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An Aerial View of Hierarchical Energy Efficient Protocols in Wireless Body Sensor Networks

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Abstract: ***A wireless sensor network is a collection of nodes organized into a cooperative network. The nodes communicate wirelessly and often self-organize after being deployed in an ad hoc fashion. Currently, wireless sensor networks are beginning to be deployed at an accelerated pace. This new technology is exciting with unlimited potential for numerous application areas including environmental, medical, military, transportation, entertainment, crisis management, homeland defense, and smart spaces. In particular, their application to healthcare areas received much attention recently. The design and development of wearable biomedical sensor systems for health monitoring has drawn particular attention from both academia and industry. Therefore, focus has been given to the routing protocols for maximize the life time of wireless sensor network. In this paper we present a survey on power efficient hierarchical routing protocols in Wireless Sensor Network. Firstly, the routing techniques has been discussed for WSN. The drawbacks and comparative study of routing protocols has been discussed. Finally, the existing research issue in wireless sensor network is provided.***

Keywords: Cluster, Distance, Energy consumption, Lifetime, Wireless body sensor networks

1. Introduction

A wireless sensor network is a collection of nodes organized into a cooperative network. The nodes communicate wirelessly and often self-organize after being deployed in an ad hoc fashion. Currently, wireless sensor networks are beginning to be deployed at an accelerated pace. This new technology is exciting with unlimited potential for numerous application areas including environmental, medical, military, transportation, entertainment, crisis management, homeland defense, and smart spaces. In particular, their application to healthcare areas received much attention recently. The design and development of wearable biomedical sensor systems for health monitoring has drawn particular attention from both academia and industry. As an extension to the WSN a body area network (BAN), also referred to as a wireless body area network (WBAN) or a body sensor network (BSN), is a wireless network of wearable computing devices. The development of WBAN technology started around 1995 around the idea of using wireless personal area network (WPAN) technologies to implement communications on, near, and around the human body. The implanted sensors in the human body will collect various physiological changes in order to monitor the patient's health status no matter their location. The information will be transmitted wirelessly to an external processing unit. This device will instantly transmit all information in real time to the doctors throughout the world. If an emergency is detected, the physicians will immediately inform the patient through the computer system by sending appropriate messages or alarms. Currently the level of information provided and energy resources capable of powering the sensors are limiting factors. Hence this paper presents the current state in research and development of wireless sensor networks and related sensors for health monitoring.

1.1 Classifications for Routing Protocols For Wireless Sensor Network

There are many routing protocols designed for wireless sensor network but most of them were not implemented because they are in a developing stage. Generally, routing protocols on the basis of network structure are divided into three main groups:

1.1.1 Flat-based Routing

All nodes play the same role and many apply flood based data transferring. The disadvantages of flooding include implosion (duplicate message sent to the same node). Examples of Flat based routing protocols are:

(a) Direct Diffusion
(b) SPIN (Sensor Protocols for Information via Negotiation
(c) Rumor Routing

1.1.2 Hierarchical-based or cluster Routing

Hierarchical routing protocols have proved to have considerable savings in total energy consumption of the Wireless Sensor Network. In hierarchical routing protocols, clusters are created and a head node is assigned to each cluster. The head nodes are the leaders of their groups having responsibilities like collection and aggregation the data from their respective clusters and transmitting the aggregated data to the BS. Hierarchical routing [2] is utilized to perform energy efficient routing in Wireless Sensor Network. It is an efficient way to lower energy consumption within cluster.

1.1.3 Location based Routing

Location-based protocols utilize the position information to relay the data to the desired regions rather than the whole network. In this kind of routing, sensor nodes are addressed by means of their locations. The distance between neighboring nodes can be estimated on the basis of incoming

signal strengths. Examples of Flat based routing protocols are:

- GAF(Geographic adaptive fidelity)
- GEAR(Geographic and energy aware routing)
- MECN(Minimum energy communication network)
- SMECN (Small MECN)

In this work Hierarchical based routing protocols alone are taken into the survey and the detailed explanation are given below

