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동적 무선 인체 통신망의 에너지 효율과 신뢰성을 위한 토폴로지 인식 기반 패킷 크기 및 포워딩 비율 결정 방법☆

Topology-aware Packet Size and Forward Rate for Energy Efficiency and Reliability in Dynamic Wireless Body Area Networks

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요 약

인체에 부착된 센서들의 위치는 인간의 신체적 활동에 따라 자주 이동된다. 이에 따른 노드 위치 이동과 비가시선상의 문제들은 무선 인체 통신망에서 핫 스팟과 에너지 효율, 그리고 신뢰적인 통신 성능에 영향을 미친다. 우리는 빈번히 변화하는 네트워크 토폴로지와 채널 조건을 고려한 포워딩을 결정하는 방법을 제안하였다. 본 논문에서는 각 노드의 라우팅 레벨에서 입, 출력 링크들의 비율에 근거하여 포워딩 비율과 패킷들의 크기를 제어한다. 또한 패킷 크기와 포워딩 비율 제어를 지원하는 격자 기반의 연결을 확장함으로써 네트워크 토폴로지를 견고하게 한다. 본 논문의 시뮬레이션은 이러한 접근들이 네트워크 수명을 48.2% 증가시키는 것뿐 아니라 약 6.08%의 패킷 전달율의 증가가 있음을 증명한다. 또한 핫 스팟 문제도 본 제안을 통해 해결된다.

☞ 주제어 : 무선 인체 통신망, 격자형 토폴로지, 에너지 효율, 패킷 전달율

ABSTRACT

The sensors attached on/in a person are moved since human body frequency changes their activity, therefore in wireless body area networks, nodal mobility and non-line-of-sight condition will impact on performance of networks such as energy efficiency and reliable communication. We then proposed schemes which study on forwarding decisions against frequent change of topology and channel conditions to increase reliable connections and improve energy efficiency. In this work, we control the size of packets, forwarding rate based on ratio of input links and output links at each node. We also robust the network topology by extending the peer to peer IEEE 802.15.4-based. The adaptive topology from chain-based to grid-based can optimal our schemes. The simulation shows that these approaches are not only extending network lifetime to 48.2 percent but also increase around 6.08 percent the packet delivery ratio. The "hot spots" problem is also resolved with this approach.

☞ keyword : Wireless Body Area Networks, Grid Topology, Energy Efficient, Packet Delivery Ratio.

1. INTRODUCTION

Healthcare sector is becoming increasingly interested in using this new technology to more effectively administer healthcare delivery. The use of a wireless interface enables an easier application and is more cost efficiency. Therefore, the wireless networks are one of the most suitable technologies for building unobtrusive, scalable, and robust e-Health systems.

In order to fully exploit the benefits of wireless technologies in telemedicine and Healthcare, the IEEE committee formed IEEE 802.15 Task Group 6 [2] to standardize and address both medical healthcare and non-medical healthcare applications. It optimized for ultra-low power devices and operation on, in, or around the human body to serve variety of applications. As nodes are placed on clothes, on the body or under the skin, the sensor nodes are changed their locations due to motion of human

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body. It effects on both reliability of packet delivery ratio (PDR) and energy consumption. Therefore, the need for extending and combining structure of topologies is necessary [6,7].

Until now, very few works studied on extending topologies based and the effective routing schemes which against frequent the change of topology. It should be noticed that the topologies used in these researches are analyzed and investigated on star and tree topologies of the IEEE 802.15.4 or IEEE 802.15.6 with heterogeneous sensors that are deployed in the single-hop topology or the multi-hop topology. In [4,5], authors proposed the topology control scheme takes into account the movement of the body for single-hop while reported in [6,7,8] researchers study on multi-hop communication. As the single-hop topology usually uses as a default topology for body area networks (BAN), the quality of links between the coordinator and end nodes may degrade significantly due to dynamic change of environment conditions such as non-line-of-sight and mobility[2,4,6,18]. In order to avoid the links become unreliable due to path loss and mobility, in the literate [7,8], the authors proposed multi-hop topology using relays between end nodes and coordinators, these approaches are limited from two hops to four hops. They are commonly used in tree topology in which a parent takes care more than two children, thus the sensors nodes in higher levels (close to the sink) will have more chance to deplete their energy. Moreover, the collision and congestion will be occurred at the nodes which are near to the sink. Therefore, these works could not resolve both reliability of data delivery problem and energy consumption problem.

