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

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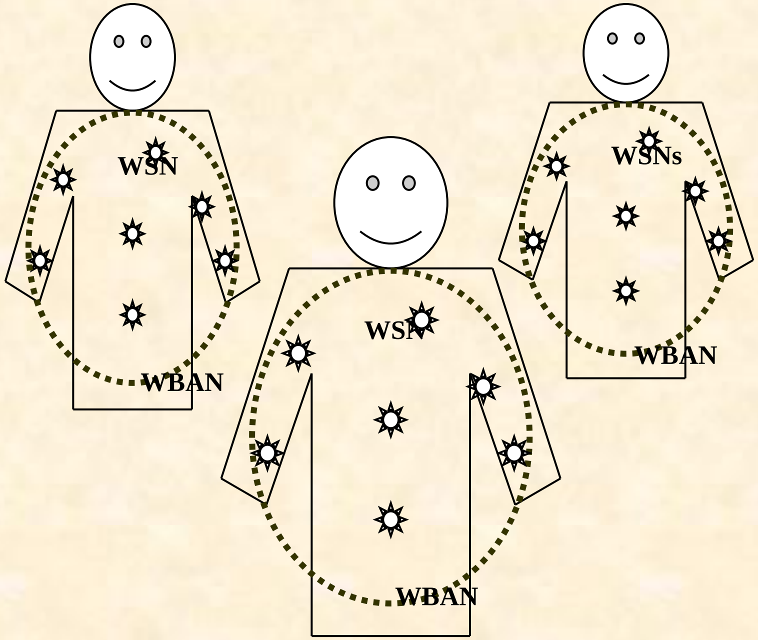
Introduction

A Wireless Body Area Network (WBAN) comprises various types of wireless sensor nodes that are attached to the human body or clothes



Introduction

The special characteristics of applications of WBAN and challenges:

- higher moving speed and more frequent topology changes.
- Serious interference and have a greater impact on the communication.

Introduction

How to meet the challenge?

●The most effective techniques that can be used to mitigate interference are WBAN scheduling (WS). Sensors are asked to operate in different time slots or channels.

●we propose the Clique -Based WBAN Scheduling for mobile wireless Body Area Networks（CBWS） to meet these challenges.

Introduction

- The main idea of CBWS :
- 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.

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Related Works

Most existing work on body sensor networks has focused on the development of sensors and sensor platforms .The work on the impacts of interference can be classed into two groups:

1) the impacts of interference for sensor networks

2) the impacts of interference for body sensor networks.

these approaches 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:

1)round-based node scheduling

2)group-based node scheduling.

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.

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The System Model

- A dispatch center based WBAN scheduling Model
- CBWS system is composed of dispatch center and many WBANs
- The dispatch center manages the join, leave, and functional-control of the WBANs
- 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.)

