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Original Research Paper

Engineering

Survey of Body Area Network and Its Routing Techniques

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ABSTRACT Wireless Body Area Networks (WBANs) provide efficient communication techniques to the ubiquitous healthcare systems. WBAN has its application in the field of Health monitoring, telemedicine, military, interactive entertainment, and portable audio/video systems. Research on routing in a network of intelligent, lightweight, micro and Nanotechnology sensors deployed in or around the body, namely Body Area Network (BAN), has gained great interest in the recent years. In this paper architecture of BAN is discussed along with the requirements and challenges. Various routing protocols available are discussed in section V. Various routing algorithms are discussed with their limitations and advantages.

KEYWORDS : BAN, Routing

IINTRODUCTION

The field of computer science is constantly evolving to process larger data sets and maintain higher levels of connectivity. At same time, advances in miniaturization allow for increased mobility and accessibility. Body Area Networks represent the natural union between connectivity and miniaturization. The focus is shifting from hospital centred treatment to a patient-centric healthcare monitoring. A body area network (BAN), also referred to as a wireless body area network (WBAN) or a body sensor network (BSN), is thus formerly defined as a wireless network of several small body sensor units (BSUs) together with a single body central unit (BCU). 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. About six years later, the term "BAN" came to refer systems where communication is entirely within, on, and in the immediate proximity of a human body. A WBAN system can use WPAN wireless technologies as gateways to reach longer ranges. A Body Area Network is formally defined by IEEE 802.15 as, "a communication standard optimized for low power devices and operation on, in or around the human body (but not limited to humans) to serve a variety of applications including medical, consumer electronics / personal entertainment and other" [1]. In more common terms, a Body Area Network is a system of devices in close proximity to a person's body that cooperate for the benefit of the user. They will tend for people's need of self-monitoring and facilitate healthcare delivery. A typical BAN or BSN requires vital sign monitoring sensors, motion detectors to help identify the location of the monitored individual and some form of communication, to transmit vital sign and motion readings to medical practitioners or care givers. A typical body area network kit will consist of sensors, a Processor, a transceiver and a battery. These radio-enabled sensors can be used to continuously gather a variety of important health and/or physiological data (i.e. information critical to providing care) wirelessly. Sensors that monitor the heart, blood pressure, movement, brain activity, dopamine levels, and actuators that pump insulin, "pump" the heart, deliver drugs to specific organs, stimulate the brain are needed as pervasive components in and on the body. These networks aim to augment the power to monitor the human body and react to problems discovered with this observation. A simple example of BAN application would be a device equipped with a built in reservoir and pump. This device can administer just the right amount of insulin to a diabetic person based on wirelessly received glucose level measurements from another body sensor.

Fig. 1 Basic working of a BAN [4]

These networks serve many advantages:

1. They open the door to "anytime, anywhere" health and wellness monitoring.
2. These connected systems of smart, highly sensitive, miniaturized sensors can be worn comfortably and continuously measure your vital signs and brain activity without disrupting your daily life.
3. Such solutions could revolutionize healthcare, allow us to get more from our workouts and even help us monitor and control our emotional wellbeing.
4. They offer a revolutionary set of applications among which we can point to smart pills for precision drug delivery, intelligent endoscope capsules, glucose monitors and eye pressure sensing systems.

However these networks do not come with such comfort, they pose great challenges:

1. Scalability and Traceability: WBAN systems would have to ensure seamless data transfer across standards such as Bluetooth, ZigBee etc. to promote information exchange, plug and play device interaction. Further, the systems would have to be scalable, ensure efficient migration across networks and offer uninterrupted connectivity.
2. Sensor characteristics: The sensors used in WBAN would have to be low on complexity, small in form factor, light in weight, power efficient, easy to use and reconfigurable. Further, the storage devices need to facilitate remote storage and viewing of patient data as well as access to external processing via the Internet.
3. Security: Considerable effort would be required to make BAN

transmission secure and accurate. It would have to be made sure that the patient "secure" data is only derived from each patient's dedicated BAN system and is not mixed up with other patient's data. Further, the data generated from WBAN should have secure and limited access.

4. Privacy Disruption: People might consider the WBAN technology as a potential threat to freedom, if the applications go beyond "secure" medical usage
5. Erroneous Datasets: Pervasive sensing devices are subject to inherent communication and hardware constraints including unreliable wired/wireless network links, interference and limited power reserves. This may result in erroneous datasets being transmitted back to the end user. It is of the utmost importance especially within a healthcare domain that all sensor readings are validated.
6. Data consistency: Data residing on multiple mobile devices and wireless patient notes need to be collected and analysed. Within body area networks, vital patient datasets may be fragmented over a number of nodes and across a number of networked PCs or Laptops. If a medical practitioner s mobile device does not contain all known information then the quality of patient care may degrade.
7. Crosstalk: The wireless link used for body sensors should reduce the interference and increase the coexistence of sensor node devices with other network devices available in the environment. This is especially important for large scale implementation of WBAN systems.

