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Mobility Prediction and Interference Avoidance for Reliable Communication in Dynamic WBAN

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Abstract

Recently Wireless Body Area Network (WBAN) became a major technology used for the assessment of Human body parameters where highly reliable communication is required for accurate health information. The major source of error that diminishes the reliability of communication is signal interference. In this paper, proposed a technique to estimate the link reliability of the dynamic nodes in WBAN using Markov chain model. For that, four states of WBAN nodes are considered based on node mobility; High speed, Low speed, Pause and Ideal states. Then, a physical interference model is proposed and properly devised the routing and link planning problem with the aim to improve the throughput.Later,the performance of the proposed model is validatedby comparing the simulated outputs with the existing model outputs. This proposed model exhibited better performance than the existing model in terms of interference mitigation, power consumption, Packet Delivery Ratio (PDR) and network lifetime.

Keywords—*WBAN, Sensor Networks, Sensor Mobility, Interference, PDR, Throughout, Delay Time, Dynamic Nodes, Reliable Communication*

INTRODUCTION

WBAN is the most admired means of communication in the fields of personal healthcare, sports, entertainment, etc., because of its ease of use and effective performance [1, 13, 15]. First, from the body sensors, the health information of patient is carried to Patient Care Unit (PCU) from there to Internet Access Point and then to Doctor or will be saved in Server [14, 16]. So, there should be a continuous and accurate data transfer otherwise the person under monitoring will be affected [2]. Due to interference, the network performance gets reduced resulting in the decrease of its reliability [3]. As shown in Fig. 1, when a WBAN sensor node (of WBAN1) enter into the signal coverage

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range of another WBAN (WBAN2) coordinator, there is a possibility of data transfer between them due to which the coordinator carries wrong information of that particular patient and vice versa [10, 12].

Interference in WBAN is of two types: mutual interference and cross interference [4, 18, 19]. If the interference to the node data transfer is because of the nodes within the WBAN or because of the coexisting WBANs, it is called mutual interference and the interference because of other networks operating in the same ISM band is called cross interference. Interference reduces the WBAN performance by degrading the packet transfer rate resulting in an increase in power consumption.

For seamless data transfer, an interference mitigation scheme needs to be implanted for a WBAN. The WBAN nodes do not always experience a similar kind of interference [4]. The interference on a node is not just because of the decisions of the nodes in that network but also because of operations of different coordinators. Implementing a mitigation scheme for a single central coordinator node cannot reduce the interference level as it does not have continuous control with the other networks [5].The operations of each WBAN should be adaptable with other nodes in the network. The conventional interference mitigation schemes such as antenna schemes and cellular network schemes cannot be adapted in WBANs because of the densely deployed nodes and high mobility of the nodes [22].

With high mobility, the network topology changes and the interference changes with the relative location of the nodes. For the effective functioning of a WBAN, mobility of the network is to be considered for implementation of interference mitigation scheme.

Generally, WBANs operate in 2.54GHz ISM band. Fig. 2 shows that, when a dynamic WBAN (WBAN1) enter into the vicinity of other dynamic WBAN (WBAN3) or when a dynamic WBAN (WBAN1) enter into the vicinity of a static WBAN (WBAN2), the nodes experience signal interference [8].

The authors'samanehmovassaghi, et al. developed a model for signal interference minimization considering the separation between communicating networks [4]. They have applied node-level power control using the "Sample and Hold" channel prediction method to manage the WBAN transmission power efficiently. Mohammad Faisal Uddin, et al. in their work demonstrated that bigger framework throughput can be accomplished when both the range width and information rate are considered as versatile in network design [6]. Samanehmovassaghi, et al. built an expectation calculation for dynamic channel assignment among existing together WBANs. This calculation catches the obscure dynamics and gives input to the coordinator of each WBAN and rapidly refreshes its channel assignment depending on the ongoing changes in the network, which lead to expanded system lifetime, huge energy savings and higher throughput [31].

RamtinKazemi, et al. proposed a non-cooperative power control game to reduce the cross Interference in WBAN and used pricing to handle the power constraints of WBANs [28]. The author proved that, even for increase in the number of users in the system, this method offered stable average capacity and power consumption.Tigang Jiang, et al. proposed a power control game technique for communal interaction to reduce cross interference in WBAN with innovative utility and cost functions. This method proved that the convergence is guaranteed with only one existing Nash equilibrium point [29]. ZilongJin,et al. proposed an algorithm to anticipate the coexistence state in multiple-WBAN situation by jointly applying the PRR, SINR and Previous state to a Bayesian classifier. This study helped in classifying the coexistence states [30].

The reliability and effectiveness of WBAN trusts upon how rapidly and precisely the system reacts to exchange information between the nodes, which inevitably relies upon the opted algorithms or routing protocols. The protocols that are used for Wireless Sensor Networks (WSNs) cannot be used for WBANs due to its precise requirements [25].

In this paper, we have presented a mobility prediction algorithm for WBAN nodes to estimate the link availability [26] by considering different states viz., high speed, idle speed, low speed and pause states as shown in Fig. 2. Adapting the mobility prediction algorithm, interference cancellation scheme is proposed and NS3 simulator is used to evaluate the algorithm in terms of Packet Delivery Ratio (PDR), Delay and Energy consumption. The next sections of the paper are as follows: The node mobility prediction is explained in section II. The proposed dynamic WBAN Signal interference cancellation technique is explained insection III. The path seek strategy is explained in section IV. The simulated results are explained in detail in section V followed by conclusions in section VI.