The System Model

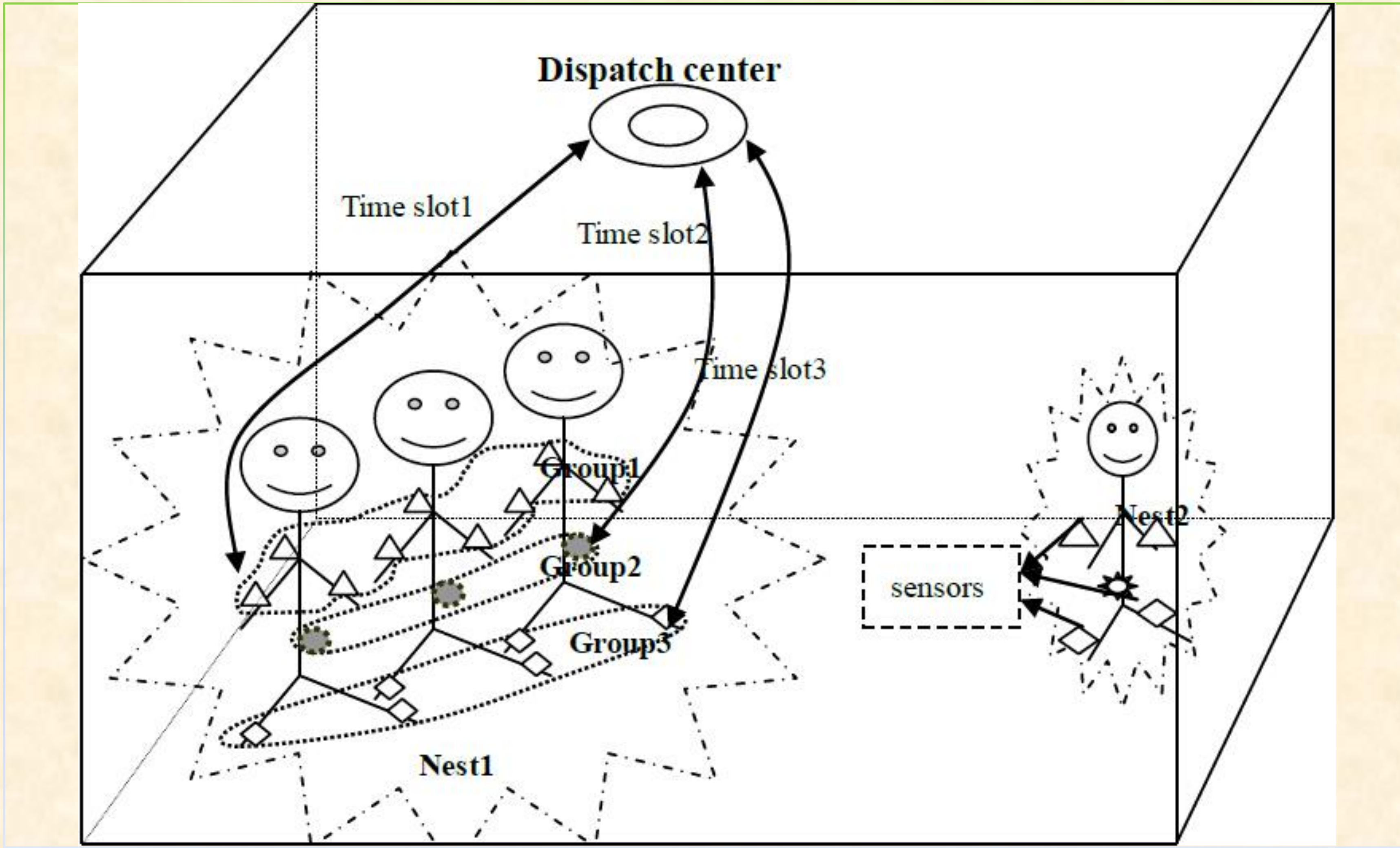

Fig.1 Scheduling model

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Clique based WBAN scheduling Algorithm

Algorithm:CBWS
Step 1: Use the Finding local Nest algorithm illustrated in Section 4.2 to find all local Nest by a distributed method. **Step 2**: For each local Nest, use the Group ID Assignment for Nodes Algorithm assign Group IDs (GIDs) to all nodes in the local Nest. **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 Nest. **Step 4**: Each group works by turns during its own time slots.

For any *t-Nest consisting of t sensors {p1,p1, …, pt}, with ID{ p'1,p'2, …, p't },the sensors will be allocated into k(k ≤ t) different groups {0,1,…,k-1} according to the following steps :*

Clique based WBAN scheduling Algorithm

Algorithm: Group ID Assignment for Nodes Algorithm(GANN)

Step 1: Without loss of generality, assume that $p'_1 = \min\{p'_1, p'_2, \ldots, p'_t\}$.then p_1 declares itself as the Nest Head in the t-Nest$\{p_1, p_2, \ldots, p_t\}$, $p_1$will collect the GIDs of all its Nest members in the Nest $\{p_1, p_2, \ldots, p_t\}$.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$\{p_1, p_2, \ldots, p_a\}$ in $\{p_1, p_2, \ldots, p_t\}$ have been assigned GIDs $\{g'_1, g'_2, \ldots, g'_a\}$ respectively already, and$\{g_1, g_2, \ldots, g_b\}$ are all the different GIDs in $\{g'_1, g'_2, \ldots, g'_a\}$, where $b \leq a$.

