty-cycle time-ratio • To improve throughput | • duty cycle, energy harvesting, optimal control • transmission | Optimal control policy |
| 2019[53] | CMDP | • To optimize energy efficiency | • power consumption • throughput | Intelligent adaptive learning algorithm |
| 2019[43] | DTSA | • To optimize energy efficiency | • Energy ratio, buffer ratio, and packet arrival rate | MAC | fuzzy |
| 2017[45] | NA with length and width of size 1000×1000 and 50 No. of sensor nodes | • To improve QoS | • Energy Consumption • Throughput • E2E delay • BER | Routing | GA & Fuzzy |
| Author | Proposed | Objective | Metrics | Protocol | Optimization |
|--------|----------|-----------|---------|----------|--------------|
| 2016[68] | An APC scheme for IoT systems. | To effectively solve the power control problem in IoT systems. | Power Control | Network | IoT Game theory |
| 2017[74] | (GT-ACR) based on NZSC game is presented | To select the best possible next-hop to forward data packets efficiently | Average latency, No. of messages dropped, Overheard Ratio | Routing | NZSC game theory |
| 2017[76] | CR spectrum sensing& sharing scheme for IoT systems. | To ensure cooperative spectrum sensing and sharing. | Reciprocal fairness | - | IoT |
| 2017[60] | The ACO to TSP A static Bayesian game formulation with mixed strategy was analyzed | To determine the shortest route for sending emergency message to the doctor via sensor nodes. | Message latency, Network lifetime | - | ACO and Bayesian game formulation |
| 2017[47] | Cross Layer Design Optimal (CLDO) | To maximize energy efficiency, To choose optimized relay nodes | Low delay, Energy efficiency, Lifetime | Transport | cross layer optimal |
| 2017[49] | Two cross-layer optimized dynamic routing techniques TDMA & CMR | To mitigate interference | SPR, SINR, duty cycle | CMR | cross layer optimized |
| 2017[50] | SPR & CMR | To reduce delay | PER | CMR | cross layer optimization |
| 2017[62] | BIC | To find the best node location among the predefined options that results in the most reliable performance | Symbol error rate | - | Bayesian optimum values |
| 2018[75] | SG to balance the tradeoff between network performance and security | Security, throughput | throughput, interference | authentica tion | Nash-Equilibrium Adaptive security game theory |
| 2019[50] | An intelligent gateway for WBAN to access of licensed PU channels using CR | To facilitate spectral-efficient, cost-efficient and reliable Non-Real Time (NRT) | Cost-efficiency, Energy-efficiency | Stack | Cross-layer design Convex optimization |
| 2016[73] | A flexible game theoretic framework is formulated | To provide a detailed mathematical analysis for a 2-player game | Utility Function | - | game theory |
4. Conclusion

The study illustrates the optimization algorithms revision in WBAN to improve several key issues such as energy efficient, power consumption, throughput, reliability, and duty cycle. These algorithms of optimization are offered a wide range of benefits to patients, healthcare monitoring, staff in hospital to detect abnormal condition early. Recently paper used Cross-layer design optimization and game theory. The future work is to optimize QoS using game theory in modelling mathematic with cooperative communication.

Significance of Work

The presented work will provide the following advantages:

- The accomplishment is about to perform the WBAN communication, so that the work will provide the recent papers that relate with improving of energy and power consumption to increase network lifetime using optimization algorithm such as: genetic algorithms, fuzzy, optimization methods, cross layer optimization, and game theory.