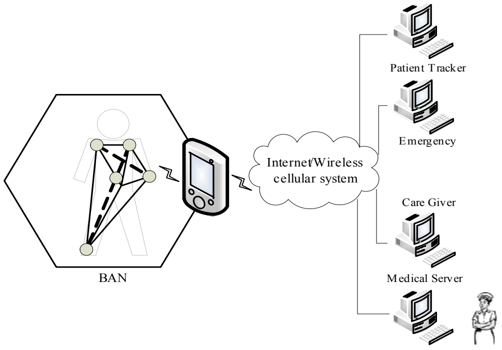
Our motivation focus on BAN, the sensor devices attached on human body may be moved frequently. At the local areas, one of the following two events eventually occurs: (i) links may become unreliable connections or (ii) the nodes close to the sink are exhausted energy due to forwarding messages of the other sensor nodes. Therefore, if each node can get more chance to transmit its packets to sink node via various relay nodes. Our distributions include following aspects:

- We investigate and analyze energy lifetime and energy imbalance problem and their relationship with the topology architectures in wireless body area networks.
- We proposed the controlling schemes based on changing size of message, and forwarding rate at each node.
- We robust the network topology by extending chain based to grid-based for increasing data delivery ratio and improving total network lifetime.

The remainder of this paper is organized as follows: Section 2 includes WBAN topologies and their problems. Section 3 is the proposing algorithms. Section 4 is performance analysis and section 5 is our conclusions.

2. WBAN TOPOLOGIES

Architecture of E-Health in a wireless body area network is illustrated in figure 1 [1], where the sensor nodes are scattered on/in the body. They are responsible for collecting data and transferring data in single-hop or multi-hops back to the sink (gateway), which is usually a powerful device with more computing power, large memory, and infinite energy. The sink then communicates with the remote diagnosis centers such as patient tracker, emergency, caregiver and medical serve, which are probably far from the sensor field, via the internet or wireless cellular system. The mobile devices could act as a gateway for the BAN to access to external networks.



(Figure 1) Architecture of E-Health

Vital signs are measured from most basic functions of human body. The main vital signs routinely monitored by medical professionals and health care providers include temperatures, ECG, etc. [14,16]. Due to heterogeneity of the applications, data rate will vary strongly. Packets are sent in burst or low bit-rate, during the burst, data is sent in high bit-rate. The data rate is calculated by mean of sampling rate. The vitals signals received from the sensor devices are delivered to the gateway based on the other devices. At the sink node, the quality of packets should be measured and valued [17]. As the result, the delivered quality of service depends on the topology architectures chosen for the delivery data packets. In this situation, the reliability of these topologies can be considered on a link based.

Depending on the type of medical applications, the wireless sensor nodes which are tiny, light-weight and limited power resource can be placed on/in body in the whole body. The exact location of devices will depend on application, e.g. a heart sensor must be placed in the neighborhood of the heart while a temperature sensor can be placed anywhere. While the entire network needs to extend its lifetime, the maintaining energy of each node is also important. Because when the sensor nodes run out of their energy, the lifetime of the nodes are ended, the whole network will be down because just a few sensors are down or healthcare function of the nodes in WBANs are ended. Therefore, the residual energy of each sensor should affect its actions to minimum its energy and maximum the network lifetime. These is driven by the need to develop the generic schemes that provide cross layer approaches and routing on grid-based is a case study for these combinations of the networking and medium specific aspects. We focus on how to make a decision at forwarder nodes to reduce packet drops and enable a higher degree of fairness and balance.

2.1 RELIABILITY PROBLEM

WBANs are constrained by several other factors that challenge their use in real environments. One of these is reliable connectivity due to changing of network topology. For on body applications, it should be noticed that the distance between the wireless connections plays an important in the reliable connections. When the distance between the transmitter and the receiver increase, the receiving signal levels decrease and reverse. This phenomenon is called path loss. Attenuation of radio signals has been modeled by averaging the measured signal powers over long times and over various locations with the same distances to the transmitter. The path loss model in *dB* between the transmitting and the receiving antennas as a function of the distance r [6]:

$$PL(r) = PL_0 + 10\eta \log\left(\frac{r}{r_0}\right) \tag{1}$$

Where $PL_0$is path loss at distance r_0, η are the pathless exponents. Due to the obstructions and irregularities such as body segments in the surroundings of the transmitting and the receiving antennas, the strength of received signals may show significant variations around the area mean power value. Therefore, the connectivity becomes unreliable and asymmetry. These variations are well described by lognormal distribution. The link probability found based on lognormal shadowing radio model is [11]:

$$S = \frac{1}{2}\left[1 - erf\left(\alpha \frac{\log(\hat{r})}{\xi}\right)\right], \qquad \xi = \frac{\sigma}{\eta} \tag{2}$$