Case1:If $b=k$, then for each sensor node $p_j \in \{p_{a+1}, p_{a+2}, \ldots, p_t\}$,then p_1 selects $g \in \{0,1,\ldots,k-1\}$ randomly, and assigns GID $\{0,1,\ldots,k-1\}$ to node p_j.

Clique based WBAN scheduling Algorithm

Algorithm: Group ID Assignment for Nodes Algorithm(GANN)

Case 2: If $b<k$, then let $U= \{0,1,\ldots,k-1\} \setminus \{g_1, g_2, \ldots, g_b\} = \{u_0, u_1, \ldots, u_{k-b-1}\}$

Subcase A:

If $t-a \geq k-b$, then p_1 selects $t-a-k+b$ different GIDs $V=\{v_0, v_1, \ldots, u_{t-a-k+b}\}$ from $\{0,1,\ldots,k-1\}$ randomly, and distributes $U \cup V$ to nodes $\{p_{a+1}, p_{a+2}, \ldots, p_t\}$ randomly.

Subcase B:

If $t-a<k-b$, then p_1 selects $t-a$ different GIDs $\{v_0, v_1, \ldots, u_{t-a-1}\}$ from U randomly, and distributes these GIDs to $\{p_{a+1}, p_{a+2}, \ldots, p_t\}$ randomly

Clique based WBAN scheduling Algorithm

We give a simple example as follows to demonstrate Algorithm

Fig. 2 is a 5-Clique consists from WBAN1 and WBAN2. Suppose *k=4, i.e. there are 4 different groups {0,1,2,3}. Since node 001 has the smallest ID in the Nest, it will become the Nest Head according to the step 1 in the Algorithm GANN.* In this example, nodes 001, 010, 011, 101, 111 are assigned 2, 1, 0, 3, 3 respectively as Fig. 2(b) illustrates.

