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A Clique-Based WBAN Scheduling for Mobile Wireless Body Area Networks

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Abstract

Wireless-body-area-networks (WBAN) that generally comprises different types of sensors are useful to gather multiple parameters together, such as body temperature, blood pressure, pulse, heartbeat and blood sugar. However, a dense and mobile WBAN often suffers from interference, which causes serious problems, such as degrading throughput and wasting energy. So, the sensors in WBAN are not active together at the same time and they can be partitioned to different groups and each group works in turn to avoid interference. In this paper, we provide a Clique-Based WBAN Scheduling (CBWS) algorithm to cluster sensors of a single or multiple WBAN into different groups to avoid interference. Particularly, we propose a coloring based scheduling method to schedule all groups to work in a sequence of time slots. The experimental results demonstrate the performance of the proposed CBWS algorithm in terms of system throughput.

Key words:wireless body area networks; sensors; scheduling; clique

1. Introduction

A Wireless Body Area Network (WBAN)[1] comprises various types of wireless sensor nodes that are attached to the human body or clothes, A single WBAN can be treated as a “personal sensor network”, which monitors and collects various vital signals, such as the body temperature, blood glucose from human body. These sensed data can be gathered and transmitted to the monitoring server for healthcare applications or surveillance systems. The WBAN overcomes the wire-line limitation of conventional near/inner body signal

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measurements [2,3,4,5], and thus has wide applications in ubiquitous health monitoring and advanced athlete performance enhancement. Unlike a sensor network focused on static or low mobility scenarios [6], a WBAN has a higher moving speed and more frequent topology changes due to user movement [3,5]. The moving topology of multiple WBANs is similar to that of mobile ad hoc networks (MANETs) [7], but with group-based rather than node-based movement. The "high mobility" and "group-based movement" is the basic characteristics of WBAN.

However, a dense and mobile WBAN often suffers from interference, which causes serious problems, such as degrading throughput and wasting energy. Since the two nodes in the same or neighbour WBANs is very close to each other, this may cause serious interference [8, 9] and reduce the quality of the communication [8,9]. According to the IEEE 802.15 TG6, the standard task group of WBAN, requires that the WBAN protocol should support at least the sensor density: 60 sensors in a 6^3 m^3 space [10]. Such dense nodes create a high probability of mutual interference [8,9]. The interference that results due to the communications of wireless BSNs operating in proximity of one another [9]. When the nodes of several BSNs try to communicate data in their respective networks at the same time in the same vicinity, it will have the adverse effect of increasing interference and therefore reducing the reception probabilities and throughput achieved by all the networks. Note that interference can occur due to the effects of any communication source in the vicinity of the WBAN.

The most effective techniques that can be used to mitigate interference are WBAN scheduling. Sensors are asked to operate in different time slots or channels. The WBAN consists of different types of sensors for gathering different parameters such as body temperature, blood pressure, pulse, heartbeat and blood sugar, but these sensors cannot collect the data simultaneously. For example, during the health examination, only the heart rate data are queried by the hospital cardiology through the WBAN, while other sensor nodes, such as blood pressure sensors, can be in a dormant state. Another example is that the sensors for the diabetes patients gather the blood sugar parameters only before dinner but in a dormant state in the other time. So, the sensors in WBAN are not active together at the same time and they can be partitioned to different groups and each group works in turn to avoid interference. Therefore, a scheduling strategy should be provide to enable different nodes to work in different time slots.

Currently, there are many node scheduling methods of sensor networks proposed, which can be classified into the following two major categories: the round-based node scheduling [11,12,13,14] and the group-based node scheduling [15,16]. However, the existing scheduling method mentioned above is not sustainable for WBAN scheduling since they focus specifically on scheduling the static sensor networks. Unlike a sensor network focused on static or low mobility scenarios [6], a WBAN has a higher moving speed and more frequent topology changes due to user movement [3,5]. The WBAN movement is with group-based rather than node-based movement. The "high mobility" and "group-based movement" is the characteristics of WBAN and which make the WBAN neither equivalent to a sensor network nor to a MANET.