2. Hierarchical Protocols

2.1 LEACH

LEACH is mostly called as Low Energy Adaptive Clustering Hierarchy protocol. W.R. Heinzelman, A.P Chandrakasan and H. Balakrishnan [3] projected LEACH protocol in 2000. It is one of the mostly used hierarchical routing algorithms used in the sensor networks. The main plan of LEACH protocol is to divide the total wireless sensor network into many clusters. The cluster head node is randomly selected; the chance of every node to be selected as cluster head is equal attributable to which energy consumption of whole network is averaged. Thus LEACH will prolong the network life cycle. LEACH algorithm is cyclical; it provides a conception of round. LEACH protocol runs with several rounds. Every round contains two states: cluster setup state and steady state. Within the cluster setup state it forms cluster within the self-adaptive mode whereas in steady state it transfers the information. The selection of cluster head depends on decision made 0 and 1. If number is smaller than the threshold value, the node becomes a cluster head for the current round. The threshold is mostly given as:

$$T(n) = \begin{cases} \dfrac{p}{1-p*(r*\bmod 1/p)} & \text{if } n \varepsilon G \\ 0 & \text{else} \end{cases}$$

Where, P is that the desired percentage of cluster heads (e.g. is like 4% or 5%), r is that the current round, and G is that the set of nodes that haven't been cluster heads within the last 1/p rounds.

By considering this threshold, each node can be the cluster head at some point with 1/p rounds. Nodes that are cluster heads cannot become cluster head for the second time for 1/p-1 rounds. Therefore, mostly every node has a 1/p probability of becoming cluster in every round. At the end of each round, every traditional or normal node that's not a cluster head choose the closest or nearest cluster head and joins that cluster to transmit the information. The cluster heads mix or combine and compress the information and forward it to the sink or the base station, thus it extends the life of the most important or major nodes.

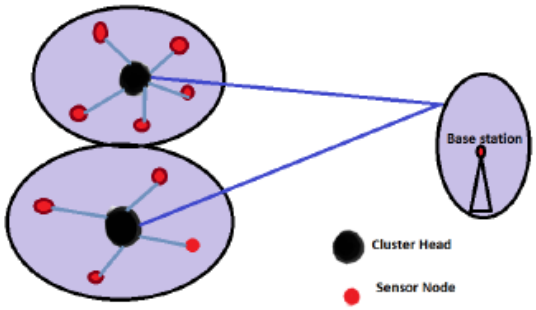

Figure 1: Cluster -based routing protocol in wireless sensor networks.

2.2 PEGASIS

S. Lindsey and C. Raghavendra [4] introduced Power Efficient Gathering in Sensor Information Systems (PEGASIS) protocol in 2002. It is an improved version of LEACH. Rather than forming clusters, it is based on forming chains of sensor nodes. One node is mainly responsible for routing the aggregated information to the sink. Every node aggregates the collected information with its own information, and then passes the aggregated data to the next ring. The distinction from LEACH is to employ or use multi hop transmission and choosing or selecting only one node to transmit to the sink or base station. Since the overhead caused by dynamic cluster formation is eliminated, multi hop transmission and data or information aggregation is employed or used, PEGASIS outperforms the LEACH

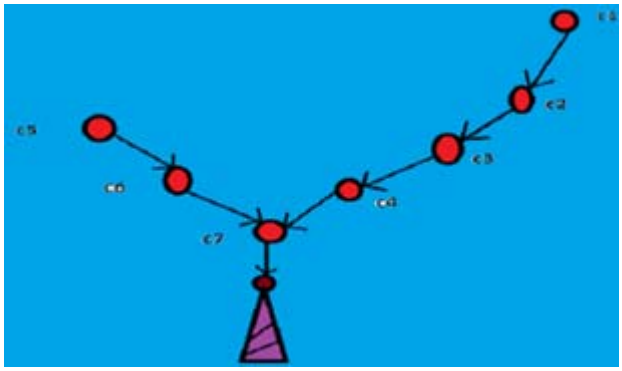

Figure 2: Chain -based routing protocol in wireless sensor networks.