Clique based WBAN scheduling Algorithm

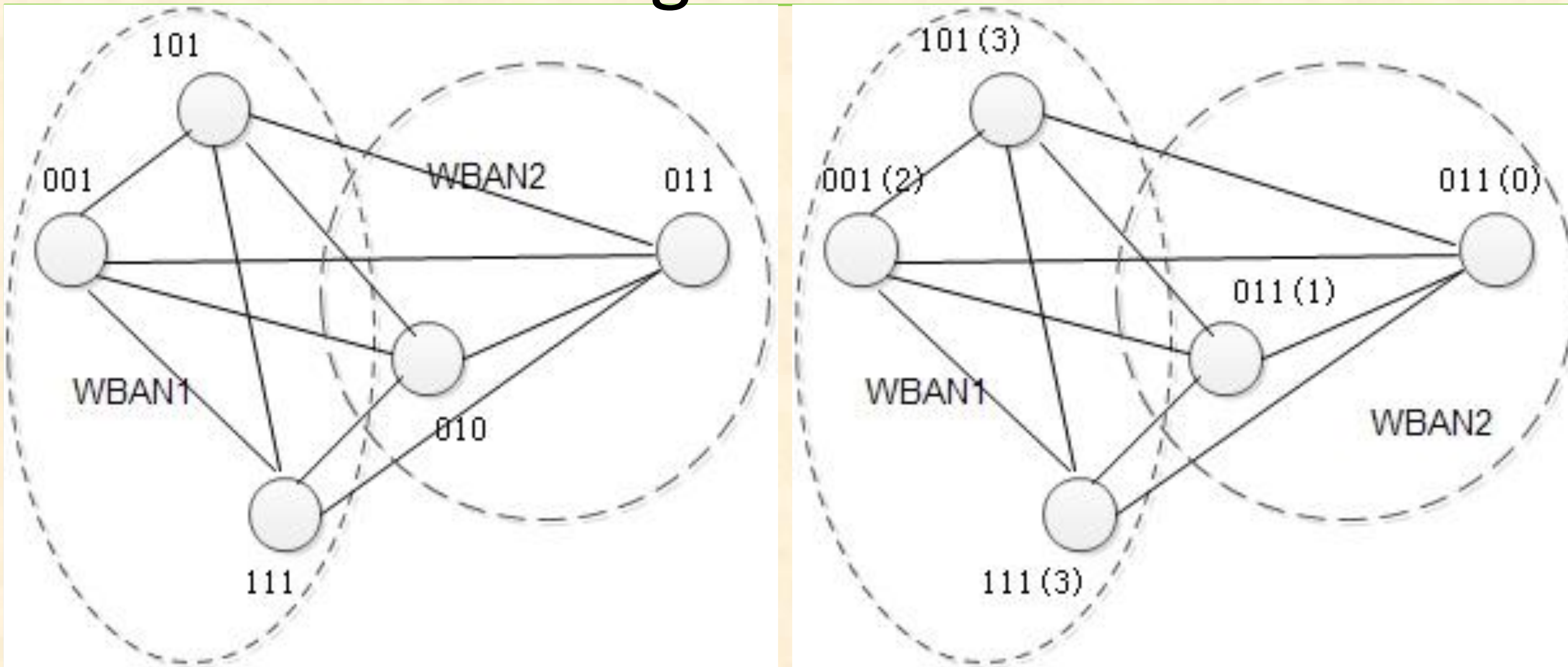


Fig2(a) Fig2(b)

Fig.2 a 5-Nest consists from WBAN1 and WBAN2

Clique based WBAN scheduling Algorithm

Algorithm:Fingding local Clique Algorithm

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-Nest($t<x \leq s$) that have been found by node p_1; represent the node sets of a x-Nest in C_x .

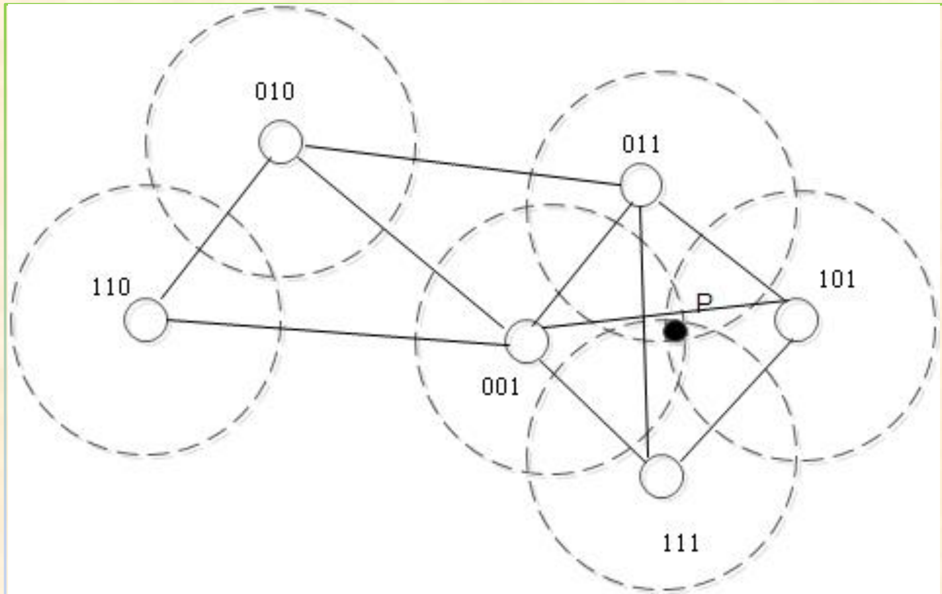
For ($j=1;j \leq \binom{s-1}{t-1} ;j++$) do

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-Nest **end IF** **End for** **End for**

Example of Find local t-Clique



Row ID	IDNS	NSLN	{ IDNS} ∪ { NSLN}
1	001	010,011,101,111	001,010,011,101,111
2	010	001,011,110	001,010,011,110
3	011	001010,101,111	001,010,001,101,111
4	101	001,011,111	001,011,101,111
5	110	001,010	001,010,110
6	111	001,001,101	001,011,101,111

Fig.3Example of Clique Finding and the corresponding information

Algorithm : Coloring-based Time Slot Allocate to Group 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* $|C_w(0)| = k$ *; for each coloring cycle:*