Besides hardware challenges, there are various challenges that are posed by the body itself. These include:

1. Cost: Today's consumers expect low cost health monitoring solutions which provide high functionality. WBAN implementations will need to be cost optimized to be appealing alternatives to health conscious consumers.
2. Continuous Supervision: Users may require different levels of monitoring, for example those at risk of cardiac ischemia may want their WBANs to function constantly, while others at risk of falls may only need WBANs to monitor them while they are walking or moving. The level of monitoring influences the amount of energy required and the life cycle of the BAN before the energy source is depleted.
3. Constrained deployment: The WBAN needs to be wearable, lightweight and non intrusive. It should not alter or encumber the user's daily activities. The technology should ultimately be transparent to the user i.e., it should perform its monitoring tasks without the user realizing it.
4. Efficiency: The performance of the WBAN should be consistent. Sensor measurements should be accurate and calibrated even when the WBAN is switched off and switched on again. The wireless links should be robust and work under various user environments.

II. ARCHITECTURE

The proposed wireless body area sensor network for health monitoring integrated into a broader multitier telemedicine system is illustrated in Fig. 2. The telemedical system spans a network comprised of individual health monitoring systems that connect through the Internet to a medical server tier that resides at the top of this hierarchy. The top tier, centered on a medical server, is optimized to service hundreds or thousands of individual users, and encompasses a complex network of interconnected services, medical personnel, and healthcare professionals. Each user wears a number of sensor nodes that are strategically placed on her body. The primary functions of these sensor nodes are to unobtrusively sample vital signs and transfer the relevant data to a personal server through wireless personal network implemented using ZigBee (802.15.4) or Bluetooth (802.15.1) [2]. The personal server, implemented on a personal digital assistant (PDA), cell phone, or home personal computer, sets up and controls the WBAN, provides graphical or audio interface to the user, and transfers the information about health status to the medical server through the Internet or mobile telephone networks (e.g., GPRS, 3G). The medical server keeps electronic medical records of registered users and provides various services to the users, medical personnel, and informal caregivers. It is the responsibility of the medical server to authenticate users, accept health monitoring session uploads, format and insert this session data into corresponding medical records, analyze the data patterns, recognize serious health anomalies in order to contact emergency care givers, and forward new instructions to the users, such as physician prescribed exercises. The patient's physician can access the data from his/her office via the Internet and examine it to ensure the patient is within expected health metrics (heart rate, blood pressure, activity), ensure that the patient is responding to a given treatment or that a patient has been performing the given exercises.

The Body Area Network consist of the following sensors-

- Sensors implanted inside human body
- External Device(Control Node)
- Base Stations

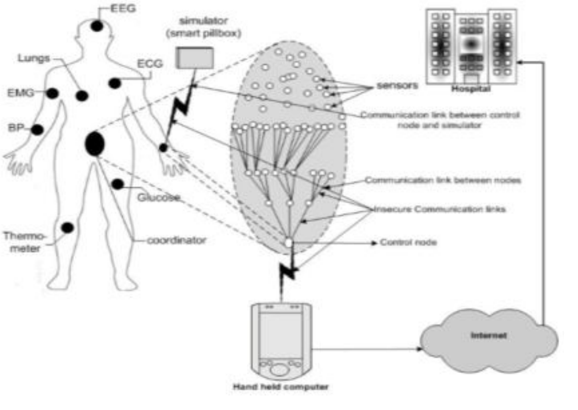

Fig. 2 An example of BSN [2]

These networks work in a defined frequency spectrum of 2360-2400MHZ [3]. MBANs will measure and record patient physiological information and perform diagnostic and therapeutic functions using electromagnetic signals in a wireless environment. Body data sensors will transmit data to a hub, which will aggregate the patient data and transmit it via a hospital's local area network (LAN) to a place where it can be analyzed. MBANs will operate in the 2360-2400 megahertz (MHz) range. MBANs will only be secondary users in the 2360-2390 MHz portion of the band, however, subject to primary use of the band by Aeronautical Mobile Telemetry (AMT) licenses. Healthcare facilities must operate within this range, and all use must be indoors. Significantly, any MBAN operating within this segment must be capable of receiving and complying with control messages notifying the device to limit or cease operations if there is interference with a primary user. MBANs operating here must therefore not only be capable of receiving and operating with interference from a primary user, but they must not cause interference for a primary user.