2.3 TEEN

In 2001, A. Manjeshwar and D. P. Agarwal [5] projected Threshold sensitive Energy Efficient sensor Network Protocol (TEEN) protocol. Nearer nodes form clusters, with a cluster heads to transmit the collected information to one higher layer. Forming the clusters, cluster heads broadcast 2 threshold values. 1st one is hard threshold; it is minimum possible value of an attribute to trigger a sensor node. Hard threshold permits nodes transmit the event, if the event happens within the range of interest. Thus a significant reduction of the transmission delay happens. Unless an amendment of minimum soft threshold happens, the node doesn't send a new data packet. Using soft threshold prevents from the redundant information/data transmission. Since the protocol is to be attentive to the rapid changes in

the perceived attribute; therefore, it is appropriate for time-critical applications.

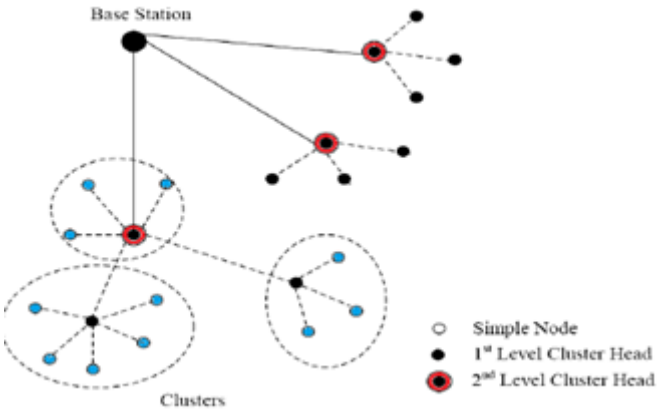

Figure 3: Threshold -based routing protocol in wireless sensor networks.

2.4 APTEEN

A. Manjeshwar and D. P. Agarwal [6] projected Adaptive Threshold sensitive Energy Efficient sensor Network Protocol (APTEEN) protocol in 2002. The protocol is a modification of TEEN aiming to capture time-critical events and periodic data collections together. The network architecture is same as TEEN. While forming clusters, the cluster heads circulate attributes, the threshold values, and therefore the transmission schedule to any or all nodes. Cluster heads are also responsible for data aggregation so as to decrease the size of data transmitted and the energy consumed. According to energy dissipation and network lifetime, TEEN provides higher performance than LEACH and APTEEN because of the reduced number of transmissions. The main shortcomings of TEEN and APTEEN are overhead and complexity of forming clusters in multiple levels, implementing threshold-based function etc. APTEEN is based on query system which permits 3 types of queries: historical, on-time, and persistent which can be employed in hybrid network

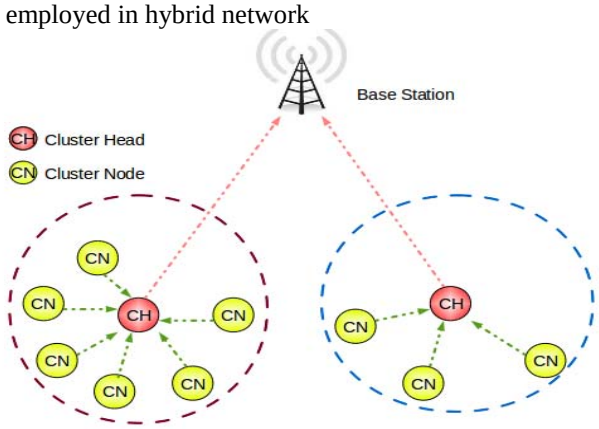

Figure 4: Adaptive Threshold Sensitive Energy Efficient Sensor Network Protocol

2.5 Base Station Controlled Dynamic Clustering Protocol (BCDCP)

Siva D.et al[7] propose a centralized routing protocol called base station controlled dynamic clustering protocol, which scattered the energy among all sensor nodes in the network to improve network life time and save energy. It operates in two major phase: 1. Setup phase 2. Data transmission In setup phase, following are the activities:- Cluster head to cluster head routing path information and scheduled are created for each cluster (shown in Figure 5). During each setup phase, sink receives data on the current energy status from all the nodes in the network. After this, sink computes the average energy level after getting information from each node and then decides nodes are to be considered as cluster head (CH)

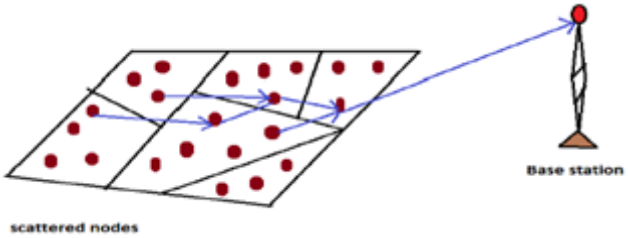

Figure 5: Base station controlled dynamic clustering protocol.