While *w is uncolored,*

{

1. *w chooses a color 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* $\overline{C}_w(r+1)$

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Performance Analysis and Evaluation

Theorem 1. For *n groups, the probability that each group can be allocated the time slot by the algorithm RCTSAG, written as Pc , is satisfied by the equation (1).*

$$P_c = \sum_{i=1}^{k} (-1)^{i-1} \binom{k}{i} \left(1 - i\frac{p_c}{k}\right)^{n-1} \qquad (1)$$

Theorem 2. Suppose there are *t* sensors in a *t*-Nest will be allocated into *k* different groups,the probability that the given node in the t-Nest will be assigned *j* (*j* $\leq$ *k*) given different GID by algorithm GANN is p_G .

$$p_G = \sum_{j=1}^{k} \frac{1}{j} \times p(t,k,j)$$

$$p(t,k,j) = \frac{1}{k^t} \sum_{i=0}^{j-1} (-1)^i \binom{k}{j} \binom{j}{i} (j-i)^t$$

Performance Analysis and Evaluation

Theorem 3. There are *t* sensors in a *t*-Nest are allocated into k groups by algorithm GANN , **t**he probability that at least k in the t sensors have different GIDs is

$$P=\begin{cases} 1 & if t_2 \geq k \\ \frac{1}{k^{t_1}} \sum_{j=(k-t_2)}^{\min(k,t_1)} \sum_{i=0}^{j-1} (-1)^i \binom{k}{j} \binom{j}{i} (j-i)^{t_1} & if t_2 < k \end{cases}$$

Theorem 4. Suppose that there t nodes will be allocated into k different groups {0,1,…,k-1}, Then the new group assign algorithm GANN has better performance than the randomized scheduling scheme RSS. More over, the value of P_{GANN} - P_{RSS} is:

$$\begin{cases} \sum_{j=1}^{k-1} p(t,k,j) & if t_2 \geq k \\ \sum_{i=0}^{t_2-1} \frac{1}{k^{t-i}} (k-i-1)(k-i-1)! \binom{k}{k-i-1} S(t-i-1, k-i-1) & otherwise \end{cases}$$