Where $\alpha = 10/(\sqrt{2}\log 10)$, and $\hat{r}$ is the normalized distance between the transmitter and the receiver. The parameter ξ is defined as the ratio between the standard deviation of shadowing, σ, and the path loss exponent, η. ξ presents for variation of signal power around area mean power and high values of ξ correspond to stronger shadowing effects. When considering shadowing effects, the total path loss can be expressed as

$$PL = PL(r) + S \tag{3}$$

Where S is a zero-mean Gaussian random available with standard variable σ and $PL(r)$is path loss in (1). All of recent researches [12,13] concluded that path loss on BAN is very high compare with free space propagation and the value η varies greatly. In [12], a path loss exponent of 7 was found in non-line-of- sight (NLoS) propagation along human body. Due to the high path loss and NLoS, the long distance communication and direct communication between the sensor and sink will not always possible, network architecture should not only base on start topology or peer to peer topology. The WBANs should have hierarchical topology and cooperative architecture to against mobility of nodes and long distance communication.

2.2 ENERGY IMBALANCE PROBLEM

Our motivation lies in the fact that the single-hop and the multi-hop that have problems of energy efficient. In multi-hop topology, the nodes closest to the gateway will be the heaviest load. Therefore, following events eventually occur at the nodes closest to gateway such as the packets are dropt due to congestion, the nodes are exhausted energy. After the nodes near the sink fail, the sink cannot gather information from the other sensor nodes in the network. On the other hand, in single-hop topology, nodes far from the sink have to spend drama energy consumption when the distance between the nodes increases [6].

In order to better understand full optimal energy efficient, let us investigate important parameters that impact on power consumption: (1) transmission distance, and (2) size of a message. In Figure 2, nodes D and E have to forward a message to sink S, there are some situations following:

- Packet of node D and node E are forwarded directly to sink (single-hop).
- Packet of node D and node E are forwarded the same next-hop node (multi-hop tree).
- Packet of node D and node E are forwarded different net-hop nodes (multi-hop chain)
- Packet of node D and node E are forwarded different net-hop nodes (grid).

We borrow the energy model from [3] to calculate the energy consumption of each message transmission. The energy consumed when the sensor receives a message of size k is:

$$E_{rx}(k,r) = E_{elec}.k \tag{4}$$

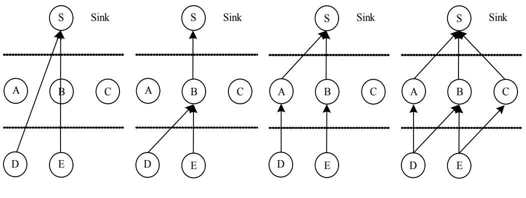
Energy consumed on sending a message of size k is:

$$E_{tx}(k,r) = E_{elec}.k + E_{amp}.k.r^2 \tag{5}$$

Where E_{elec} is the energy that the radio dissipates to run the circuitry for the transmitter and receiver, E_{amp} is the energy for the transmit amplifier. From (4) and (5), $E_{tx}(k,r)>>E_{rx}(k,r)$ when distance or size of message increase. The single hop architecture spends largest energy consumption. The chain topology and the tree topology have the same problem that the nodes close to the sink become hotspot. As reported in paper [1], in NLoS environment, single hop should not selected.

The other factor will impact on energy consumption on each node. Assumed that B belongs to energy-efficient paths, if there are k bits of each packet from D and E, the maximum number of bits received and transmitted at B in case (b) are $4k$ bits. It means that node B has spends $4.E_{elce}.k+2.E_{amp}.k.r^2$ in which $2.E_{elce}.k+2.E_{amp}.k.r^2$ is used for transmitting. In case (c), imbalance problem has also resolved by sharing load that is used in multi-path protocol, therefore, load is shared $2k$ bits for set of nodes {A,B}, in this set, each node used $E_{elce}.k+E_{amp}.k.r^{22}$ for transmitting. In case (d), a set of nodes {A,B,C} has spends $2k$ bits in which $2/3(E_{elce}.k+E_{amp}.k.r^2)$ is used for transmitting for eachnode. Under this analyzing, we identified that certain paths and nodes of the topologies are not only consume larger energy but also create hotspots in the networks.