2.6 SEP

In 2004, G. Smaragdakis, I. Matta and A. Bestavros [8] projected Stable Election Protocol (SEP). This protocol is also a further modification to the LEACH protocol. It's heterogeneous aware protocol, supported weighted election probabilities of every node to become cluster head according to their specific energy. This approach certifies that the cluster head election is arbitrarily selected and distributed based on the fraction of energy of every node assuring a uniform use of the nodes energy. In this protocol, 2 types of nodes (two tier in-clustering) and 2 level hierarchies were considered.

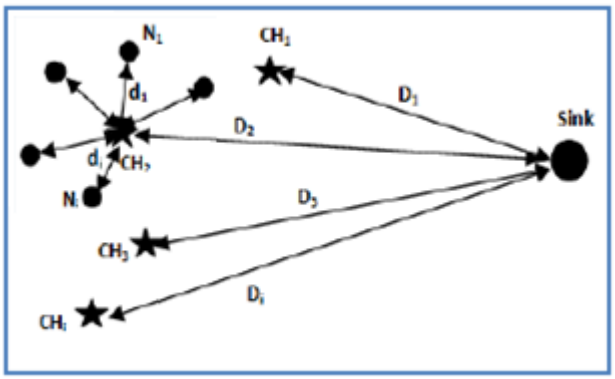

Figure 6: Heterogeneous aware stable election protocol.

2.7 EECS

In 2005, M. Ye, C. Li, G. Chen and J. Wu [9] projected Energy Efficient Clustering Scheme (EECS) protocol. It is a novel clustering scheme for periodical data collecting applications for wireless sensor networks. It elects cluster heads with more remaining energy through local radio communication. In the cluster head election phase, a stable number of candidate nodes are elected and compete for cluster heads according to the node residual energy. The competition method is localized and without iteration. The

process also produces a near uniform distribution of cluster heads. Moreover in the cluster formation phase, a unique approach is introduced to balance the load among cluster heads. However, on the other hand, it will increase the necessity of global knowledge regarding the distances between the cluster-heads and the base station.

2.8 DEEC

In 2006, Q. Li, Z. Qingxin and W. Mingwen [10] projected Distributed Energy Efficient Clustering Protocol (DEEC) protocol. DEEC protocol is a cluster based method for multi level and 2 level energy heterogeneous wireless sensor networks. In this scheme, the cluster heads are chosen using the probability based on the ratio between residual energy of every node and the average energy of the network. The era of being cluster-heads for nodes are entirely different according to their initial and residual energy. The nodes with more initial and remaining energy have greater chances of the becoming cluster heads compared to nodes with low energy.

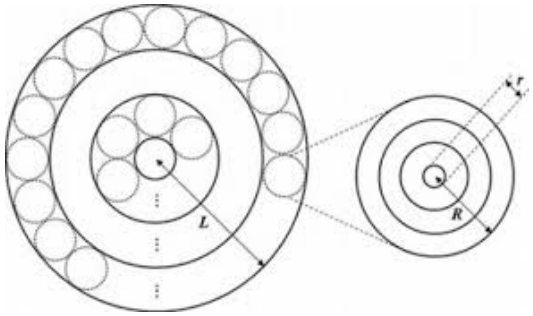

Figure 7: Distributed energy efficient clustering protocol for multilevel wireless sensor networks.