In this paper, we propose the Clique -Based WBAN Scheduling for mobile wireless Body Area Networks(CBWS) to meet these challenges. The main idea of CBWS is that we construct t nodes in a single or multiple close WBAN into a t-Clique, the t nodes are assigned to the k groups ($t>k$), and then allocate the k groups different time slots by coloring method. The dispatch center find all Cliques by the finding Clique algorithm in first step, and in step 2, the nodes in Cliques are assigned into different virtual groups; in step 3, the virtual groups are allocated time slot by coloring method and the time slot will broadcast to all nodes in Cliques. In step 4, After getting the time slot, each group works by turns during its own time slots (wake or sleep).

The most related work is RIC for CPN-Based CIWS method (Random Incomplete Coloring for the Central Processing Node based Coloring Inter-WBAN Scheduling) [8], which proposed an incomplete-coloring approach based on the central processing node system model. Our CBWS is totally different from RIC .RIC treats all the nodes in WBAN as a whole and all the nodes in the same WBAN must work at the same time slot or channel when scheduling. I.e. When two or more WBANs have mutual interference, The CPN-Based RIC will get the resources (channel or time slot) for the WBANs using Random Incomplete Coloring Scheduling method and then assign the resources to the CPN (the Central Processing Node) in WBAN, the CPN allocated the resources to the corresponding nodes, all nodes in the same WBAN will work in accordance with their own resources. While in CBWS, the nodes work in different time slot according its function, all the nodes have the same function in a single or multiple close WBAN will work at the same time slot, and nodes in the same WBAN will work in different time slots since they have different functions.

One advantage of CBWS is that it can meet the needs of practical applications better than the existing scheduling method such as CPN-Based RIC Etc, since the WBAN consists of several different sensors which are used to gather parameters and have different functions, and these different sensors can not work at the same time. Another advantage is that the each nodes works by turns during its own time slots(wake or sleep), which will greatly prolong the network lifetime Meanwhile, The theoretical analysis and experimental study demonstrates that CBWS consumes significantly less energy and have long lifetime than the counterpart methods.

The rest of this paper is organized as follows: Section 2 presents related works. Section 3 introduces the WBAN system model. Section 4 reveals the proposed Clique based node scheduling Algorithm. Section 5 presents the simulation settings and results. Section 6 concludes this paper

2. Related Works

In this section, we conduct a survey of the impacts of interference for body sensor networks and the node scheduling methods in sensor networks.

Most existing work on body sensor networks has focused on the development of sensors and sensor platforms [1,2,17,18,19,20]. The link layer behavior of nodes placed on a human body has been proposed in [17].Exploiting the secure and reliable routing in wireless body area networks have been discussed in [18]. An incremental learning method based on probabilistic neural networks and adjustable fuzzy clustering for human activity recognition has been proposed in [19]. A hierarchical approach of recognition in body sensor networks has been proposed in [20].

The work on the impacts of interference can be classed into two groups, the impacts of interference for sensor networks [21,22] and the impacts of interference for body sensor networks [8,17,23,9]. Although the problem of cluster interference in wireless sensor networks mentioned in [21,22] has similarities to our problem, these systems do not have to contend with mobility. The researchers studied the impact of interference due to sources such as WiFi, Bluetooth and microwave ovens on body sensor networks' operating at 2.4GHz In [17,23]. The work highlighted the existence of the inter-user interference effect in [9], but did not give the solution in that paper. An incomplete-coloring approach based on the central processing node system was proposed in [8], which proposed model which treats all the nodes in WBAN as a whole and all the nodes in a WBAN must work at the same time slot or channel when scheduling. However, this approach can only be used in the special WBAN which contains only one kind of sensors, because in the most of practical application, the WBAN usually contains a variety of sensor nodes, they need to work in different time periods.

The research work about node scheduling for sensor networks can be classified into the following two major categories: round-based node scheduling and group-based node scheduling. In a round-based node scheduling method, the sensor nodes will execute the scheduling algorithm during the initialization of each round. According to some kind of competition scheme, some nodes will be keep active in the current round, and other nodes will sleep instead[11,12,13,14]. In a group-based node scheduling method, all sensor nodes will be allocated into some different groups. Each node will execute the scheduling algorithm after its deployment. [15,16].However, the node scheduling for sensor networks can not be directly applied to the WBAN since the WBAN has a higher moving speed and more frequent topology changes due to user movement.