References

[1] A. Alkhayyat, O. Gazi, and S. B. Sadkhan. "The role of delay and connectivity in throughput reduction of cooperative decentralized wireless networks." Mathematical Problems in Engineering 2015 (2015).
[2] A. Alkhayyat. Joint next-hop/relay selection for distributive multihop cooperative networks. Discrete Dynamics in Nature and Society. 2015.
[3] A. alkhayyat and S. B. Sadkhan. "Bandwidth efficiency analysis of cooperative communication with Reactive Relay Selection. In preceding of IEEE international Iraqi conference of engineering technology and its application (IICETA-2018), Najef, Iraq,8-9 may 2018.
[4] Al-Mishmish, H., et al. Critical Data-Based Incremental Cooperative Communication for Wireless Body Area Network,” Sensors 2018, 18, 3661.
[5] D. A. Hammood, et al., “Reliable emergency data transmission using transmission mode selection in wireless body area network,” Cogent Engineering. 2018 Jan 1;5(1):1562859.
[6] Hammood DA, et al., “Enhancement of the Duty Cycle Cooperative Medium Access Control for Wireless Body Area Networks,” IEEE Access. 2019;7:3348-59.
[7] A. Alkhayyat, and N. A. Habeeb. "A Cooperative MAC Aware Network Coding toward Improving Throughput Wireless Body Area Network." In 2019 2nd Scientific Conference of Computer Sciences (SCCS), pp. 182-187. IEEE, 2019.
[8] A. Alkhayyat, M. Shuker Mahmoud. " Novel cooperative mac aware network coding under log-normal shadowing channel model in wireless body area network. " International Journal on Communications Antenna and Propagation, Volume 9, Issue 3, June 2019, Pages 198-206
[9] D. A. Hammood, et al., “An energy-efficient optimization based scheme for low power devices in wireless body area networks,” Journal of Computational and Theoretical Nanoscience, Volume 16, Issue 7, 2019, Pages 2934-2940
[10] A. Alkhayyat, A. A. Thabit, F. Al-Mayali, Q. h. Abbasi, “WBSN in IoT Health-Based Application: Toward Delay and Energy Consumption Minimization,” Journal of Sensors. 2019.
[11] A. A. Thabit, et al., “Energy harvesting Internet of Things health-based paradigm: Towards outage probability reduction through inter–wireless body area network cooperation,” International Journal of Distributed Sensor Networks 2019, Vol. 15(10)
[12] D. A. Hammood, et al., “Body-to-Body cooperation in Internet of Medical Things: Toward Energy Efficiency Improvement,” future internet 2019.

[13] X. Liu, A. Liu, Q. Deng, and H. Liu, “Large-Scale Programming Code Dissemination for Software-Defined Wireless Networks,” Comput. J., vol. 60, no. 10, pp. 1417–1442, 2017.

[14] Y. Xu, A. Liu, and C. Huang, “Delay-Aware Program Codes Dissemination Scheme in Internet of Everything,” Mob. Inf. Syst., vol. 2016, 2016.

[15] H. Moosavi and F. M. Bui, “Optimal relay selection and power control with quality-of-service provisioning in wireless body area networks,” IEEE Trans. Wirel. Commun., vol. 15, no. 8, pp. 5497–5510, 2016.

[16] T. Li, M. Zhao, A. Liu, and C. Huang, “On Selecting Vehicles as Recommenders for Vehicular Social Networks,” IEEE Access, vol. 5, no. c, pp. 5539–5555, 2017.

[17] Z. Tang, A. Liu, and C. Huang, “Social-aware data collection scheme through opportunistic communication in vehicular mobile networks,” IEEE Access, vol. 4, pp. 6480–6502, 2016.

[18] Y. Liu, M. Dong, K. Ota, and A. Liu, “ActiveTrust: Secure and Trustable Routing in Wireless Sensor Networks,” IEEE Trans. Inf. Forensics Secur., vol. 11, no. 9, pp. 2013–2027, 2016.

[19] F. Meshkati, H. V. Poor, S. C. Schwartz, and R. V. Balan, “Energy-efficient resource allocation in wireless networks with quality-of-service constraints,” IEEE Trans. Commun., vol. 57, no. 11, pp. 3406–3414, 2009.

[20] D. Goodman and N. Mandayam, “Power control for wireless data,” IEEE Pers. Commun., vol. 7, no. 2, pp. 48–54, 2000.