2.9 HEED

O. Younis and S. Fahmy projected [11] Hybrid Energy Efficient Distributed clustering Protocol (HEED) protocol in 2004. It extends the fundamental or the basic scheme of LEACH by using residual energy as primary parameter and network topology features such as node degree, distances to neighbors are only used as secondary parameters to shatter the tie between the candidate cluster heads, as a metric for cluster choice to attain power balancing. The clustering process is split into a number of iterations, and in every iteration nodes that are not covered by any cluster head doubles their probability of becoming a cluster head. As these energy-efficient clustering protocols further enables each node to probabilistically and independently decide its role in the clustered network. Moreover they cannot guarantee optimal elected set of cluster heads

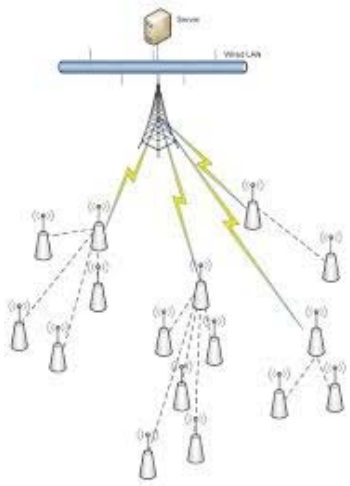

Figure 8: Hybrid energy efficient distributed clustering protocol.

2.10 H-HEED

Harneet Kour and Ajay K. Sharma, 2010 discuss about the H-HEED protocol. This protocol is basically used in heterogeneous wireless sensor network. H-HEED protocol is employed to extend the network life [12]. The impact of heterogeneity in terms of node energy in wireless sensor network has been stated. H-HEED (Heterogeneous Hybrid Energy Efficient Distributed) is the revised version of the HEED protocol in terms of non- homogeneity. Here the cluster head is chosen based on the fraction of residual energy to the utmost energy possessed by the sensor nodes. Head to head communication takes place and unlike energy leveled networks have been formed. The energy efficiency has been verified in terms of the energy needed for the transmission and reception of the data. Here the node substitution takes place in order to reenergize the network and to enhance the network life.

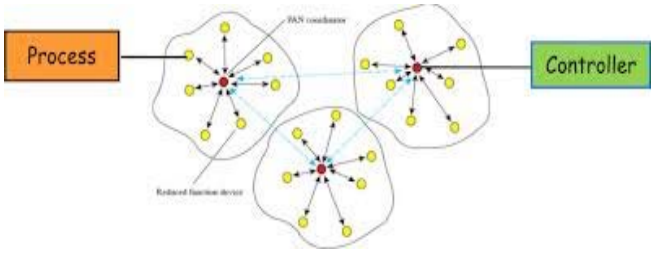

Figure 9: Clustering structure of H-HEED

2.11 Sleep/Wake Scheduling Protocol

This protocol is used to minimize end-to-end delay for event driven multi-hop wireless sensor network. This protocol is used to extend the energy and life time of network. It consists of two main phases. 1. Setup phase 2. Operation phase. Setup phase is divided into two sub-phases a. Initialization b. Route update Initialization: Energy level and position in the network [13] are computed by each node. This information is used in sleep/wake scheduling, route update [14] and event reporting. Therefore, base station divides the network into three different regions. BS transmit message to all the nodes in the network three different transmission power (TP).Therefore, TP1< TP2< TP3. TP1

define region 1, TP2 define region 2, TP3 define region 3 as describe in Figure 10.

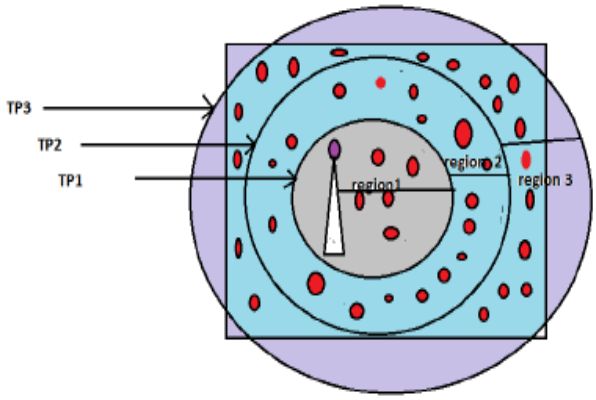

Figure 10: Clustering structure of sleep /wake scheduling protocol

Base station propagates beacon message with transmission power TP1. When node receives this message then it mark its region status as region 1 and will go to sleep state. Next, control messages are propagated by BS with transmission [15] power TP2. As we know region 1 is in sleep state and will not receive this message. All other nodes after getting this message will mark their region status as region 2 and will go to sleep state. Therefore, rest of the nodes will mark their region status as region 3 when message is received as TP3. Each node transmit control message to maintain first hop neighbour information. Once a node gets information of its neighbor it may decides whether it is connectivity critical nodes or normal nodes. Route update, Base station generates a route discovery [12] message with hop count 0 and messages are broadcasted throughout the network. A node that receives this broadcast message update its hop count value, that is, if received hop count is less than the previous hop count value then values changes to new value otherwise, it retains the previous value. Before forwarding the route discovery message, hop count is incremented by each node and then broadcasts the message to nodes in its communication range.