3. The WBAN System Model

A dispatch center based WBAN scheduling Model will be adopted in this study. CBWS system is composed of dispatch center and many WBANs. The dispatch center manages the join, leave, and functional-control of the WBANs. The WBAN is composed of WSNs which are designed to retrieve specific vital signals such as blood pressure or electrocardiograms (ECG) etc. One or more close WBANs form a Clique, and the dispatch center find all Clique at first, then the nodes in Clique are assigned into different virtual groups which will be allocated time slot by dispatch center running coloring method. At last, the time slot will broadcast to all nodes in Clique and work by turns during its own time slots (wake or sleep.)

Next, We assume that a sensor's sensing range, which is represented by r_s , is defined as the range beyond which the sensor's sensing ability can be neglected. Furthermore, we assume that sensors' communication range r_c is larger than or equal to 2 r_s. which is usually true in practice. For example, ultrasonic sensors have a sensing range of approximately 0.2–6m while the transmission range of MICA motes is about 30 m [24].

Finally, we assume that all of the nodes of WBAN are encoded from according to the coding method of the n-dimensional Hyper-cubes[25,26], So after deployment, each node will have a unique ID. For any two sensor nodes $p_1$and p_2, if the ID code of $p_1$is bigger than that of the p_2, then we record their relationship as $p_1 > p_2$.

$\overbrace{00\cdots001}^{n}$ to $\overbrace{11\cdots111}^{n}$

We present a t-Clique concept which will be used in the following sections. For any t wireless sensors nodes $p_1, p_2, \ldots, p_t$ in one or more WBANs, if they are all neighboring to each other, then the set $\{p_1, p_2, \ldots, p_t\}$ is called a t-Clique. The nodes in a single WBAN or in a number of adjacent WBANs form a Clique. For example, the transmission range of MICA motes is about 30 m [24]. As for the WBAN, the human torso range is less than 3m × 3m, the longest distance in WBAN is the diagonal of the 3m × 3m square. While the distance of the 3m × 3m square's diagonal is $\sqrt{3^2+3^2}=3\sqrt{2}$ far shorter than 30 m. For any two Clique $N_1$and N_2, if the nodes in N_1all belong to N_2 ($N_1 \subseteq N_2$), then we record their relationship as $N_1 \in N_2$,and call N_1 a sub-Clique of N_2 . Otherwise, if there exists at least 1 node in N_1 that does not belong to N_2, then we record their relationship as $N_1 \notin N_2$.

4. Clique Based WBAN Scheduling Algorithm

We propose a novel distributed Clique based scheduling method-CBWS (Clique based WBAN scheduling Algorithm) In this section, we give overview of our Clique based WBAN scheduling algorithm CBWS briefly as follows:

Table 1:CBWS Algorithm.

Algorithm 1:CBWS
Step 1: Use the Finding local Clique algorithm illustrated in Section 4.2 to find all local Clique by a distributed method. Step 2: For each local Clique, use the Group ID Assignment for Nodes Algorithm assign Group IDs (GIDs) to all nodes in the local Clique. Step 3: the groups are allocated time slot by Coloring based Time Slot Allocate to Group Algorithm and the time slot will broadcast to all nodes in Clique. Step 4: Each group works by turns during its own time slots.

4.1. Group ID Assignment for Nodes Algorithm

For any t-Clique consisting of t sensors $\{p_1,p_1, ..., p_t\}$, with ID$\{ p'_1,p'_2, ..., p'_t \}$,the sensors will be allocated into $k(k\leq t)$ different groups $\{0,1,...,k-1\}$ according to the following GID(Group ID) Assignment for Nodes in a t-Clique Algorithm:

Table 2: GANN: Group ID Assignment for Nodes in a t-Clique Algorithm.