Performance Analysis and Evaluation

Simulation Settings of Coloring-Based WBAN Scheduling

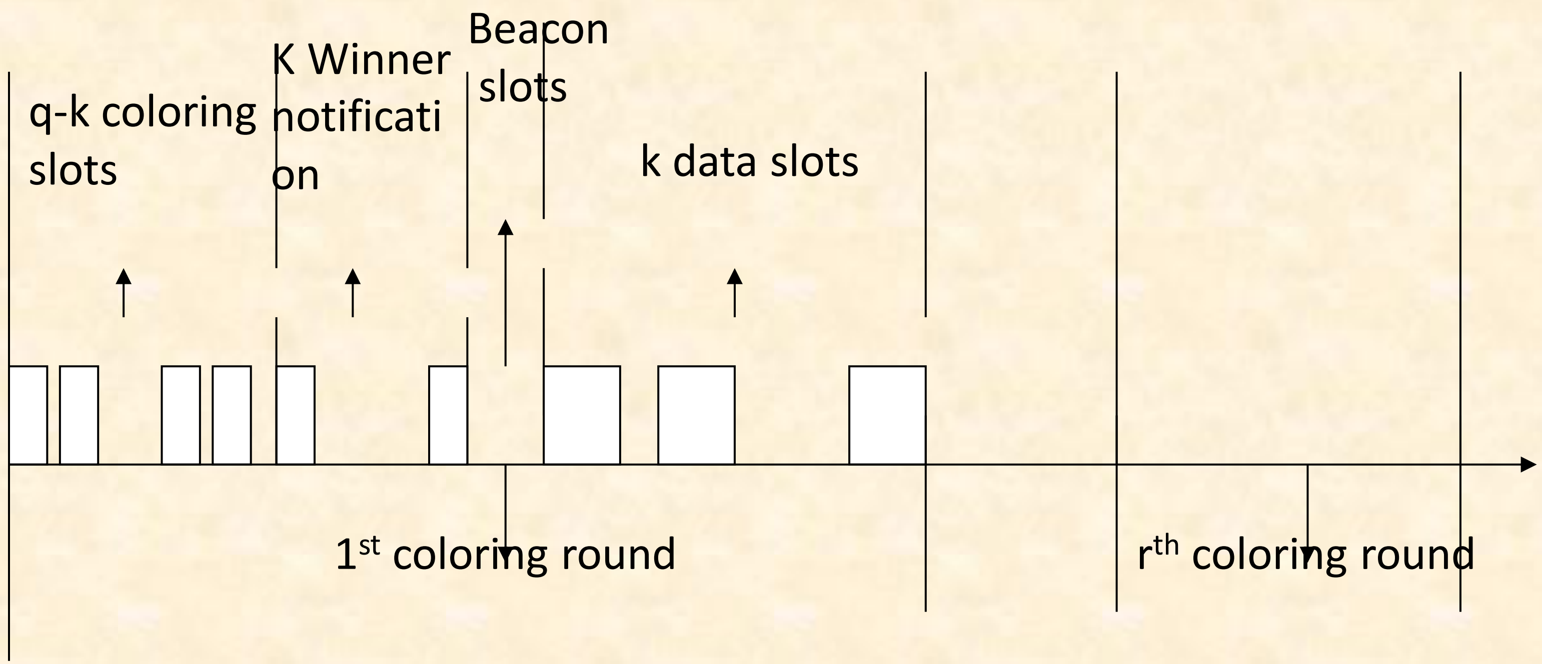
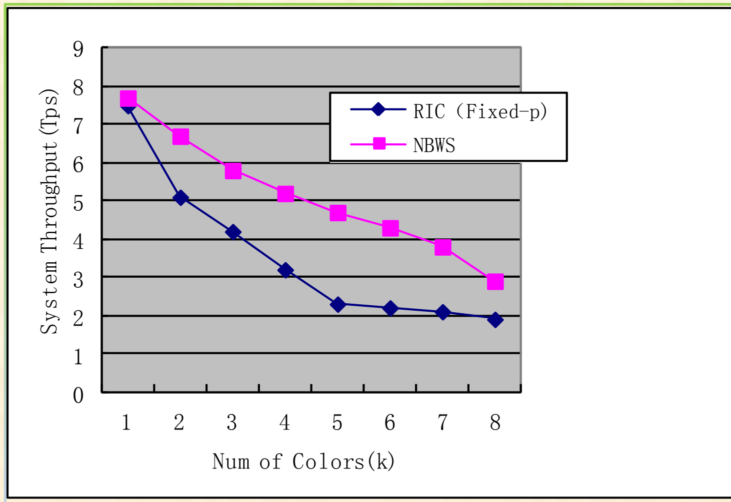
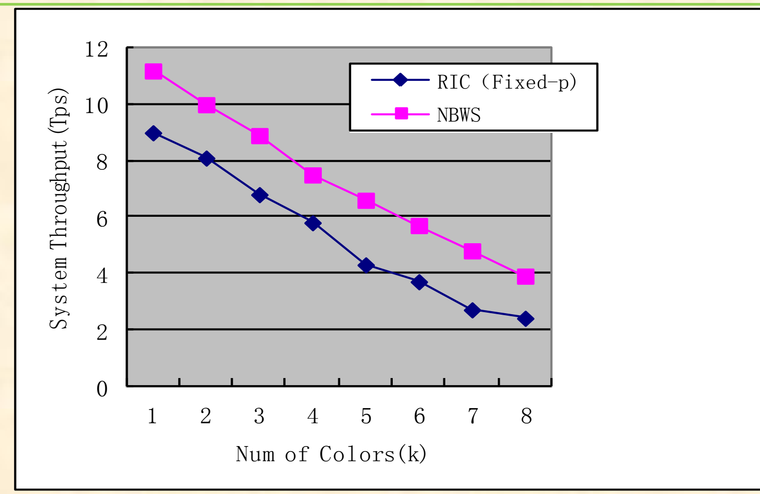