2.12 Virtual Grid Architecture

It is a hierarchical routing protocol that utilizes the data aggregation and processing in the network in order to extending the life time of network. Nodes in WSNs are fixed topology. It works without GPS and data are organized in grid of symmetric shapes. Inside each cluster a cluster head known as Local Aggregator [16] and aggregation is performed. Moreover, VGA uses a two-level data aggregation model: - Local Aggregator (LR) each grid square has a cluster head and subset of the local aggregator also perform global aggregation. Global Aggregators are called Master aggregators (MA). Therefore, optimal selection of Master Aggregators is difficult problem and many algorithms are existing for that, all aiming at extending the life time of network. In the data aggregation phase, some heuristic are proposed which may give efficient, sample and near optimal solution. An example of virtual grid architecture is depicted in Figure 11.

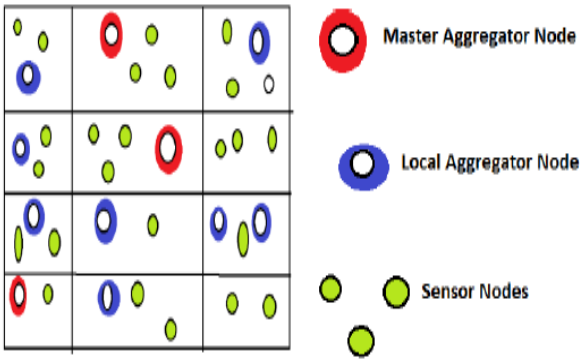

Figure 11: Virtual grid architecture.

Table I shows Schematic overview of comparative study of hierarchical routing protocols

Table 1: Hierarchical routing protocols comparison

Protocols	*Mobility*	*Scalability*	*Route Metric*	*Power usage*	*Overhead*	*Robust*
LEACH	Fixed Base Station	Good	Shortest path	Low	Yes	Limited
PEGASIS	Fixed Base Station	Good	Greedy approach	Max	No	Good
TEEN	Fixed Base Station	Good	Best route	Low	Yes	Limited
APTEEN	Fixed Base Station	Good	Best Route	Low	Yes	Limited
BCDCP	No	Limited	Best route	Low	No	Limited
SEP	No	Good	Best route	Low	No	Good
EECS	Fixed Base Station	Good	Best route	Low	Yes	Good
DEEC	No	Good	Best route	Low	No	Good
HEED	Fixed Base Station	Good	Shortest Path	Low	Yes	Good
H-HEED	Fixed Base Station	Good	Shortest Path	Low	Yes	Good
VGA	No	Good	Greedy route approach	N/A	No	Good
Sleep/ wake scheduling	No	Good	Best route	Low	No	Limited

3. Research Issues In Wireless Sensor Networks

The limited capabilities of sensor node and the deployment of sensor networks raise several research issues. A sensor node is designed with limited processing capabilities and equipped with limited amount of energy. The limited processing capabilities of node emphasis researchers to develop algorithms which involve minimum possible computation and data storage. The sensors implanted into the body are of small size and cannot accommodate huge processing power. In this section, we address some of the limitations of WSN when implemented for medical healthcare.

3.1 Energy Consumption

Typically sensor nodes are equipped with small batteries which cannot be changed or recharged and a node destroys when its battery exhausts. The experimental evaluations highlights that data communication consumes more energy as compare to data processing. The energy cost of receiving or transmitting a single bit of information is approximately the same as that required by processing executing a thousand operations [12] [13]. The continual operation of sensors is vital for healthcare applications.

Two major techniques, duty cycling and in-network processing are used in WSN to reduce power consumption. The power reservation algorithms in medical healthcare must be able to reduce power consumption without compromising on system reliability.