Algorithm 2: GANN
Step 1: Without loss of generality, assume that $p'_1 = \min\{ p'_1 ,p'_2, ..., p'_t \}$.then p_1 declares itself as the Clique Head in the t-Clique$\{p_1 ,p_2, ..., p_t\}$, p_1 will collect the GIDs of all its Clique members in the Clique $\{p_1 ,p_2, ..., p_t\}$.If all nodes have been assigned GIDs already, then the algorithm is terminated. Otherwise, go to Step 2. Step 2: Suppose that the first $a(a<t)$ nodes$\{p_1 ,p_2, ..., p_a\}$ in $\{p_1 ,p_2, ..., p_t\}$ have been assigned GIDs $\{g'_1 ,g'_2, ..., g'_a\}$ respectively already, and$\{g_1 ,g_2, ..., g_b\}$ are all the different GIDs in $\{g'_1 ,g'_2, ..., g'_a\}$, where $b\leq a$. Case1:If $b=k$, then for each sensor node $p_j \in \{p_{a+1},p_{a+2}, ..., p_t\}$,then p_1 selects $g\in \{0,1,...,k-1\}$ randomly, and assigns GID $\{0,1,...,k-1\}$ to node p_j. Case 2: If $b<k$, then let $U= \{0,1,...,k-1\}\setminus \{g_1 ,g_2, ..., g_b\}=\{u_0 ,u_1, ..., u_{k-b-1}\}$ Subcase A: If $t-a\geq k-b$, then $p_1$selects $t-a-k+b$ different GIDs V=$\{v_0 ,v_1, ..., u_{t-a-k+b}\}$from $\{0,1,...,k-1\}$ randomly, and distributes $U\cup V$ to nodes$\{p_{a+1},p_{a+2}, ..., p_t\}$randomly. Subcase B: If $t-a<k-b$, then p_1 selects $t-a$ different GIDs $\{v_0 ,v_1, ..., u_{t-a-1}\}$ from U randomly, and distributes these GIDs to $\{p_{a+1},p_{a+2}, ..., p_t\}$randomly.

4.2. Fingding local Clique Algorithm

In this subsection, we consider how to find out these local Cliques. If all sensors of *t*-Clique come from a single WBAN, We can found the local Clique easily by the identifier of the sensors. Otherwise, if the sensors of *t*-Clique come from a number of different Cliques, we found all the local Cliques by Fingding local Clique Algorithm.

In general, we can bring forward a solution to the problem of finding the *t*-Clique in a distributed way as follows. We assume that the sensor maintains an information table including IDNS(ID of its Neighboring Sensors), NSLN(Neighboring Sensors List of its Neighbors), and *m* is the minimum number of sensors in a WBAN to monitor body disease[5]. Then DLNF(Distributed Local Clique Finding) algorithm is used to find local *t*-Clique. For each sensor, say p_1 does as the following.

Table 3: DLNF: Distributed Local Clique Finding Algorithm.

Algorithm: DLNF
Step 1:let $p_2, p_3, \ldots, p_s$ be all the active neighbors of p_1 and $p'_1, p'_2, \ldots, p'_s$ represent the IDs of $p_1, p_2, \ldots, p_s$ respectively. Let $N_1, N_2, \ldots, N_s$ Represent NSLN and $N'_1, N'_2, \ldots, N'_s$ represent IDNS $\cup$ NSLN of $p_1, p_2, \ldots, p_s$ respectively.
Step 2:
For ($t=s;t\geq m;t$--) do
p_1 compute $\binom{s-1}{t-1}$ different subsets $S_1, S_2, \ldots, S_{\binom{s-1}{t-1}}$ of{ $p_2, p_3, \ldots, p_s$}
Let C_x represent the set of all the *x*-Clique(t<x$\leq$ s) that have been found by node p_1; S_x represent the node sets of a *x*-Clique in C_x.
For ($j=1;j\leq \binom{s-1}{t-1}$;j++) do
IF there is no $S_x \in C_x$ such that $S_j \subseteq S_x$ then
Let $S_j = S_j \cup \{ p_1 \}$
Let D=$\bigcap_{i\in S_j} N'_i$
IF |D|=*t*, record D as a *t*-Clique end IF
End for
End for

4.3. Coloring based Time Slot Allocate to Group Algorithm

In this subsection, we allocate the time slot to groups by The Random Coloring based Time Slot Allocate to Group Algorithm (RCTSAG). The main ideal of RCTSAG is that we model the WBAN network topology as a graph $G=(V, E)$. $V(G)$ represents the set of groups; $E(G)$ represents the set of links between groups. Consequently, edges are added to connect groups. The color set C in a coloring of G represents the set of distinct resource units (can be time slots, frequency bands, or code sequences). A complete vertex *k*-coloring of a graph G is a mapping $V(G) \rightarrow C$, where |C|=*k*, such that adjacent vertices receive distinct colors. Thus, the sensors can work in different time slots according to the need and the type of the sensors. Moreover, interference between WBAN can be avoided by mapping different colors (time slots) to adjacent vertices.