[21] M. Dong, K. Ota, L. T. Yang, A. Liu, and M. Guo, “LSCD: A Low-Storage Clone Detection Protocol for Cyber-Physical Systems,” IEEE Trans. Comput. Des. Integr. Circuits Syst., vol. 35, no. 5, pp. 712–723, 2016.

[22] R. Xie, A. Liu, and J. Gao, “A Residual Energy Aware Schedule Scheme for WSNs Employing Adjustable Awake/Sleep Duty Cycle,” Wirel. Pers. Commun., vol. 90, no. 4, pp. 1859–1887, 2016.

[23] Y. Hui, Z. Su, and S. Guo, “Utility Based Data Computing Scheme to Provide Sensing Service in Internet of Things,” IEEE Trans. Emerg. Top. Comput., vol. 7, no. 2, pp. 337–348, 2019.

[24] Y. Hu, M. Dong, K. Ota, A. Liu, and M. Guo, “Mobile Target Detection in Wireless Sensor Networks with Adjustable Sensing Frequency,” IEEE Syst. J., vol. 10, no. 3, pp. 1160–1171, 2016.

[25] and M. S. Proakis, John G., Digital Communications, 5th ed. New York: New York: McGraw-hill, 2001.

[26] X. Liu, M. Dong, K. Ota, P. Hung, and A. Liu, “Service Pricing Decision in Cyber-Physical Systems: Insights from Game Theory,” IEEE Trans. Serv. Comput., vol. 9, no. 2, pp. 186–198, 2016.

[27] S. Van Roy et al., “Dynamic channel modeling for multi-sensor body area networks,” IEEE Trans. Antennas Propag., vol. 61, no. 4, pp. 2200–2208, 2013.

[28] Sengupta, S., Basak, S., & Peters, R. A. (2019). Particle Swarm Optimization: A survey of historical and recent developments with hybridization perspectives. Machine Learning and Knowledge Extraction, 1(1), 157-191.

[29] R. Negra, I. Jemili, and A. Belghith, “Wireless Body Area Networks: Applications and Technologies,” Procedia Comput. Sci., vol. 83, pp. 1274–1281, 2016.

[30] W. A. N. Wan Abdullah, N. Yaakob, M. E. Eloabid, M. N. Mohd Warip, and S. A. Yah,
“Energy-efficient remote healthcare monitoring using IoT: A review of trends and challenges,” ACM Int. Conf. Proceeding Ser., vol. 22-23-Marc, 2016.

[31] ZigBee, “ZigBee alliance,” 2017. [Online]. Available: http://www.zigbee.org/(accessed%0A6 July 2017).

[32] Bluetooth., “Bluetooth technology website,” 2017.

[33] H. C. · V. C. M. L. Vasilakos, Min Chen · Sergio Gonzalez · Athanasios, “Body Area Networks: A Survey,” springer, vol. 16, no. April, pp. 171–193, 2011.

[34] S. Movassaghi, M. Abolhasan, J. Lipman, D. Smith, and A. Jamalipour, “Wireless Body Area Networks: A Survey,” IEEE Commun. Surv. Tutorials, vol. 16, no. 3, pp. 1658–1686, 2014.

[35] G. Tzanis, “Healthcare Data Analysis in the Internet of Things Era,” Encycl. Inf. Sci. Technol. Fourth Ed., no. January 2018, pp. 1984–1994, 2017.

[36] D. A. Hammood, “Using Genetic Algorithms To Break a Simple Transposition Cipher,” no. 1, pp. 1–9, 2013.

[37] S. Omran, … A. A.-K.-… S. C. of, and undefined 2014, “Using genetic algorithms to cryptanalyse A mono alphabetic cipher by using different mutation rates and lengths of text,” Researchgate.Net, no. August, 2015.

[38] J. Holland, Adaptation in natural and artificial systems. 1975.

[39] P. Erdogmus, A. Ozturk, and S. Tosun, “Continuous optimization problem solution with simulated annealing and genetic algorithms,” J. Eng. Res. Appl. Sci., vol. 2, no. 1, pp. 116–121, 2013.