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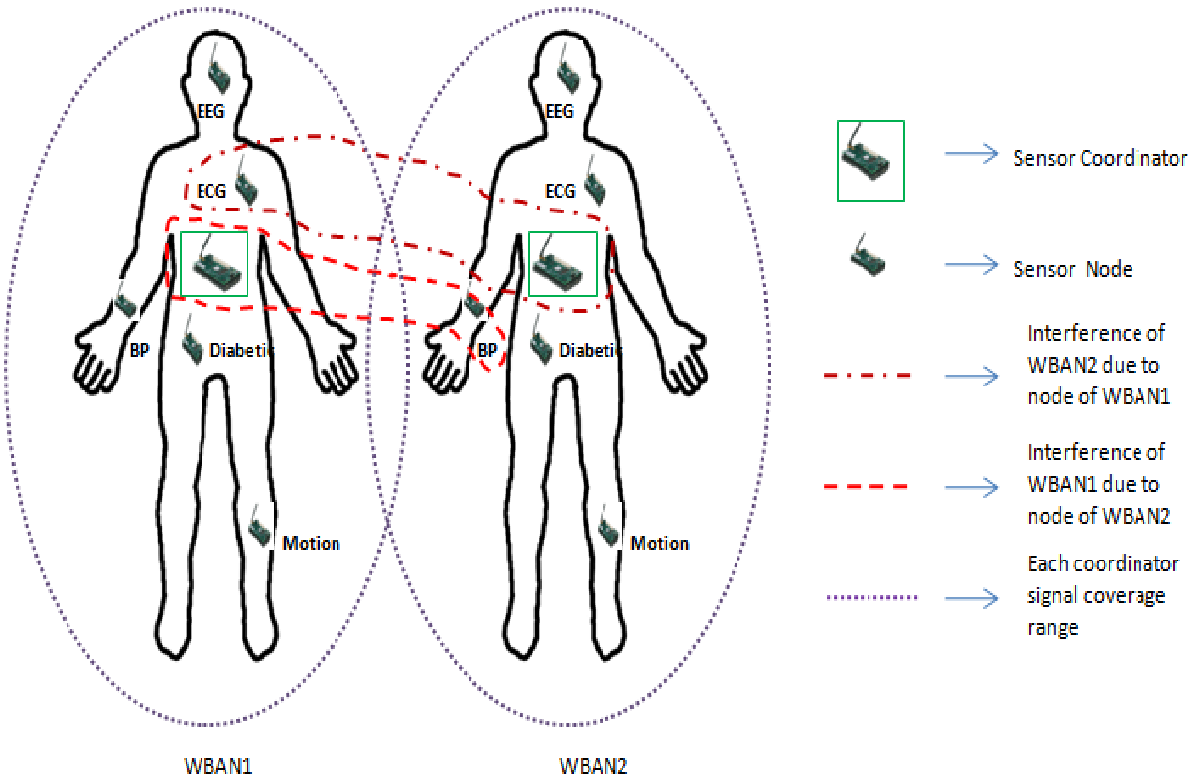

Fig. 1: Interference occurrence in WBAN [27]

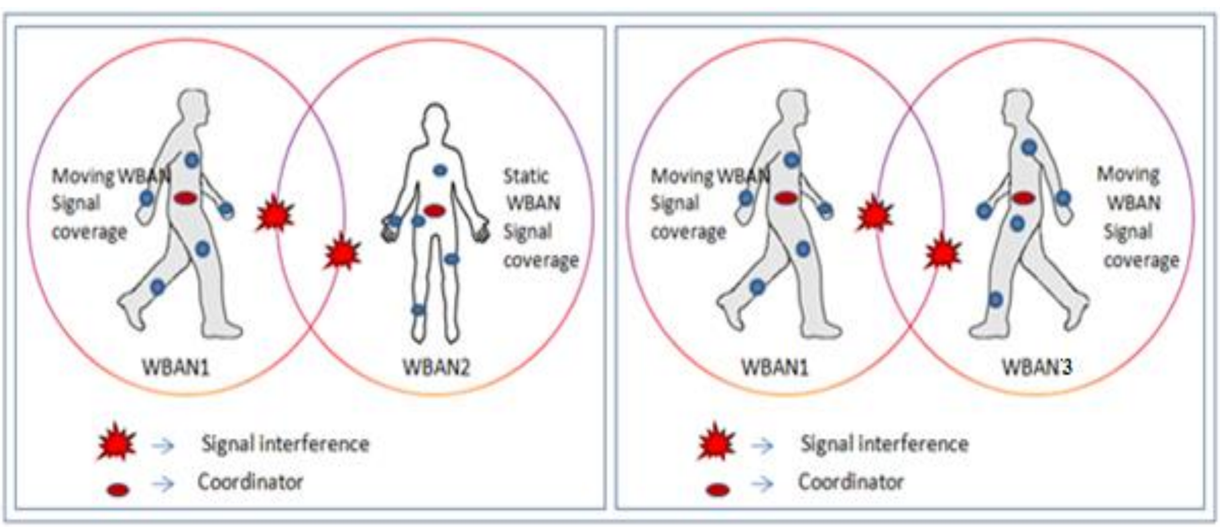

Fig 2: Interference in Mobile WBANs

I. Node Mobility Prediction

In our proposed work we have mainly considered two stages. They areNode Mobility prediction and Dynamic WBAN Signal Interference Cancellation (DWBANIC).

As discussed in the introduction mobility of the network is to be considered for implementation of interference mitigation scheme [23, 24]. In this regard, we are going to describe different mobility states of the nodes in dynamic WBANs in section II and the implementation of an effective interference mitigation scheme in sections III and IV. The node interference is more with low mobility and less with high mobility of WBANs.

A. Node Mobility prediction

Let us consider the mobility of WBAN sensor node as high speed, idle speed, low speed and pause states [24]. Movement of nodes is denoted as $X = \{H_\alpha, I_\beta, L_\sigma, P_\varphi\}$ respectively [17].

1) High speed state(H_α)

In this H_α state, node speed N_s will be uniformly accelerated from 0 to target value $N_{s\alpha}$. Consider, T_0, D_x, a_x and λ_x, which denotes, an initial time of S, the direction of moving, rate of acceleration and duration of this phase S_X, respectively. Where, $\{X \in \{\alpha, \beta, \sigma, \varphi\}\}$, λ_α, $N_{s\alpha}$ and D_α are distributed uniformly i.e. $\lambda_\alpha \sim \mathrm{U}(\lambda_{\alpha\min}, \lambda_{\alpha\max})$, $N_{s\alpha} \sim \mathrm{U}(N_{s\min}, N_{s\max})$ and $D_\alpha \sim \mathrm{U}(0, 2\pi)$.

If $T_\alpha = T_0 + \lambda_\alpha$; H_α will last for (T_0, T_α).

$$a_\alpha = \frac{N_{s\alpha}}{\lambda_\alpha};$$

Let *r(.)* denotes general probability density function and $r_V^X(N_s)$ denotes probability density function of N_s in S_X. Then $r_V^\alpha(N_s)$ can be derived as

$$r_V^\alpha(N_s) = \frac{2}{(N_{s\min} + N_{s\max})}, \text{if } 0 \le N_s \le N_{s\min}$$

$$= \left(\frac{2}{(N_{s\min} + N_{s\max})} \cdot \frac{(N_{s\max} - N_s)}{(N_{s\max} - N_{s\min})} \right), \text{ if } N_{s\min} \le N_s \le N_{s\max} \quad (1)$$

2) Idle speed state(I_β)

In this idle speed state, nodes are expected to move in straight line direction towards $D_{\beta E}$ and idle speed is $N_{s\beta}$ and its practical trajectory is acceptable to somewhatdeviation from $D_{\beta E}$ at any movement. To take in the transition from H_α to I_β, variation between $D_{\beta E}$ and D_α ought to be within D_d^β and it should be greater than 0 and also memory degree $\Upsilon (\Upsilon \in (0,1))$ will exist among $N_{s\beta}$ and $N_{s\alpha}$.