However this architecture poses several threats:

First, hospital MBAN users in the 2360-2390 MHz band must be subject to interference caused by AMT licensees and must be capable of shutting down or defaulting to the 2390-2400 MHz range. These devices must, therefore, be capable of functioning through interference without the loss of potentially critical patient monitoring functions.

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Finally, FCC has noted that a 40 MHz range allows for MBAN use within "high density settings" (e.g., hospital waiting rooms) where many MBAN patient users may congregate. However, there must be concern about the possible future shortage of bandwidth for MBAN users, particularly if the number of primary AMT users increases.

Thus the architecture of body area networks though being complex and cumbersome is a proliferation of wireless devices and recent advances in miniature sensors that prove the technical feasibility of a ubiquitous heath monitoring system.

I. REQUIREMENTS OF BAN

A. HARDWARE REQUIREMENTS of BAN

A typical BAN or BSN requires vital sign monitoring sensors, motion detectors (through accelerometers) to help identify the location of the monitored individual and some form of communication, to transmit vital sign and motion readings to medical practitioners or care givers. A typical body area network kit will consist of sensors, a Processor, a transceiver and a battery.

- **Biosensors:** Biosensors are the sensors present in the BAN network that is responsible for detecting the vital physiological signs including heart rate, blood pressure and temperature. On the other side there is also a motion sensors that are responsible for collecting the information about the recent state of humans' body. The patient may be in a running state, walking state etc. In terms of hardware these biosensors normally consist of a micro controller, light weight memory of few kilobytes, data converters, RF transceivers and a battery to charge them. The sensors also loaded with an operating system that is responsible for transferring, formatting and encrypting the data.
- **Gateway:** Along with the Biosensors, the BAN network also consists of controller. The biosensors also communicate with controller which is called as gateway. The role of gateway is to gather the data from multiple nodes and store that data in local memory until the Internet connection is not available. As soon as Internet connection is available the gateway further moves the data into the systems' database through one of its outgoing port. The gateway take cares of the BAN network. The gateway can be a PDA device with WiFi or it can be a mobile device with GPRS.
- Monitoring Server: - It consists of a database for storing and further processing the data. For detailed diagnosis, the physician will examine the stored data.

B. NETWORK REQUIREMENTS FOR BAN

- **Range:** Communication between the sensors can take place in or around the human body so 2 to 5 meters of range is sufficient.
- **Interference:** Communication among the sensors nodes should be reliable and efficient so interference need be suppressed as much as possible.
- **Network density:** Number of sensors can be placed for measuring data based on different applications requirements. Accordingly, a number of WBAN networks can be formed within the body. The WBAN standard permits 2 to 4 networks per m2.
- **Sensors number per network:** The number of sensors to be implanted varies from application to application. The WBAN standard permits a maximum of 256 devices per network.
- **Security/encryption:** There is a need to protect the transmitted data and also to maintain the integrity of received information.
- **Latency:** The time delay must be lower than 125 ms for the medical applications and for non-medical applications it need not to be more than 250 ms. Jitter must also be controlled.
- **Enabling priority:** Emergency packets must be assigned higher priority as compared to the other packets in the network.

IV. WBAN APPLICATION AREAS

Fig. 3 Capabilities of BANs [5]

According to World Health Organization, aging population is becoming a significant problem at the same time that sedentary lifestyle is causing millions of people to suffer from obesity or chronic diseases everyday [5]. It is thus reasonable to expect that this circumstance will only contribute to an ongoing decline in the quality of services provided by an already overloaded health- care system [6]. In summary, several key applications will benefit from the advanced integration of BANs and emerging wireless technologies:

1. Medical Applications

1.1 Chronic Disease Monitoring

As the costs of treating diseases in US contribute to around 75% of total health care costs, it is the most important use case of all mentioned. Chronic diseases are a wide range of illnesses: heart diseases, diabetes, asthma and many more. In most cases these diseases require constant long term monitoring, to assure proper level of treatment and correct diagnosis

1.2 Episodic Patient Monitoring

This use case focuses on periodical testing of patient's health status in order to keep a long term data on his/hers health state. It helps doctors to determine trends in patient's EKG, blood pressure etc. Information gathered in this use case is sent to the remote data center, and kept there for further reference.

1.3 Patients Alarm Monitoring

Monitoring equipment in this category targets constant monitoring in case of medical emergency (heart attack etc). Data can be processed in two ways- locally or remotely. In case of local processing, the data is checked for sings of emergency and if such occurs the alarm signal is sent to the response center.

1.4 Elderly people monitoring

This type of monitoring apart from normal vital signals checking also can record other data helping to determine wellbeing of old person. It can information on a current place where a patient is, or a distress signal in case of need of assistance. Such information could be accessed (with permission) by the members of family remotely.