An attempt to maintain a relatively balanced load of each sensor node can be much more critical than find the best route. Base on observation in case (c), an amortizing of energy consumption at the hotspot nodes can be resolved if multiple routes are available to the sender. An expanding the chain topology is beneficial not only from load sharing but also minimum packet dropt due to congestion and disconnection problem.



Single-hop b) Multi-hop tree c) Multi-hop chain d) Grid

(Figure 2) Sharing load based topology

3. THE PROPOSED ALGORITHM

Based on equations (4) and (5), if multipath routes are available at each sensor node, it could make a forwarding decision related with size of message, and forwarding rate to adapt with reliable data reliability and energy efficient.

3.1 DATA FRAGMENTS

Base on bottom-up approach, the parents at higher layer will spend more energy cost for receiving and transmitting the long data packets. We can reduce this energy cost by splitting original packets into smaller packets and these packets are distributed over multipath. This work is not only minimizing packet drop rate but also achieving load balance. In our network model, we assume that h is number of nodes at higher level (parents) available for forwarding. By splitting maximum bits for each hop path, the forwarder nodes can be reduced maximum bits for transmitting and receiving on each round of routing. Maximum numbers of bits could be reduced by using splitting factor:

$$S = \frac{\sum_{i=0}^{m} k_i}{h} \tag{6}$$

Where k_i is size of the i^{th} packet ($0 < i < m$). At a fixed round, nodes can determine the probable measurement if incoming traffic include their own data packets and forward packets of all other at lower level nodes. Our approach is to fragment the long data packets and forward these fragments on the different output links. This approach yields itself wells to achieving load balance, however, if we fragment the long packets into many smaller packets, we have to pay the penalty for control overhead, especially when node density is high and traffic load is heavy. Let's suppose that the propose scheme has h output links and l input links from the neighbor discovery phase, the ratio value of h and l can be used to making a forwarding decision. We define f, $f = (f_1, f_2, \cdots, f_n), n \leq h$, are fragments that are divided at each node. Load sharing is beneficial when forwarding load is split among node at each level. For example, a node has two output links and two input links. Therefore, ratio value is *2:1*, this means that two nodes at higher level can take turns in data packets from lower level.

3.2 FORWARDING RATE

Data rate in WBAN are not high and the higher delivery ratios, the lesser energy consumption. This leads to an increase the lifetime for the networks. However, a node become a “hot spot” if the arrival rate of packets at input links is large higher than service rate or the number of input links is more than output links. These are affected by the controlling of forwarding rate. For example, a node has one output link and two input links, ratio value is *1:2*, therefore, a rate reduction will be informed to lower level nodes to send lesser number of packets.

On the other hand, due to nodal mobility, the energy efficient requires determining whether forwarding rate is affected by level of person activity. In [15], the packet arrival rate and topology change rate are related with nodal mobility. The mobility impact on the forwarding energy consumption as a function of the packet arriver rated and topology change rate. The higher mobility of node, the lower bit rate can be used to making forward decision.

3.3 GRID BASED TOPOLOGY

As we mentioned in section 2, we only consider the failure resulting from the depletion energy. The failure of sensor is related not only to the number but also to the location of the failed sensor. Therefore, the sensors closer to the sink are more important than the sensor far from the sink. We define the important factor (IF) for sensors at each level as:

$$IF = \frac{1}{r^2} \tag{7}$$

where r is the distance from a sensor to the sink.

A logical hierarchical architecture will be formed at each round of routing which satisfies group of sensor nodes close to the sink spends lower energy for each round of transmitting and receiving.