Let $T_\beta = T_\alpha + \lambda_\beta$;

$$\lambda_\beta \sim \mathrm{U}(\lambda_{\beta\min}, \lambda_{\beta\max})$$

$$D_{\beta E} \sim \mathrm{U}(D_\alpha + D_d^\beta, D_\alpha - D_d^\beta).$$

Consider F_0, a Gaussian random variable, which belongs to N(0,1) and initial node speed I_β(N_{s0}^β) equal to $N_{s\alpha}$ then $N_{s\beta}$ can be defined as below.

$$N_{s\beta} = \Upsilon N_{s0}^\beta + ((1-\Upsilon) N_{s\alpha}) + \sqrt{1-\Upsilon^2 F_0}$$
$$= N_{s\alpha} + \sqrt{1-\Upsilon^2 F_0}$$

Now

$$r_V^\beta(N_s) = \frac{\left(G\left(\frac{(N_s - N_{s\min})}{(\sqrt{1-\Upsilon^2})} \right) - G\left(\frac{(N_s - N_{s\max})}{(\sqrt{1-\Upsilon^2})} \right) \right)}{(N_{s\max} - N_{s\min})} \quad (2)$$

Where,

$$G(x) = \left(\frac{1}{\sqrt{2\pi}} \right) \int_{-\infty}^{x} \exp((-y^2)/2) dy$$

From the above equation, the main difference between I_β and middle smooth phase is, that I_β exclusively uses above equation to devise $r_V^\beta(N_s)$ for the complete phase period, while middle smooth model extends I_β to a multi-state Gauss-Markov process [21].

3) Low speed state(L_σ)

In L_σ, N_s decelerate uniformly from N_{s0}^σ to 0.

Now $T_\sigma = T_\beta + \lambda_\sigma$;

$$\lambda_\sigma \sim \mathrm{U}(\lambda_{\sigma\min}, \lambda_{\sigma\max})$$

$$N_{s0}^\sigma = N_{s\beta}$$

$$a_\sigma = \frac{N_{s0}^\sigma}{\lambda_\sigma}$$

$$D_\sigma \sim \mathrm{U}(D_{\beta E} + D_d^\sigma, D_{\beta E} - D_d^\sigma).$$

Where D_d^σ can deviate range from D_σ and $D_{\beta E}$.

Let $F_0 = \sqrt{1-\Upsilon^2 F_0}$ then $F_0 \sim \mathrm{N}(0, 1-\Upsilon^2)$.

First F_0^σ is mainly determined by $N_{s\alpha}$, so we can assume F_0^σ is also uniformly distributed as $N_{s\alpha}$.

Based on "3-σ" rule, thepossibility of h falling exterior of (μ-3σ, μ+3σ) is less than 3 percentage when

$h \sim N(\mu,\sigma^2)$. So we can assume $F_0 \in \left[-3\sqrt{1-Y^2}, 3\sqrt{1-Y^2}\right]$.

Based on the above assumption,

$$F_0^{\sigma} \sim U\left[N_{s\min} - 3\sqrt{1-Y^2}, N_{s\max} + 3\sqrt{1-Y^2}\right]$$

and

$$P(F_0^{\sigma} \geq N_s) = \frac{(N_{s\max} + 3\sqrt{1-Y^2} - N_s)}{(N_{s\max} - N_{s\min} + 6\sqrt{1-Y^2})}$$

Since L_{σ} has symmetric properties with H_{α}, we can derive $r_V^{\alpha}(N_s)$ as follows [7].

$$r_V^{\alpha}(N_s) = \frac{2}{(N_{s\min} + N_{s\max})}, \text{ if } 0 \leq N_s \leq N_{s\min}^{low}$$

$$= \left(\frac{2}{(N_{s\min} + N_{s\max})}\right) P(F_0^{\sigma} \geq N_s), \text{if}$$

$$N_{s\min}^{low} \leq N_s \leq N_{s\max}^{high} \qquad (3)$$

Where,

$N_{s\min}^{low} = N_{s\min} - 3\sqrt{1-Y^2}$ and

$N_{s\max}^{high} = N_{s\max} + 3\sqrt{1-Y^2}$.

The assumption here is, F_0^{σ} is useful only inside L_{σ} and it will not affect $r_V^{\beta}(N_s)$ for I_{β}.

4) Pause state (P_{φ})

In pause state, P_{φ}, nodes will pause for a random interval $[T_{\sigma}, T_{\varphi}]$, where $\lambda_{\varphi} \sim U(\lambda_{\varphi\min}, \lambda_{\varphi\max})$, $T_{\varphi} = T_{\beta} + \lambda_{\varphi}$, before restarting a new moving cycle. So, mobility is zero in this state.

Based on the above derivations for different mobility parameters, we can estimate the link reliability as follows [20].

Let us consider from the Fig. 3, V_i, V_j and $\vec{V}$ as the pace of nodes N_i, N_j and their relative speed, respectively. $\Psi \sim U(\pi, \pi)$, φ, μ and R as the angle from V_i to V_j and angle from V_j to $\vec{V}$, N_i's true direction to N_j and range of node transmission.

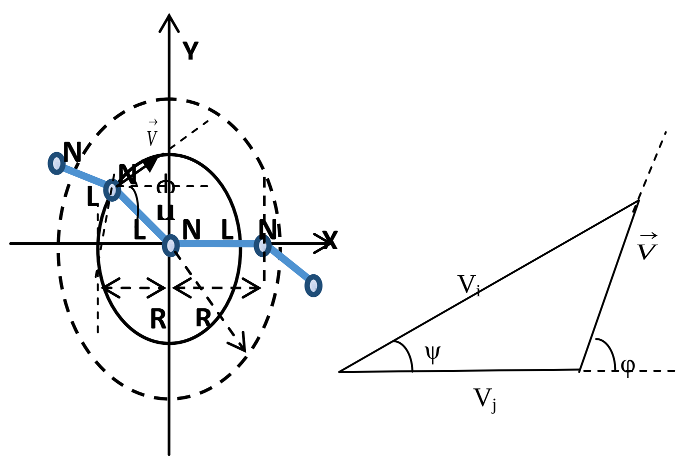

Fig. 3: Estimating parameters of WBAN node mobility

If L_{ij} is the link from N_i to N_j, RLL_{ij} is the Residual Link Lifetime (RLL) of L_{ij} and F(.) is the Cumulative Distribution Function (CDF). By using that we can derive

$$FRLL_{ij}(T_{ij}) = P\left(\frac{R_{ij}\cos(\varphi+\mu) + \sqrt{R^2 - R_{ij}^2 \sin^2(\varphi+\mu)}}{N_s} \leq T_{ij}\right) \qquad (4)$$

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If μ, $R_{ij,}$ i.e. the original distance of $L_{ij}$are known in the above equation then we can calculate the randomness of V and φ using $f_{V,\varphi}(N_s,\varphi)$

$$FRLL_{ij}(T_{ij}) = \int_{-\pi}^{\pi}\int_{w}^{N_{\sup}} f_{V,\varphi}(N_s,\varphi)dN_s d\varphi \tag{5}$$

Where,

$$w = \frac{\left(R_{ij}\cos(\varphi+\mu)+\sqrt{\mathrm{R}^2 - \mathrm{R}_{ij}^2\sin^2(\varphi+\mu)}\right)}{T_{ij}}.$$

$N_{\sup}$ is V's upper limit of V_i and V_j in specific S_X.