Fig.4 The superframe for Nest WBAN Scheduling

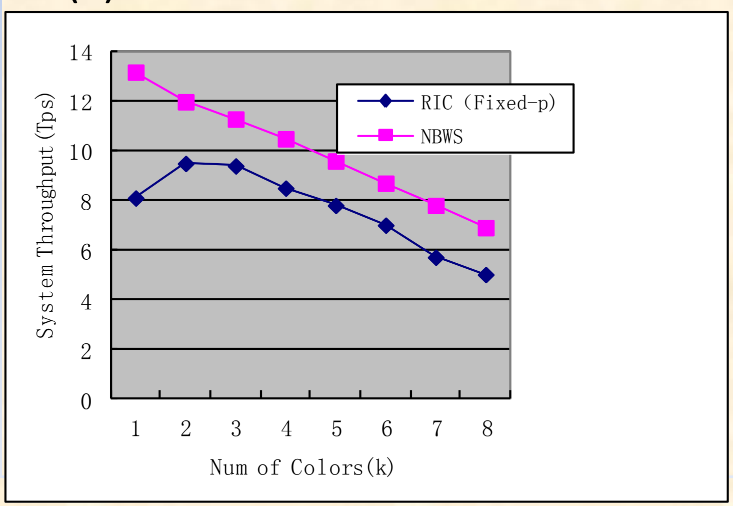
System throughput of WBAN scheduling with different WBAN densities