[40] N. Kaur and S. Singh, “Optimized cost effective and energy efficient routing protocol for wireless body area networks,” Ad Hoc Networks, vol. 61, pp. 65–84, 2017.

[41] K. Kalaiselvi, G. R. Suresh, and V. Ravi, “Genetic algorithm based sensor node classifications in wireless body area networks (WBAN),” Cluster Comput., pp. 1–7, 2018.

[42] I. Gupta, D. Riordan, and S. Sampalli, “Cluster-head election using fuzzy logic for wireless sensor networks,” Proc. 3rd Annu. Commun. Networks Serv. Res. Conf., vol. 2005, pp. 255–260, 2005.

[43] S. Pushpan and B. Velusamy, “Fuzzy-based dynamic time slot allocation for wireless body area networks,” Sensors (Switzerland), vol. 19, no. 9, 2019.

[44] O. Yazdanbakhsh and S. Dick, “A systematic review of complex fuzzy sets and logic,” Fuzzy Sets Syst., vol. 338, pp. 1–22, 2018.

[45] K. Thakur and And Er.Parvinder, “WIRELESS BODY AREA NETWORK ( WBAN ) FOR HEALTH MONITORING SYSTEM USING GENETIC ALGORITHM AND FUZZY LOGIC,” vol. 8, no. 8, pp. 92–97, 2017.

[46] Krishnaswamy, D., & Turaga, D. Adaptive Cross-Layer Strategies for Fourth Generation Wireless Communications.

[47] X. Chen, Y. Xu, and A. Liu, “Cross layer design for optimizing transmission reliability, energy efficiency, and lifetime in body sensor networks,” Sensors (Switzerland), vol. 17, no. 4, pp. 11–15, 2017.

[48] S. Shimly, D. B. Smith, and S. Movassaghi, “Cross-layer optimized routing with low duty cycle TDMA across multiple wireless body area networks,” IEEE Int. Conf. Commun., pp. 1–6, 2017.

[49] S. M. Shimly, D. B. Smith, and S. Movassaghi, “Experimental Analysis of Cross-layer Optimization for Distributed Wireless Body-to-Body Networks,” IEEE Sens. J., pp. 1–1, 2019.

[50] T. Manna and I. S. Misra, “Design, implementation and analysis of cognitive radio
enabled intelligent WBAN gateway for cost-efficient remote health monitoring,” *Phys. Commun.*, vol. 35, no. 2019, p. 100713, 2019.

[51] Vander Ark, T. (2011). *Getting smart: How digital learning is changing the world*. John Wiley & Sons.

[52] M. Logambal and V. Thiagarasu, “Healthcare Monitoring Systems: A WBAN Approach for Patient Monitoring.”

[53] W. Zang, F. Miao, R. Gravina, F. Sun, G. Fortino, and Y. Li, “CMDP-based intelligent transmission for wireless body area network in remote health monitoring,” *Neural Comput. Appl.*, vol. 0123456789, 2019.

[54] D. P. Tobón, T. H. Falk, and M. Maier, “Context awareness in WBANs: A survey on medical and non-medical applications,” *IEEE Wirel. Commun.*, vol. 20, no. 4, pp. 30–37, 2013.

[55] M. M. Alam, E. Ben Hamida, O. Berder, D. Menard, and O. Sentieys, “A Heuristic Self-Adaptive Medium Access Control for Resource-Constrained WBAN Systems,” *IEEE Access*, vol. 4, pp. 1287–1300, 2016.

[56] I. Ahmad, “Investigation of IEEE 802.15.4 Fixed Duty Cycle During Nodes Mobility Under Different Wban Performance Metrics,” vol. 17, no. 4, 2019.

[57] M. CICIOGLU and A. CALHAN, “Performance Evaluation of Dynamic HUB Selection Algorithm for WBAN,” no. October, pp. 1–5, 2019.

[58] K. Genova, “A heuristic algorithm for solving mixed integer problems,” *Cybern. Inf. Technol.*, vol. 11, no. 2, pp. 3–12, 2011.