So,

$$V = \sqrt{V_i^2 + V_j^2 - 2V_iV_j\cos\psi}$$

As we have already derived the equationsfor speed of nodes in different criteria, by using them we can give the final equation as

$$f_{V,\varphi}(N_s,\varphi) = \int_{N_{sj}} \frac{N_s r_{Vi}^m(N_{si}^*) r_{Vj}^n(N_{sj})}{2\pi\sqrt{N_s^2 + N_{sj}^2 + 2N_sN_{sj}\cos\varphi}} dN_{sj} \tag{6}$$

Here, $N_{si}{*} = \sqrt{N_s^2 + N_{sj}^2 + 2N_sN_{sj}\cos\varphi}$, $r_{Vi}^m(N_{si}^*)$ and $r_{Vj}^n(N_{sj})$ where m and n$\in\{H_\alpha, I_\beta, L_\sigma, P_\varphi\}$.

If link reliability of previous link RLL is longer than the threshold T_{tr}. Then Link reliability of two links i and j can be derived as

$$LR_{ij} = P(RLL_{ij} \geq T_{tr}) = 1 - FRLL_{ij}(T_{tr}). \tag{7}$$

The above equation is computed by substituting $f_{V,\varphi}(N_s,\varphi)$ inside $FRLL_{ij}(T_{ij})$.

B. Energy efficiency

Let $P(V_0,V_k)$ be the path between node V_0 and V_{kc}, it is represented by $P(V_0,V_k) = V_0,V_1,...V_k$. The energy path cost is represented by $e_cP(V_0,V_k)$ and it is described as

$$e_cP(V_0,V_k) = c(V_0,V_1) + c(V_1,V_2) + ... + c(V_{k-1},V_{k-1}) + ... + c(V_{k-1},V_k)$$

$$e_cP(V_0,V_k) = \sum_{i=0}^{k-1} c(V_i,V_{i-1}) \tag{8}$$

Consider the remaining energy path as $r(P(V_0,V_k))$ which is described as:

$$r(P(V_0,V_k)) = \min(E_t(V_i) - c(V_i,V_{i+1})),\ 0 \leq i \leq k \tag{9}$$

The energy restrictions that need to be followed while routing a data packet from the transmitterto its recipientare as follows [6].

$Min(e_cP(V_0,V_k)) = \sum_{i=0}^{k-1} c(V_i,V_{i+1})$ is used to select a minimum energy path and to select maximum energy path $Max(r(P(V_0,V_k))) = r(P(V_0,V_k))$ is used.

To find minimum residual path, $Min(e_cP(V_0,V_k)) = \min((E_{threshold} - c(V_i,V_{i+1}))$ is used. Where, $E_{threshold} = E_r(V_i)/Deg(V_i)$, in which, $Deg(V_i)$ is the degree of i[th] node V and $E_r(V_i)$ is the residual energy of i[th] node V.

II. Dynamic WBAN Signal Interference Cancellation

Two noteworthy techniques have been generally utilized in the writing for interference mitigation; to be specific they are Protocol Technique and Physical Interference (PI) technique. The first technique is very simple but does not provide precise output whereas the second one is very complex but provides precise portrayal and is the one considered for our work. In our technique, the transmission is effective only if the Signal to Noise Interference Ratio (SNIR) at the recipient of the interest is over a specific limit in the sight of simultaneous transmissions on adjacent links [10]. Likewise, we have assumed that every node that makes transmission accepts different modulations/coding methods, each chosen from a limited set S. The PI technique can be defined as

$$\mathrm{SNIR}_{t(i),r(i)}(s_i) = \frac{PG_{t(i),r(i)}}{\eta + \sum_{n\in N_D\setminus t(i)} PG_{n,r(i)}} \geq \Psi(s_i) \tag{10}$$

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where N_D is the collection of every dynamic node within the network, r(i) and t(i) represents the recipient and sender of link i. $\Psi(s_i)$ is the base SNIR limit that must be kept to help maintaining a transmission information rate of $s_i(s_i \in S)$ of link iat the same time ensuring a fair Bit Error Rate (BER). Consider the base SNIR limit required for effective transmission is more than 1, which if not met, the link can't continue the chosen modulation/coding and so arrived packet can't be effectively separated from the arrived signal. To avoid this and to adjust for the high interference occurred by nearby transmissions, the transmitter must transmit withlesser bit rates $s_i<s_i$, with the end goal that$\mathrm{SNIR}_{t(i),r(i)}(s_i) \geq \Psi(s_i)$.

Using an interference mitigation technique, a signal will be decoded effectively within the presence of other transmissions. Initially, a combined signal is received, from which the receiver begins decoding the robust signal which will be separated from the initial signal and this process continues with the remaining signal until the intended signal is decoded. Next, the SNIR limitations are defined under the effect of interference mitigation. Let us assume two links i and i nearby one another and their relating information rates are s_i, s_i. The signal strengths arrived at recipient r(i) from t(i) are considered as $SSe^1_{r(i)}, SSe^2_{r(i)}$ (in order from t(i)) and assume $SSe^2_{r(i)}>SSe^1_{r(i)}$. Now, the first robust signal from t(i) will be decoded by r(i),which will be done only if:

$$\mathrm{SNIR}^2{}_{t(i'),r(i)}(s_i') = \frac{SSe^2_{r(i)}}{\eta+SSe^1_{r(i)}} \geq \Psi(s_i') \quad (11)$$

After successfully decoding the first robust signal from t(i), r(i) will be subtracted from the collective signal and will endeavour to unravel the next signal transmitted by t(i):

$$\mathrm{SNIR}^1{}_{t(i),r(i)}(s_i) = \frac{SSe^1_{r(i)}}{\eta} \geq \Psi(s_i) \quad (12)$$

In our work, the journey is to appropriately plan transmission links and choose rates for transmission within the sight of interference mitigation ability which is a challenging issue. Note that while interference mitigation permits numerous simultaneous transmissions, every transmission might be liable to elevated interference; which may constrain senders to send the signals with lesser bit rates to satisfy the SNIR prerequisites at their relating recipients. Fewer bit rates make the transmissions last longer, causing expanded times of spectrum usage.