Table 4: RCTSAG: Coloring based Time Slot Allocate to Group Algorithm.

Algorithm: RCTSAG
Given *G*=(*V,E*); $w, v \in V(G)$; $C_u(r)$ is the set of available colors of *w* in coloring round *r*; The initial size of the available color set is $\vert C_w(0) \vert = k$; for each coloring cycle:
While (*w* is uncolored)
{
1. *w* chooses a color c_w from $C_w(r)$ with a random value R_w.
2. *w* broadcasts its coloring message(*CM*) including c_w and R_w to its $N(w)$
3. if *w* receives *CM* messages from $v \in N(w)$ with $R_{v\geq}R_w$ and $c_v = c_w$,*w* remains uncolored. Otherwise, w is colored by c_w.
4. if *w* wins the color, it broadcasts the color taken notification.
5. *w* removes the colors taken by $N(w)$ from $C_w(r+1)$
}

5. Performance Analysis and Evaluation

In this section, we demonstrate the effectiveness and efficiency of CBWS by evaluating the system throughput of CBWS which is applied in an WBAN scheduling with a TDMA framing structure, a common structure used in sensor or body area networks [8].

We study the system throughput with different number of colors. The system throughput is defined as effective transmissions per slot (*Tps*)[8], which counts data transmissions of all sensors in the system and is the performance index used to evaluate WBAN scheduling. We set the average number of coloring rounds as 5 in the experiments. The simulation results are shown in Figs.1-4, and all the data in these figures are the average of 10-20 times independent simulation result.

We compare the system throughput of our CBWS method with CPN-based RIC [8] in low, middle, high, and extremely high WBAN densities. Experimental results show that the system throughput of two algorithms decrease along with the increase of the number of colors, this is because the number of scheduling will increase with the increase of the colors. Compared to CPN-based RIC, our CBWS has greater system throughput in the low,middle,high, and extreme high four WBAB densities. Especially in the case of high density, CBWS has greater system throughput and the curves has more smooth than CPN-based RIC, the reason is that CBWS take the Multiple adjacent WBANs as a Clique, and then the nodes in Clique are assigned into different virtual groups which will be allocated time slot to avoid interference. However, the inter-WBAN scheduling in CPN-based RIC is taking WBAN as the unit, which will increase the collision with the increase of WBAN density.

6. Conclusion

In this work, we provide a Clique based WBAN Scheduling (CBWS) algorithm to cluster sensors of a single or multiple WBAN into different groups to avoid interference. Particularly, we propose a coloring based scheduling method to schedule all groups to work in a sequence of time slots. We then simulate the CBWS algorithm in a WBAN scheduling protocol with TDMA framing structure. The results show that CBWS outperforms a counterpart method in terms of system throughput in mobile wireless body area networks.