[59] T. Ahmed and Y. Le Moullec, “A QoS optimization approach in cognitive body area networks for healthcare applications,” *Sensors (Switzerland)*, vol. 17, no. 4, 2017.

[60] R. Latha, P. Vettrivelan, and M. Jagannath, “Balancing emergency message dissemination and network lifetime in wireless body area network using ant colony optimization and Bayesian game formulation,” *Informatics Med. Unlocked*, vol. 8, no. December 2016, pp. 60–65, 2017.

[61] R. A. Isabel and E. Baburaj, “Multi-agent based maxmin markov probability for QoS aware routing in WBAN,” *Biomed. Res.*, vol. 28, no. 9, pp. 4261–4269, 2017.

[62] A. Razavi and M. Jahed, “Node positioning and lifetime optimization for wireless body area networks,” *IEEE Sens. J.*, vol. 17, no. 14, pp. 4647–4660, 2017.

[63] R. A. Kramer and J. P. Rhee, “The Need, Advances and Challenges Related to Wireless Body Area Network Communication Technology Wireless Communication Networks,” 2000.

[64] Z. Ling, F. Hu, and M. Shao, “The Optimal Control Policy for Point-to-Point Wireless Body Area Network Based on Simultaneous Time-Ratio and Transmission Power Allocation,” *IEEE Access*, vol. 7, pp. 46454–46460, 2019.

[65] S. Kim, “Cognitive hierarchy thinking based behavioral game model for IoT power control algorithm,” *Comput. Networks*, vol. 110, pp. 79–90, 2016.

[66] S. Kim, *Game Theory Applications in Network Design*. IGI Global, 2014.

[67] Wu, T. Y., & Liu, W. K. (2016). Game theory-based global optimization for inter-WBAN interference mitigation. *Wireless Communications and Mobile Computing, 16*(18), 3439-3448.

[68] Gharehshiran ON, Attar A, Krishnamurthy V. Collaborative Sub-Channel Allocation in Cognitive LTE Femto-Cells: A Cooperative Game-Theoretic Approach. IEEE Transactions on Communications 2013; 61(1): 325–334.

[69] JE Suris, LA DaSilva, Z Han, AB MacKenzie, Cooperative Game Theory for Distributed Spectrum Sharing, IEEE International Conference on Communications, 2007: 5282–
5287, 24-28.

[70] S. Gächter, “Behavioral Game Theory,” Blackwell Handb. Judgm. Decis. Mak., vol. 03, pp. 485–503, 2008.

[71] E. Romero, J. Blesa, and A. Araujo, “An adaptive energy aware strategy based on game theory to add privacy in the physical layer for cognitive WSNs,” Ad Hoc Networks, vol. 92, p. 101800, 2019.

[72] A. Arfaoui, A. Kribeche, S. M. Senouci, and M. Hamdi, “Game-based adaptive anomaly detection in wireless body area networks,” Comput. Networks, vol. 163, p. 106870, 2019.

[73] Y. Qiu, D. Haley, T. Chan, and L. Davis, “Game theoretic framework for studying WBAN coexistence: 2-Player game analysis and n-player game estimation,” 2016 Aust. Commun. Theory Work. AusCTW 2016, pp. 53–58, 2016.

[74] S. J. Borah, S. K. Dhurandher, I. Woungang, and V. Kumar, “A game theoretic context-based routing protocol for opportunistic networks in an IoT scenario,” Comput. Networks, vol. 129, pp. 572–584, 2017.

[75] A. Arfaoui, A. Ben Letaifa, A. Kribeche, S. M. Senouci, and M. Hamdi, “A stochastic game for adaptive security in constrained wireless body area networks,” CCNC 2018 - 2018 15th IEEE Annu. Consum. Commun. Netw. Conf., vol. 2018-Janua, pp. 1–7, 2018.

[76] S. Kim, “Inspection game based cooperative spectrum sensing and sharing scheme for cognitive radio IoT system,” Comput. Commun., vol. 105, pp. 116–123, 2017.