Consider an arrangement of dynamic links such that each link must meet the SNIR limit relating to the chosen link transmission rate. Consider FC as the list of all possible arrangements and Θ_p as the part of time distributed to each possible arrangement p. Here, $\Theta_p = 0$ if p ∈FC is not planned; therefore

$$\sum_{p\in FC} \Theta_p \leq 1 \quad (13)$$

If a link i with rate s in an arrangement p is dynamic then binary variable, D^p_{is}=1, else it is 0. Similarly, if t(j) is adynamicsender in p then binary variable $u^p_{t(j)s} = 1$, else it is 0. Also, consider a set of links X^+_n with node n as transmitter and another set $X^-_n$with node n as a recipient. Thus, we have:

$$u^p_{t(k)s} = \sum_{i\in X\ t(k)} D^p_{is} \ (\forall k \in X, s \in S, p \in \mathrm{FC}) \quad (14)$$

$$= \sum_{i\in X^+_n} \sum_{s\in S} D^p_{is} \leq 1 \ (\forall n \in N, p \in \mathrm{FC}) \quad (15)$$

The half-duplex imperatives considered at every node can be composed as:

$$\sum_{s\in S} D^p_{is} + \sum_{s\in S} D^p_{js} \leq 1 \ (\forall n\in N, i\in Xn-, j\in Xn+, p\in \mathrm{FC}) \quad (16)$$

Also, consider the concept of residual SNIR. The interference mitigation ability makes it possible for the recipient node to drop every strongest signal compared to the intended signal. So, we just have to care about the interference from transmitters withweedy signals than that of the expected one. The residual SNIR is characterized as

$$r_{\mathrm{SNIR}^p{}_{t(i),r(i)}}(s) = \frac{PG_{t(i),r(i)}}{\sum^{G_{t(k),r(i)}\leq G_{t(i),r(i)}}_{K\neq i,t(k)\neq t(i)} \sum_{s\in S} PG_{t(k),r(i)} u^p_{t(k)s} + \eta} \quad (\forall i \in X, k \in X, s \in S, p \in \mathrm{FC}) \ (17)$$

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Without a doubt, when the planning variable $D_{is}^{p} = 1$ (i.e., when link i is dynamic), it is comprehended that all other robust signals received at r(i) from neighboring senders have been decoded effectively including the signal of interest at the link i. In particular, if $D_{is}^{p} = 1$, at that point the below mentioned two imperatives ought to be fulfilled:

$$r_{\mathrm{SNIR}\,{}^{D}{}_{t(i),r(i)}}(s) \geq \Psi(s), if\ D_{is}^{p} = 1, s \in S, i \in X \quad (18)$$

$$r_{SNIR^{D}{}_{t(i),r(i)}}(s^{'}) \geq \Psi(s^{'}), ifj \neq i, t(j) \neq t(i), G_{t(j),t(i)} \geq G_{t(i),t(i)}, D_{is^{'}}^{p} = 1,\ s^{'} \in S, i \in X \quad (19)$$

The constraints in equations (18) and (19) can be converted to Integer Linear Programming (ILP) arrangement, by defining a binary variable $\rho_{i,t(j)}^{ssp}$ to describe the relationship ofD_{is}^{p} and $u_{t(j)s}^{p}$. Note that $\rho_{i,t(j)}^{ssp} = 1$ if and only if $D_{is}^{p} = 1$ and $u_{t(j)s}^{p} = 1$. Then:

$$D_{is}^{p} \geq \rho_{i,t(j)}^{ss^{'}p} \quad (20)$$

$$u_{t(j)s^{'}}^{p} \geq \rho_{i,t(j)}^{ss^{'}p} \quad (21)$$

$$\rho_{i,t(j)}^{ss^{'}p} \geq D_{is}^{p} + u_{t(j)s^{'}}^{p} - 1 \quad (22)$$

Using equations (20)–(22), we can now rewrite equations (18) and (19) into the ILP constraints as shown in equations (23) and (24), which can be easily verified by using the binary values of the planning variables

$$PG_{t(j),r(i)} - \sum_{t(k)\neq t(j)}^{G_{t(j),r(i)}\geq G_{t(k),r(i)},} \sum_{s^{'}\in S} \Psi(s^{'}) PG_{t(k),r(i)} u_{t(k)s^{'}}^{p} - \Psi(s^{'})\eta \geq (1 - \rho_{i,t(j)}^{ss^{'}p})\, M_{i,t(j)}^{s,s^{'}}$$

$$M_{i,t(j)}^{s,s^{'}} = PG_{t(j),r(i)} - \sum_{t(k)\neq t(j)}^{G_{t(j),r(i)}\geq G_{t(k),r(i)},} \sum_{s^{'}\in S} \Psi(s^{'}) PG_{t(k),r(i)} - \Psi(s^{'})\eta \quad (23)$$

$$PG_{t(i),r(i)} - \sum_{t(k)\neq t(i)}^{G_{t(j),r(i)}\geq G_{t(k),r(i)},} \sum_{s^{'}\in S} \Psi(s) PG_{t(k),r(i)} u_{t(k)s}^{p} - \Psi(s)\eta \geq (1 - D_{is}^{p}) H_{is}$$

$$H_{is} = PG_{t(j),r(i)} - \sum_{t(k)\neq t(j)}^{G_{t(j),r(i)}\geq G_{t(k),r(i)},} \sum_{s^{'}\in S} \Psi(s) PG_{t(k),r(i)} - \Psi(s)\eta \quad (24)$$

For this model, all the arrangements in FC should be generated to get the solution, which is computationally infeasible. Generally, a subset of all arrangements is used to get the optimal solution. To solve this issue an approach is introduced in the next section.