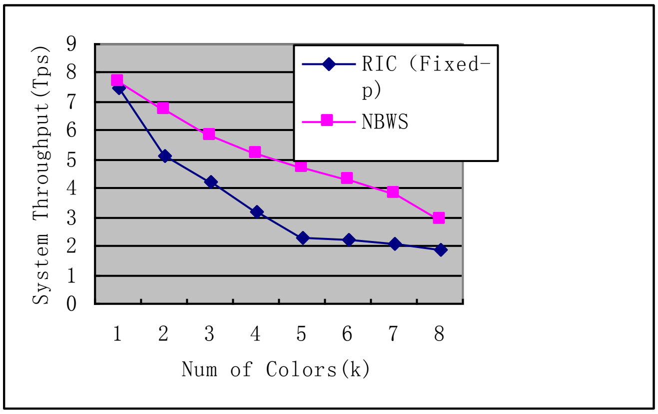

Fig.1 System throughput of WBAN scheduling with low WBAN densities

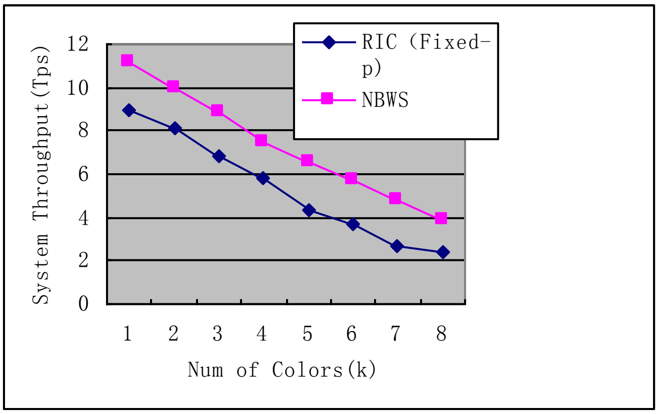

Fig.2 System throughput of WBAN scheduling with middle WBAN densities

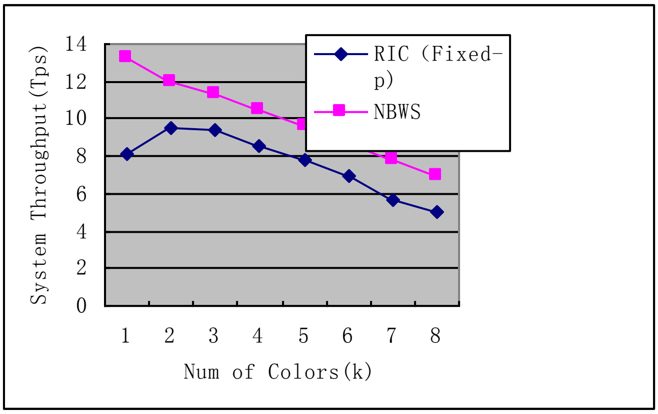

Fig.3 System throughput of WBAN scheduling with high WBAN densities

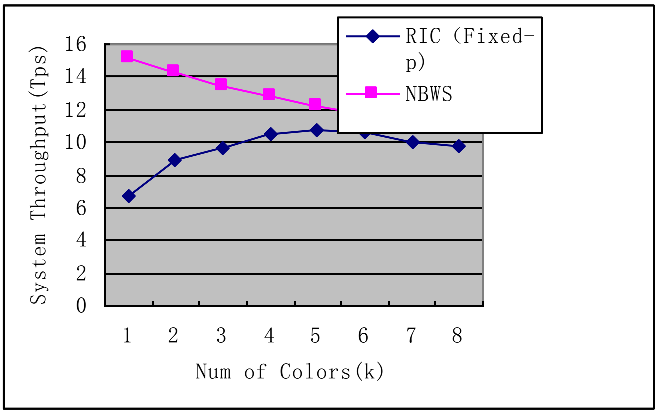

Fig.4 System throughput of WBAN scheduling with extreme high WBAN densities

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References

[1] Latré B,Braem B,Moerman I,et al. A survey on wireless body area networks.*J Wireless Networks*,2011,17(1):1-18.
[2] Hooi Been L,Baumann D,Er-ping L.A human body model for efficient numerical characterization of UWB signal propagation in wireless body area networks,*IEEE Transactions on Biomedical Engineering*,2011,58(3):689-697
[3] M. Chen, S. Gonzalez, A. Vasilakos, H. Cao, and V.C. Leung. Body Area Networks: A Survey. Mobile Networks and Applications, 2011,16(2): 171-193.
[4] Yong S,Baldus H,Espina J.The simulation method of the galvanic coupling intrabody communication with different signal transmission paths.*IEEE Transactions on Instrumentation and Measurement.*2011;60(2-3):1257-1266.
[5] Ghasemzadeh H,Jafari R.Physical movement monitoring using body sensor networks: a phonological approach to construct spatial decision trees.*IEEE Transactions on Industrial Informatics*, 2011, 7(1): 66-77.
[6] Akyildiz I.F, W.L. Su, Sankarasubramaniamv Y, Cayirciv E. A Survey on Sensor Networks, *IEEE Comm. Magazine*, 2002; 40(8):102-114
[7] Jiang S.M, Liu Y.D, Jiang Y.M, Yin Q.G.Provisioning of Adaptability to Variable Topologies for Routing Schemes in MANETs, *IEEE J. Selected Areas in Comm*, 2004; 22(7): 1347-1356.
[8] Cheng SH,Huang C Y,coloring-based inter-WBAN scheduling for mobile wireless body area networks. *IEEE Transactions on parallel and distributed systems*,2013;24(2) :250-259
[9] Buddhika de S, Anirudh N,Mehul M.,2009,"Inter-user interference in Body Sensor Networks:Preliminary Investigation and an Infrastructure-Based Solution". 4nd International Conference on Body Sensor Networks, Los Angeles, California, United States,pp:36-40
[10] IEEE 802.15 WPAN Task Group 6 Body Area Networks, "15-08-0644-0 -0006-tg6 Technical Requirements Document," 2008.
[11] Nikolaos AP, Vergados DJ, Vergados DD, Christos D. Energy efficiency in wireless sensor networks using sleep mode.*TDMA Scheduling Ad Hoc Networks*.2009;7(2):322–43.
[12] YANG Y,CARDEI M.Adaptive energy efficient sensor scheduling for wireless sensor networks.*Optimization Letters*,2010,4(3):359-369.