Grid formation

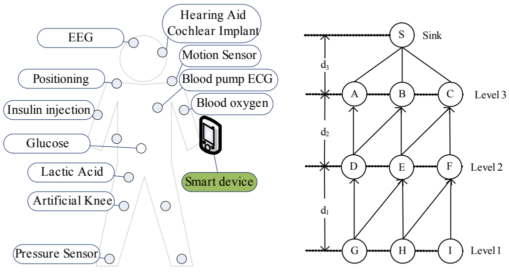
Object of system reliability is the construction of a distribution that present the lifetime of a system based on lifetime distribution of the components. In this paper, we consider relationship among components. A structure of triangular lattice is proposed, this approach shows that the failure of any parent nodes (the higher level) does not cause the system failure. For improving this point, we then present these relationships as network lifetime functions. If R_D,R_A,and R_B are reliability function of nodes *D*, *A*, and *B*, the reliability function of this triangular lattice is:

$$R = 1 - (1 - R_D)(1 - R_A \times R_B) \qquad (8)$$

In cases of chain topology or tree topology, the failure of any parent nodes will cause the system failure. Therefore, the grid topology based on a rectangular grid of size can improve reliability of data reliability for forwarding packets because the failure any single node from higher level does not cause the network failure.

Distance assignment

From (1) and (2) equations, distance is variable that impacts transmission loss and nodal degree [11]. If we assume that nodal degree is fixed and initial energy is supplied for every node is the same. E_1 is the average energy consumed by a node at level 1 (far from the sink) during each round $E_1=N_1(E_{rx}+E_{tx})$ and E_2 is the average energy consumed by a node at level 2 (closer than lever 1 from the sink) $E_2=N_2(E_{rx}+E_{tx})$,the terms E_{rx} ,and E_{tx} inequations (3) and (4), N_1 and N_2 is the number of data packets that a node at each level receives and forwards in each round. Under balancing load view, $E_2=E_1$ and $N_2>N_1$, therefore, the length of hop at level 1 is longer than the length of hop at level 2. Therefore, the distance between each hop levels is should not be fixed at the same distance. It would be beneficial to assign distance at the highest levels with the shortest distance. Because each sensor sends their own packets and forwards the packets of sensor nodes at lower level. Therefore, physical distance of hop levels, d_i, is decreased from source to sink. From equation (2), distance is the independent variable that impact on total transmission loss. It would be beneficial to assign distance at the highest levels with the shortest distance.



a) Physical area b) Logical area

(Figure 3) Hierarchical grid-based formation

We propose energy-balanced on grip topology. The active sensor numbers of each higher level will be formed based on decision of forwarder as well as the distance assignment at each round. Our example scenario, presented in Figure 3 is grid topology (*3x3*) with nine nodes. The arrows denote various paths possible to sink. The distance of each hops is d_1,d_2, *and* d_3($d_1>d_2>d_3$).

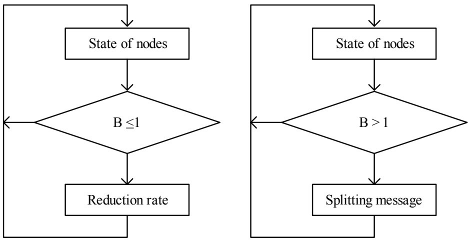
Routing in grid topology

The routing protocol in this paper allows reduce energy consumption at higher level. Grid-based architecture aims at achieving flexible, fast balance as well as fair network. In this architecture, two nodes with the same child 1) share their load by taking turn child's data packets, and 2) reduce number of bits is transmitted for higher level nodes.

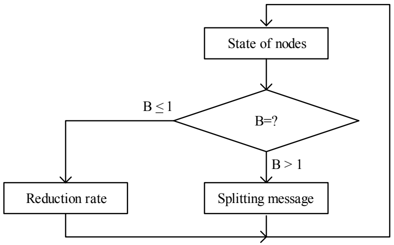
Using multipath routing, a sensor node is required to keep a list of neighbors to which it can forward its packets. In this list, a balance (*B*) value presents an approach towards making forwarding decisions.

$$B = \frac{h}{l} \qquad (9)$$

In which *h* is set of nodes on a flow which is at higher level and *l* are set of nodes on a flow which is lower level. The *B* value at each node presents information of the network state at that position. If $B > 1$, a splitting message will apply to sharing the load. On the other hand, if $B \leq 1$, a rate reduction to prevent imbalance and congestion. In case of our grid topology, *B* value is balance in term of energy due to applying distance reduction in each hop. The forwarding decisions make new three schemes: a) *rate-based* *forward scheme* (RBFS), b) *split-based forward scheme* (SBFS) and c) *hybrid forward scheme* (HFS).



a) Rate-based forward scheme (RBFS) b) split-based forward scheme (SBFS)



c) Hybrid forward scheme (HFS)

(Figure 4) Propose schemes

Suppose that a source node G has established a communication to the sink S, the routing is constructed by multipath routing protocol. G is sending a message of *k* size (bits). The forwarding schemes initial from the point of intermediate level nodes is depicted in Figure 4.