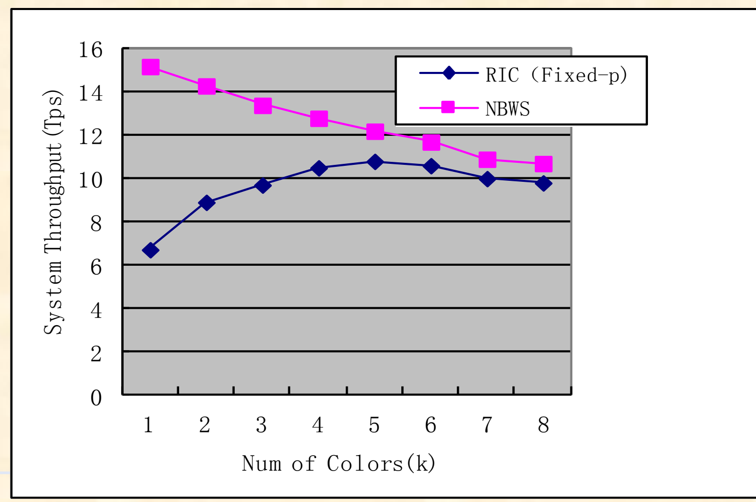
(a) low WBAN densities



(b) middle WBAN densities

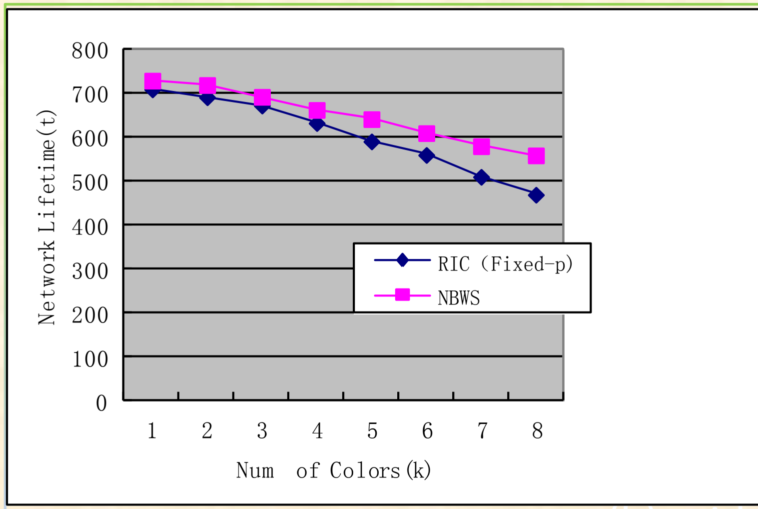


(c) high WBAN densities



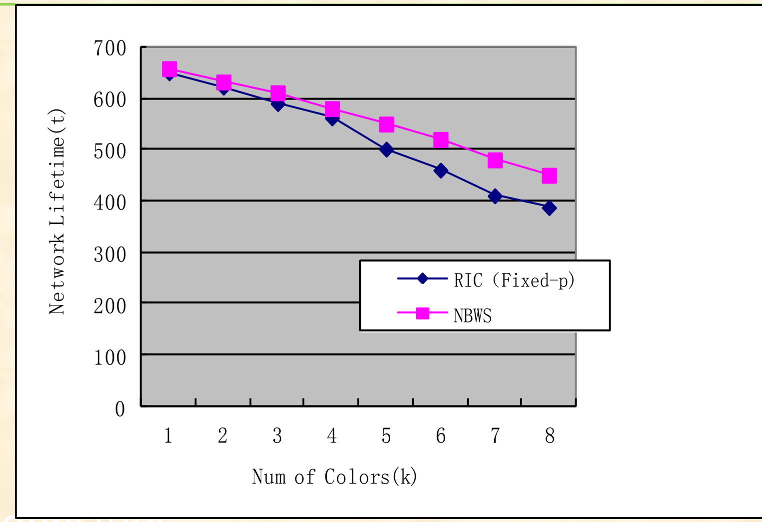
(d) extreme high WBAN densities

Network lifetime with different WBAN densities

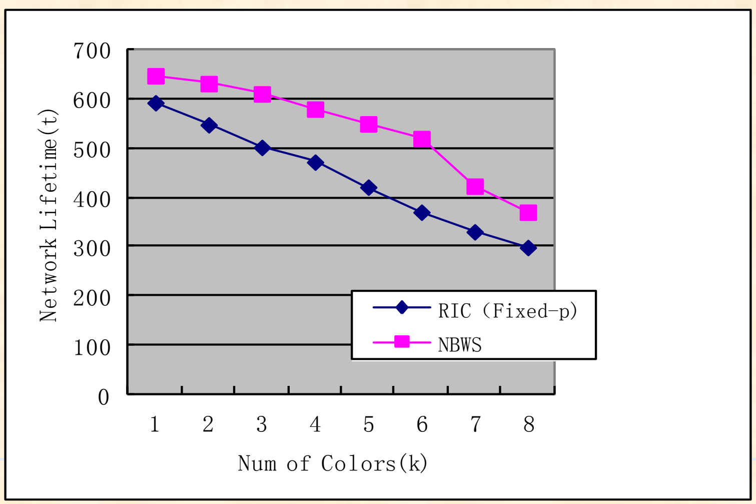


(a) low WBAN densities

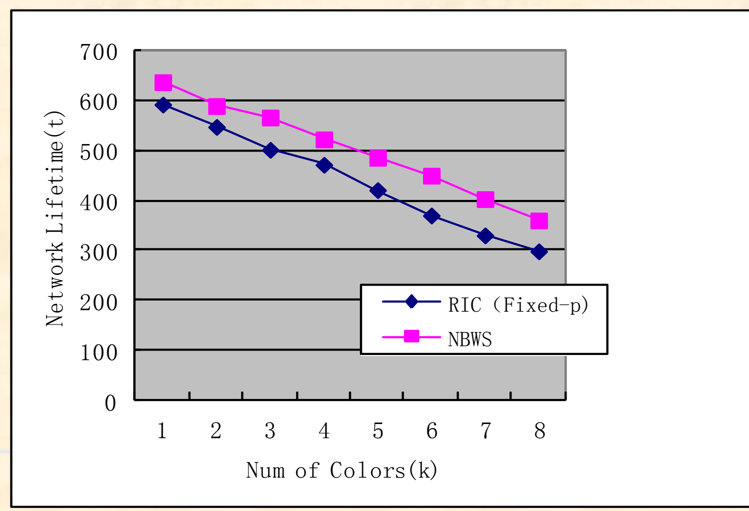
(b) middle WBAN densities



(b) middle WBAN densities



(c) high WBAN densities



(d) extreme high WBAN densities

Thank you!