3.2 Security

Security is an important part of any system and it is a major area of research in general WSN. Wireless media is always more vulnerable than wired media for attackers [14]. This is more important in healthcare applications since a security breach can result in life threatening situations.

Security can be defined at several levels in healthcare applications. The security threats can occur during routing the data where intruders may change the destination, can make routing inconsistent or even steal the data by eavesdropping the wireless communication media [14]. The attackers can steal or modify the data routing through GPRS or similar networks [14]. The criminal-minded attackers can track the user location or can keep an eye on user's activity. The attackers can fiddle with the data by forging alarms [15]. They can also wage the Denial of Service (DoS) and Jamming attacks on the networks.

Data Encryption and Authentication are major security techniques used for security provision. Data encryption techniques must be used for secured data transfer and legitimate devices must be allowed to create or inject data into the system [15]. One of the solutions against security threats is to implement different encryption techniques

3.3 Power Sources

No matter how intelligent the routing mechanism or how adaptive the network, if the sensor loses power the sensor is simply non functional. Significantly more work is needed on alternative low cost power techniques such as solar, fuel cells and RF coupling.

3.4 Usability and Durability

Much of the work in this space has stopped at lab type 'prototype' solutions. More commercial devices are needed and more studies needed on performance in real world applications

3.5 Autonomic Networks

Substantive effort is needed in the self-organizing properties of sensor networks. Also end-to-end pilots are needed that demonstrate the autonomic properties of sensor networks. In Healthcare the Reliability Dilemma is particularly important, i.e. data needs to be secure and reliable, but this brings high overheads in terms of data size, power consumption and scalability. This dilemma needs attention through appropriate studies. Body Sensor Networks need to be recognized as a special category of sensor networks as the requirements can be quite different from general wireless sensor networks.

3.6 Biocompatibility and RF Effects

Given the amount of information on aspects of sensor network design, there is very little information on biocompatibility of sensor materials. Much of the efforts here are at the basic research level (materials science, garment fabrication etc) and this is appropriate as the promise of wearable devices is quite considerable. However more initiatives aimed at investigating the long term relationship between the sensor interface and the human body/skin are required. For example RF produces a heating effect which could possibly damage human cells. Even with low emitted and radiated power levels, it remains to be proven what the effect on human tissue over time (and with many sensors on the body) would actually be

3.7 Privacy and Data Ownership

In parallel with the technical research, research in to the societal, ethnographic and demographic effects of wireless sensor networks need to be performed. This encompasses the privacy debate also. Concerns such as profiling, 'big brother', 'one big database' etc need to be addressed up front and policies developed and agreed ahead of the technology becoming mature. Issues around data ownership when data travel across multiples boundaries arise. Also the legal aspects need to be reviewed, who is liable etc.

3.8 Development Environment

Sensor network operating systems have long been the domain of programmers and technical architects. Development environments where programming detail is abstracted to a high level are needed. These can be used by non-technical people (example nurses, doctors) to quickly set up and test prototype networks. These environments need to be user friendly, intuitive, support high level user interfaces with extensive support and training available.

3.9 Programming Challenge

Also one should accept that Wireless devices are slower than wired because of traffic congestion and hence increases the challenge to create the devices that could reach to better performance. This creates a big challenge for developers in programming and designing a secure sensor network. Ensuring patients information security can be a major issue when deploying these applications. Privacy of user data over

wireless channels can be another major issue. Wireless network based medical devices can be very limited in terms of power availability and processing strength. Thus ensuring privacy without using complex encryption algorithms can be a big issue for developers of medical devices [11].

4. Conclusion

From the survey considering the existing drawbacks and issues in wireless body sensor network it is planned to propose a novel approach on increasing efficiently the lifetime of sensor nodes, energy consumption and routing design issues must be accounted for. Energy saving becomes one of the most important features for the sensor nodes to prolong their lifetime. In the wireless body sensor networks, the main power supply of a sensor node is a battery, and a sensor node consumes most of its energy in transmitting and receiving packets. However, the battery energy is finite in a sensor node, and a sensor node that has its battery drained could make the sensing area uncovered. Hence, energy conservation becomes a critical concern in wireless body sensor networks. To reduce the energy consumption and to prolong the network lifetime, new and efficient energy saving routing architectures must be developed.

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