III. Ravenous Hunt Strategy

Here we have instated Limited Master (LM): a subset of columns (the basis P_0 which is a subset of all arrangements, $P_0 \subseteq S$) of the linear program and is effortlessly solved to acquire a feasible solution. Having solved the master problem, the optimality of the solution needs to be verified during every iteration. If not optimal, select a new column to get added to the basis to improve the solution or else conclude the search. This can be accomplished by looking at whether any new column that isn't at present in P_0 has a negative decreased expense.We have built an easier path-based ravenous hunt strategy for taking care of the expense issue [9]. It is described as follows:

1. After understanding the Limited Master in one cycle, we have included every single doable link with non-zero dual variables in a set calledInitial People Set (IPLS). A similar link however with dissimilar transmission rate whose dual variables are not zeroalso should be included in the IPLS list.
2. A link x is described with 3-variables r(x), t(x), s_x,where,r(x), t(x), and s_x are the link recipient,sender and transmitting rate, respectively.
3. Every link is given with a weight,w_x and all the links in the IPLS are arranged in decreasing order of weights.
4. The goal is, creating a design with much-Decreased Expense (DE),which can be utilized by the limited master to enhance its outcome. Henceforth, link weights ought to be characterized with an approach to guide the hunt to get a better doable plan. Dual variables and transmission rates together have a noteworthy job in characterizing the goodness of the setup, consequently$w_x = |s_x\sigma_x|$.

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Our ravenous technique comprises of two methodologies; Path development and Path seek.

A. Path development

The IPLS is indicated by a path P established at node R. Every component of IPLS is a kid (K_i) of R; the furthest left kid becomes the link with maximum weight and the furthest right kid becomes the link with minimum weight. At level 1, the furthest left kid is the parent of the rest of the links in IPLS aside from the ones with similar transmitter/recipient. Set s_kid(x) describes the arrangement of kids of a node x, whose components are links in IPLS. In the event that x is a leaf node, at that point s_kid (x) is vacant. To outline, at first consider IPLS contains links l1 to l3 with weights w1 > w2 > w3.

B. Path Seek

When the path is built, next we will do path travel to seek for a design with negative DE. The path travel fills in as pursues. A list named Current Link Set (CLS) is kept up for every node x which contains active links in its path. At first, CLS = {}, for the first node. For nodes at level 1, CLS list includes just a single component related to the link in IPLS speaking to that node. The path travel begins at first node, checking the furthest left kid and assessing the DE in articulation as underneath.

$$DE = \delta + \sum_{i \in X} \sum_{s \in S} D_{is}^{p} s\sigma_i \quad (25)$$

Where δ is the present value of the limitedmaster.

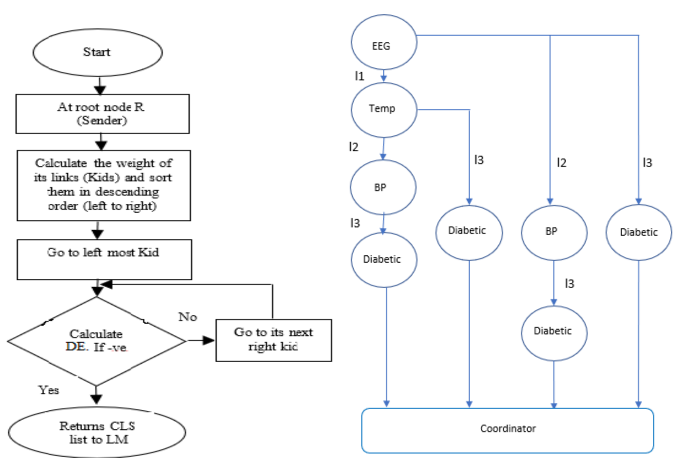
C. Link Doability Check

At the point with a goal to boost DE, the regular rotating guideline of the basic strategy is to pick the column (in S) where $\sum_{i \in X} \sum_{s \in S} D_{is}^{p} s\sigma_i$ is minimum.

On the off chance,if DE is negative, the travel ends; and the CLS at that particular node is returned as another setup to the limited master. Otherwise, test the kids of that node beginning with the furthest left one.

For every kid, produce a CLS by adding that link to its parent CLS list andverify the achievability of the new CLS set utilizing a doability check work. In the event that the SNIR requirements are fulfilled, at that point, the DE of the new simultaneous list is assessed. In the event that it is negative, at that point we end our hunt and restore the new arrangement to the limited master. On the off chance, if DE isn't negative, at that point we continue by examining the kids of the present node. If the SNIR imperatives are not fulfilled, at that point the travel continues by examining the rest of the kin until a setup with a DE < 0 is found. Note that, in the most pessimistic scenario, an entire path travel is executed. The Flowchart for this entire technique is shown in Fig. 4(b).

Consider an example of sensor nodes of a WBAN as shown in Fig. 1 and the path development between the nodes is shown in Fig. 4(a). EEG acts as parent node (sender) whereas Temp, BP and Diabetic sensors act as kids to EEG. As explained above the path between EEG and coordinator is established in such a way that the links with less interference and more transmission rates are selected for transmission of information which improves the accuracy and speed of transmission.



(a) (b)

Fig 4: (a) Flow chart of Ravenous Hunt Strategy method (b) Example for Path Development.

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Subsequently, a link doability check work is developed for verifying the activeness of the links in the present arrangement (CLS) and also to check whether they are decodable or not[11,12]. Here, Half Duplex strategy is used which guarantees that a node can't be both transmitter and recipient in the meantime.

At that point, the calculation recognizes the transmitters and collectors of every link in CLS into two sets, the Transmitter Set (TS) and the Recipient Set (RS). For every recipient in RS, we locate the gotten signals from every one of the transmitters in TS and sort them as indicated by the strength of the signals and do decoding using SIC until the intended signal is decoded or the decoding is not possible telling that CLS isn't doable. The procedure rehashes on every recipient of every link in the CLS set.

IV. Results and Discussion

With the end goal to assess the execution of the proposed technique, we have played out its recreation utilizing NS3 simulator. We have looked at the execution of the proposed method i.e. DWBANIC comparing with Power control utilizing SMAC, SCA and RPGM method in terms of WBAN energy consumption, communication delay, and PDR. The parameters considered for simulation are as follows. NS3 Simulator is used with a simulation time of 130seconds considering 9 nodes per WBAN along with a single coordinator. A total of 10 WBANs are considered with IEEE 802.15.4 MAC layer protocol. Also, packet size of 512bytes at a rate of 4packets/sec and opening energy of 50Joules are considered.

Fig. 5demonstrates the transmission delay for each sensor nodeof WBAN versus the simulation time for the proposed and previous methods. Delay is reduced by half the amount in DWBANIC method compared to the previous method since we, as a rule, don't look through the entire path, rather we seek just piece of it to figure the DE.

Fig. 6 depicts the percentage of PDR with respect to simulation time. Clearly, PDR is more for DWBANIC method which proves that this method cancels the interference more efficiently than the previous method.