[13] YARDIBI T,KARASAN E.A distributed activity scheduling algorithm for wireless sensor networks with partial coverage.*Wireless Networks*,2010,16(1):213-225.
[14] Bai X L, Yun Z Q, Xuan D.Pattern mutation in wireless sensor deployment,2010,30th IEEE INFOCOM, Piscataway, NJ, USA,pp:1-9.
[15] Liu C, Wu K, Xiao Y, Sun B. Random coverage with guaranteed connectivity: joint scheduling for wireless sensor networks. *IEEE Transactions on Parallel and Distributed Systems,*2006;17(6):62–75.

[16] Bai X, Zhang C, Xuan D.Optimal Deployment Patterns for Full Coverage and k-connectivity Wireless Sensor Networks. *IEEE/ACM Transaction on Networking*,2010,18(3):78-87.

[17] Natarajan A, Motani M, Silva B, “Investigating network architectures for body sensor networks,” 2007, HealthNet, San Juan, Puerto Rico, USA.pp:19-24

[18] Liang X, Shen Q, Lu R. Exploiting prediction to enable secure and reliable routing in wireless body area networks. 2012 IEEE INFOCOM, Orlando, USA, pp:388-396..

[19] Wang Z L, Jiang M, Hu Y H, et al. An incremental learning method based on probabilistic neural networks and adjustable fuzzy clustering for human activity recognition by using wearable sensors.*IEEE Transactions on Information Technology in Biomedicine*, 2012, 16(4): 691-699..

[20] Wang L,Gu T, Tao X P, et al. A hierarchical approach to real-time activity recognition in body sensor networks.*Journal of Pervasive and Mobile Computing*, 2012, 8(1):115-130.

[21] Liu L, Zhang X, Wang Q, Li L, Wang R. 2007,A wireless sensor network mac protocol for systems with burst and periodic signals, 2nd International Conference on Wireless Communications, Networking and Mobile Computing,Wuhan, China.

[22] Wu T, Biswas S. 2005, “Reducing inter-cluster tdma interference by adaptive mac allocation in sensor networks,” 6th IEEE International Symposium on a World of Wireless Mobile and Multimedia Networks,Giardini Naxos,Italy.

[23] Motani M, Yap K.-K, Natarajan A, Silva B, Hu S.2007, “Network characteristics of urban environments for wireless ban”,Biomedical Circuits and Systems Conference,Beijing,China,pp:179-182

[24] Lu J,Bao L,Suda T.Probabilistic self-scheduling for coverage configuration in wireless ad-hoc sensor networks.*International Journal of Pervasive Computing and Communications*,2008;4(1):26–39.

[25] Wang L,Lin Y, Liu Y.2007,Key distribution for group-based sensor deployment using a novel interconnection graph. IEEE International Symposium on a World of Wireless Mobile and Multimedia Networks(WoWMoM).Helsinki,Finland.pp.1–9.

[26] Wang L, Lin Y.2004,Petersen graphs connected hypercube networks. The IEEE international conference on networks (ICON 2004). Singapore,pp:09-11.