4. PERFORMANCE ANALYSIS

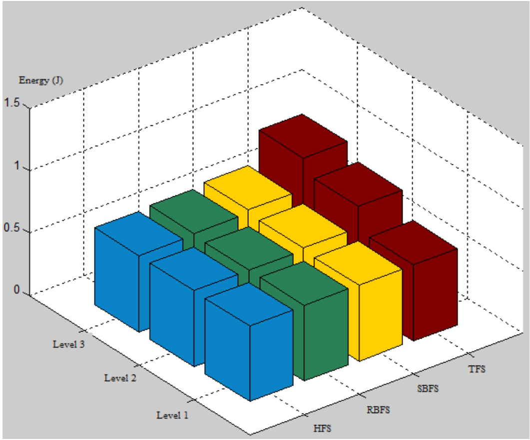
We perform several experiments to evaluate our propose schemes with IEEE 802.15.4 in network simulation 2.34 (NS2.34), the parameters used in the simulations are described in table 1. Each round, the nodes sent from 1 packet to 3 packets per second.

Energy-balanced and reliability of data delivery on grid-based topology are considered carefully in these experiments. The performance of four schemes is compared, including traditional forward scheme (TFS), RBFS, SBFS, and HFS. In the simulation, the initial energy of each sensor is set to 0.5(J).

(Table 1) The simulation parameters

Parameter	Default Value
Size of network	4(m)x4(m)
Radio propagation range	30(cm) to 1(m)
Initial energy	0.5(J)
Energy for transmitting	50(nJ/bit)
Energy for receiving	50(nJ/bit)
Energy for amplifying	100(pJ/bit/m^2)
Simulation start time	1(sec)
Simulation end time	200sec
Size of a message	250 bytes
Multi-source active	1-5
Data packet rate	Varying
Mobility of node	1m/s

4.1 ENERGY BALANCE

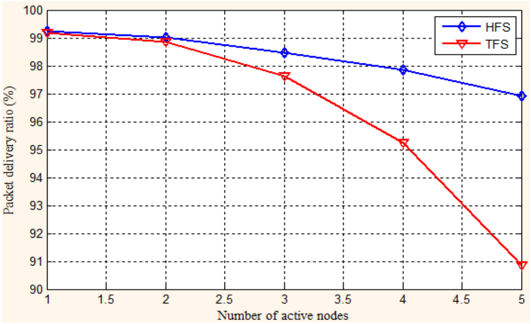


(Figure 5) Energy consumption in forward schemes

Figure 5 depicts the energy consumption of each level and energy balance in WBANs. As showed in column TFS, the same distance between of deployed sensors is fixed. The TFS spends energy more than the other schemes around 38.3% (RBFS) to 48.2% (HFS) percent and hot-spot problem still remain at the higher levels. Thus both remain lifetime of the whole network and the sensors are saved and balanced.

4.2 DATA DELIVERY

Figure 6 shows the result of the PDR for HFS and TFS with varying number of active sources up to 5 nodes, the PDR is decreased, however, it look slowly changes. This



(Figure 6) The packet delivery ratio

means that reducing forward rate affected on dropping of packets. In this simulation we reduce a half of full data rate whenever input links *l* equal 2.

5. CONCLUSIONS

This paper firstly identifies reliability problems based on energy imbalance and load imbalance in WBAN that results from the sensors close to the sink which become hot-spots and exhausted their energy. Under traffic theory, we show that controlling data fragment factor and data rate factor can effect on both reliability and energy efficiency.

Secondly, our proposal is simple way to adaptive from chain-based to grid-based. The extending topology makes each node can forward its packets in flexible, reliable, efficient energy in WBANs.

Our future research will focus in detail of these adaptations in WBAN. Moreover, this paper is a step forward to combine complex topology architecture and networking that is expected optimal fully energy balance of network as well as reducing packet drops. Simulation shows that combining these schemes can extend around 48.2% network lifetime, improve 6.08% in PDR as well as resolve “hot spots” problem.