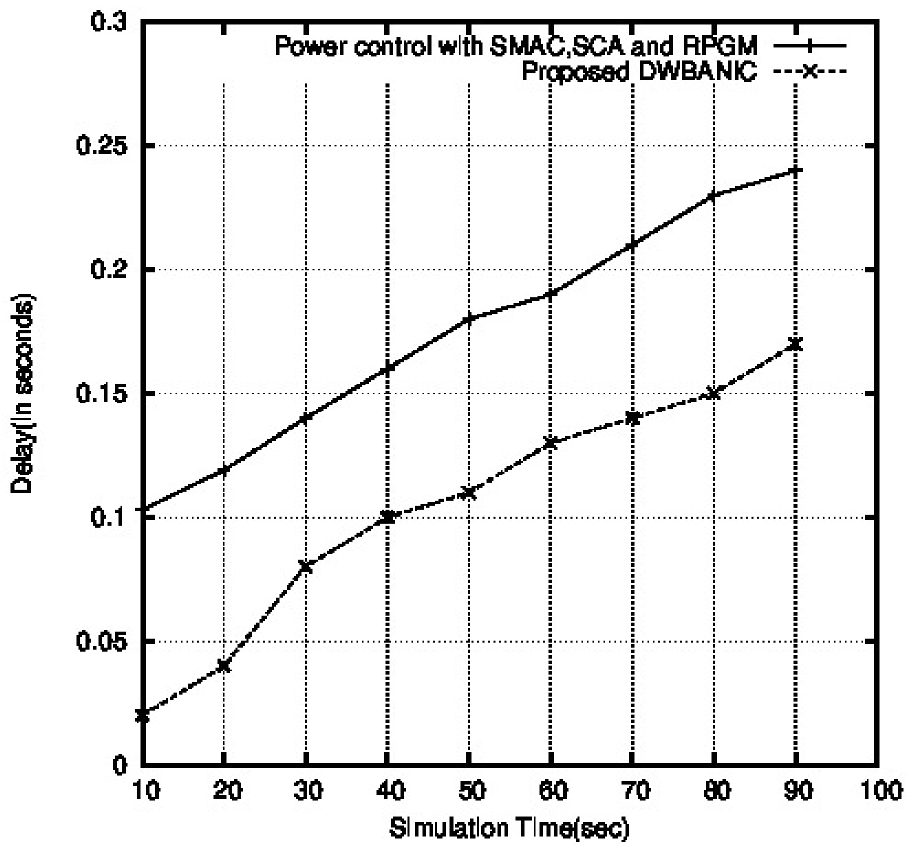

Fig. 5: Delay versus simulation time

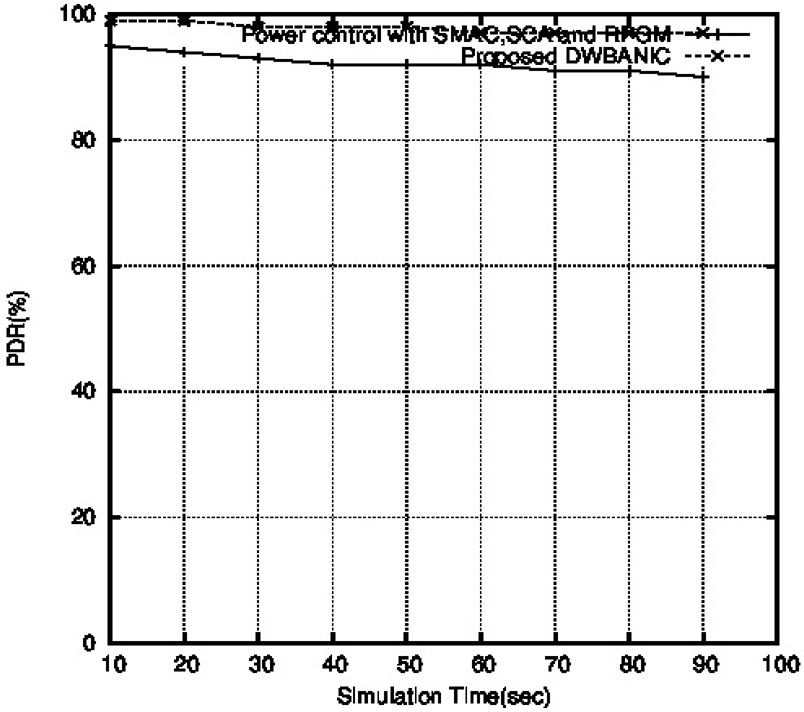

Fig. 6: Percentage of PDR versus Simulation time

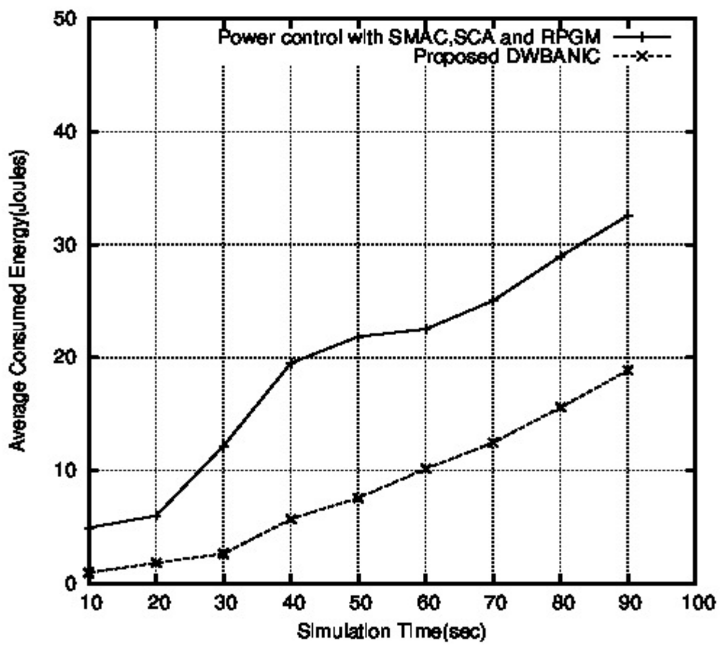

Fig. 7: Average energy consumed versus Simulation time

Fig. 7 depicts the energy consumed as average at WBAN node versus the simulation time. Compared to previousmethod, changes in energy consumption are almost linear in DWBANIC and it is less than 30Joules only.

Next, we have used multiple coexisting WBANs to evaluate the performance of the proposed method ranging from 2 to 10.

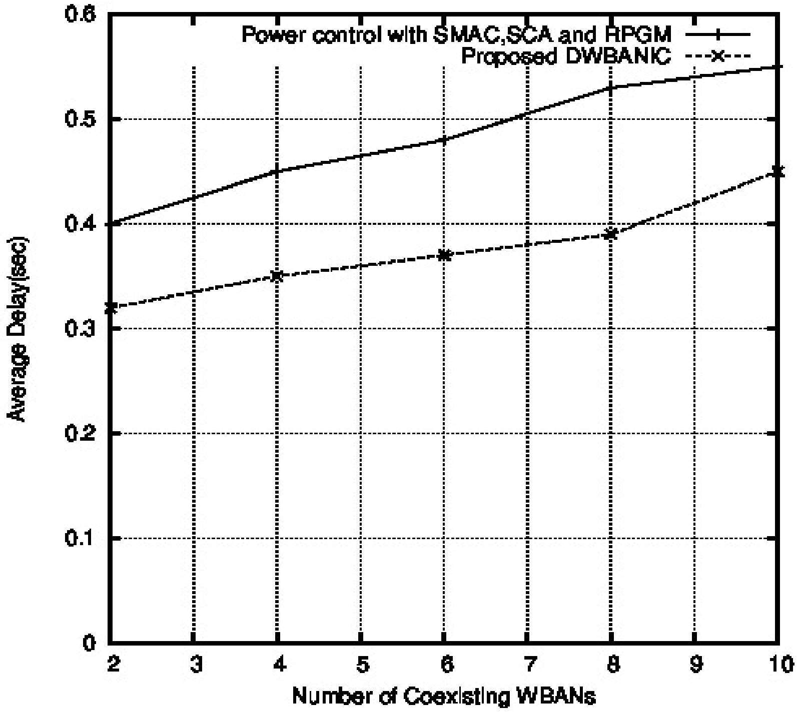

Fig. 8: Average delay versus multiple coexisting WBANs.

Fig. 8 explains the amount of average delay versusmultiple coexisting WBANs.The figureillustrates that the average delay increases slightly witha number of coexisting WBANs which is negligible with the obtained throughput.

Fig. 9 depicts the average PDR versus multiple coexisting WBANs. As per the IEEE 802.15.6 standards, PDR should be accurate and more. With the proposed method the PDR is 98% which is more than the specification of IEEE 802.15.6 standard. It is proved that efficient interference cancellation with our DWBANIC method leads to more PDR.

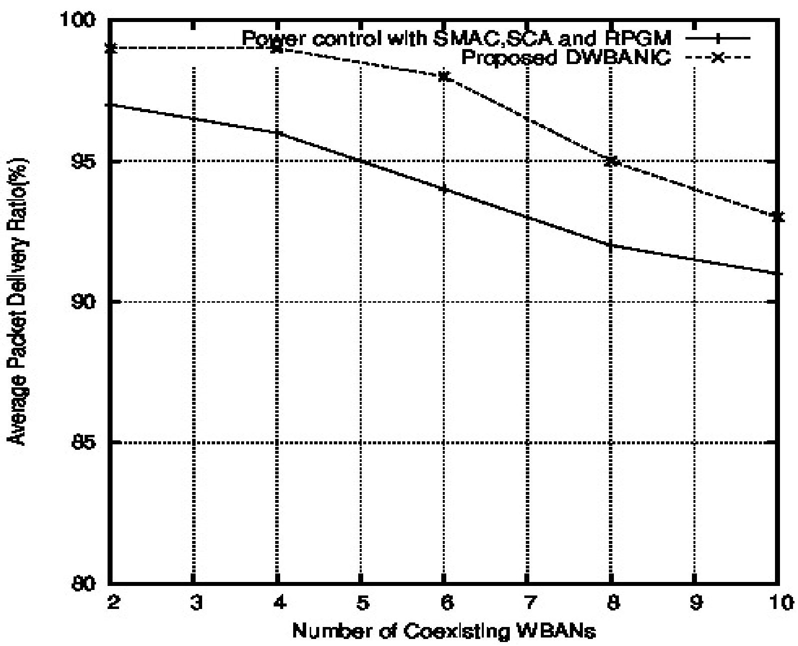

Fig. 9: Average PDR versus the No. of Coexisting WBANs.

Fig. 10demonstrates the average power consumedversusmultiple coexisting WBANs. It is clear thatpower consumption increases proportionally with the number of WBANs and there is a slight decrement in the consumed powerwith the DWBANIC method because the network dynamics has been very much anticipated and dealt ahead of time.

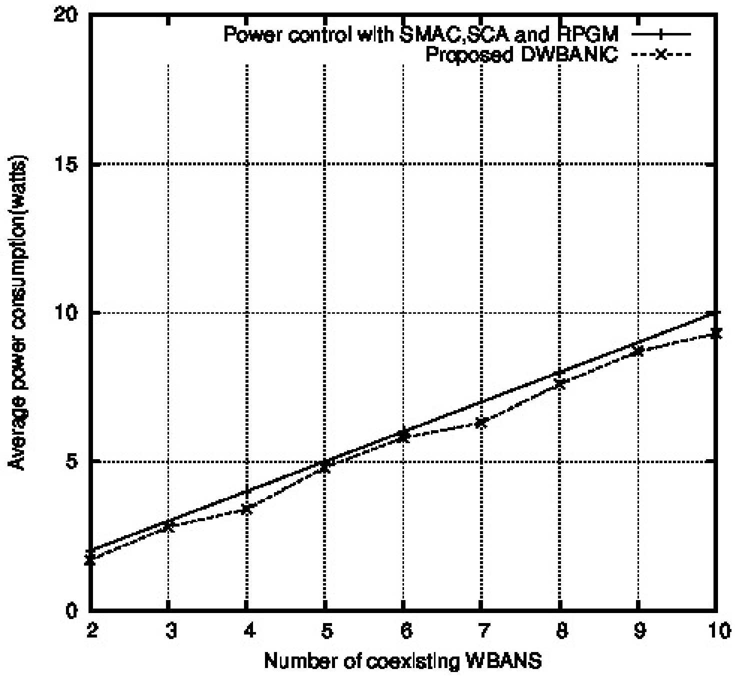

Fig. 10: Power consumed (Average) versus multiple Coexisting WBANs.

V. Conclusion

In our proposal, we have used a physical interference model and demonstrated that our methodology kept up the best possible spatial reuse with a scope of channel dynamics inside, and among coexisting WBANs. This convention dependent on socialcommunication is appeared to reduce interference, limit power consumption and improve the PDR while expanding the network lifetime. In this perspective we have furnished significant information from literature. First, we have built the interference model and presented a prediction algorithm for mobility of WBAN sensor nodes at different speeds. Next, exhibited a procedure for interference cancellationusing DWBANIC techniqueand properly devised the routing and link planning problemto improve the reliability in communication. NS3 simulator is utilized to check the rightness of our proposed model. The viability of the proposed model is exhibited through exhaustive outcomes indicating the wholeadvantages of the system by means of energy consumption, PDR and delay.

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