참 고 문 헌(Reference)

[1] Benoît Latré, Bart Braem, Ingrid Moerman, Chris Blondia, and Piet Demeester, “A survey on wireless body area networks,” *Wirel. Netw. 17*, 1 (January 2011), 1-18.

[2] “IEEE 802.15 WPAN Task Group 6 (TG6)- Body Area Networks,” 2010.

[3] Chandrakasan,A, Balakrishnan,H, “Energy-Effiient Communication Protocol for Wireless Micro sensor Networks,” *Proceedings of the 33*rd *Annual Hawaii International Conference on System Sciences,* 2000.

[4] M. Quwaider, J. Rao, and S. Biswas, "Body-posture-based dynamic link power control in wearable sensor networks," *IEEE Communications Magazine*, 2010., pp. 134-142.

[5] Emil Jovanov, Aleksandar Milenkovic, Chris Otto and Piet C de Groen, “A wireless body area network of intelligent motion sensors for computer assisted physical rehabilitation,” *Journal of NeuroEngineering and Rehabilitation, vol. 2, no. 1,* March 2005, pp. 16-23.

[6] B. Braem, B. Latré, I. Moerman, C. Blondia, E. Reusens, W. Joseph, L. Martens & P. Demeester, “The Need for Cooperation and Relaying In Short-Range High Pass Loss Sensor Networks,” *SENSORCOMM ’07 Proceedings of the 2007 International Conference on Sensor Technologies and Applications,* pp. 566-571.

[7] Hind Chebbo, Saied Abedi, Tharaka Lamahewa, David Smith, Dino Miniutti, Leif Hanlen, “Reliable Body Area Networks Using Relay: Restrict Tree Topology,” *International Conference on Computing, Networking and Communications (ICNC* 2012*)*

[8] Jocelyne Elias and Ahmed Mehaoua, “Energy-aware Topology Design for Wireless Body Area Networks”, *IEEE ICC* 2012.

[9] Christopher L. Barrett, Stephan J. Eidenbenz, Lukas Kroc, Madhav Marathe, James P. Smith, “Routing coverage and topology control: parametric probabilistic sensor network routing,” *Proceeding WSNA ’03 Proceedings of the 2nd ACM international conference on Wireless sensor networks and applications*

[10] Qinhe Yin, Seng Kee Tan, Qi Yao, Boon Sain Yeo, Seah, W, “GREEN: A Grid-Based Energy Efficient Probabilistic Routing in Wireless Sensor Networks,” Vehicular Technology Conference, 2005.

[11] R. Hekmat and P.Van Mieghem, “Connectivity in wireless ad-hoc networks with a log-normal radio

model," *Mobile Networks and Applications*, June 2006.

[12] Andrew Fort, Julien Ryckaert, Claude Desset, Philippe De Doncker, Piet Wambacq, and Leo Van Biesen, "Ultra-wide band channel model for communication around the human body," *IEEE Journal on selected areas in communications, vol. 24, no. 4*, April 2006.

[13] Joseph, W, Vermeeren, G, Martens, L, Latre, B, Moerman, I, Braem, B, Blondia, C, "Path loss model for wireless communication channel along arm and torso", *Antennas and Propagation Society International Symposium*, 2007 IEEE

[14] Gama O, Carvalho P, Afonso JA, Mendes PM, "Quality of service support in wireless sensor networks for emergency healthcare services," *Conf. Proc IEEE Eng Med Biol Soc*, 2008.

[15] Jinman Jung, Yookun Cho, and Jiman Hong, "Impact of Mobility on Routing Energy Consumption in Mobile Sensor Networks," *International Journal of Distributed Sensor Networks,* 2012.

[16] Woong-Sik Kim and Jong-Ki Kim," Design of ECG Measurement System based on the Android," *Journal of Korean Society for Internet Information, vol.13, no.1,* Feb 2013, pp. 135-140.

[17] Lee, HyunJu, A Performance Evaluation Framework for e-Clinical Data Management, *Journal of Korean Society for Internet Information, vol.13, no.1,* Feb 2013, pp. 45-55.

[18] Myong Lyol Song, A Detection Method of Interference from WiFi Network in IEEE 802.15.4 Network, *Journal of Korean Society for Internet Information, v.14, no.4,* Aug 2013, 13-24.

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