1.5 Cardiovascular diseases

It is one of the leading causes of annual deaths in almost every developed country. Lightweight sensor nodes that can be placed on the patient in an un-obtrusive manner can surely avoid a huge number of deaths caused by cardiovascular diseases. It will instruct the medical staff to be prepared in advance as they obtain crucial information regarding heart-rate or any other irregularities of the heart while examining the health status of the patient. A WBAN is a vital technology to overcome the occurrence of myocardial infarction, observing the episodic events or any other abnormal condition.

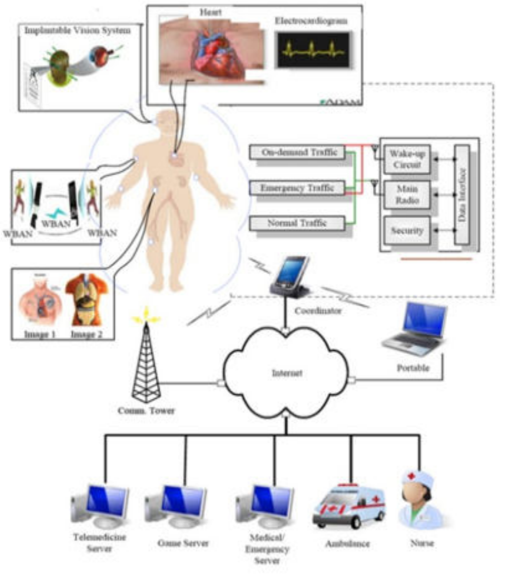

Fig. 4 Application of BANs [3]

1.6 Cancer Detection

A sensor that is capable of detecting nitric oxide that is emitted by cancerous cells can be placed in the suspect locations. These sensors have the capability to distinguish cancerous cells, between the various other types of cells.

1.7 Glucose Level Monitoring

Diabetes can give rise to many other diseases including heart diseases, high blood pressure, blindness, kidney disease, etc [11]. A bio-sensor that is implanted in the patient could offer a more reliable, precise and less invasive scheme by checking glucose levels, broadcast the results to a wireless PDA or a permanent terminal, and by injecting insulin automatically when a blood glucose level exceeds a threshold level.

1.8 Asthma

Asthma can be monitored by incorporating the sensor nodes within the human body that can detect the various allergic agents present in the air and report the same status constantly to the physician.

1.9 Organ Monitors

Organ monitor observes the condition of various organs such as kidney, livers and heart so that they can be transplanted at the right time before it is no longer viable. Different organs have distinct preservation time such as for heart it is 4-6 hours, for a liver it is 12-24 hours, for a kidney it is 48-72 hours [5]. With the installation of smart sensors, organ monitors could observe the levels of in vitro heart carbon dioxide (CO2), Oxygen (O2) & methane to monitor heart viability before transplant.

3. General Health Monitors

Numerous wireless bio-medical sensors have also been proposed for use as a general health monitors. With the help of bio-medical sensors, general health monitors would regularly monitor various tissues in its environment. Such systems would surely help individuals with digestive problems. By just consuming one pill with smart sensor would clearly depict intestinal acidity or pressure that would further help the physicians to better diagnose gastrointestinal diseases in a non-invasive manner. There are other pills also that would serve the different purpose such as measuring the heart rate, brain activity etc.

4. Military Operations

In battlefield WBAN can play a very important role. It will provide secure connectivity among soldiers and will also enable the commander to get to know about the various soldiers' activities such as running, firing & digging. It will also assist in preventing the surprise attacks [14]. The commander can even control the positions of soldiers in case if any danger is encountered in near-by areas.

5. Sports Training

For better sports training, sensors can be appropriately placed on several body parts so that the numerous postures can be easily recognized. This will further enable the players in various sports including golf, cricket to improve their performance and also prevent injuries by correcting their body postures.

6. Interactive gaming

Body sensors enable game players to perform actual body movements, such as boxing and shooting, that can be feedback to the corresponding gaming console, thereby enhancing their entertainment experiences.

7. Personal information sharing

Private or business information can be stored in body sensors for many daily life applications such as shopping and information exchange [3].

8. Secure authentication

This application involves resorting to both physiological and behavioral bio- metrics schemes, such as facial patterns, finger prints and iris recognition. The potential problems, e.g., proneness to forgery and duplicability, however, have motivated the investigations into new physical/behavioral characteristics of the human body, e.g., Electroencephalography (EEG) and gait, and multimodal biometric systems.

V. ROUTING

Several routing protocols in wireless sensor networks have been studied in past few years but these are not suitable for BANs. BANs face stringent requirements which must be considered in design of routing protocols. These stringent requirements are in terms of delay, temperature, power, network lifetime and energy.

Routing in BANs are classified with respect to their aims .They are broadly classified into three categories-temperature based routing protocols, cluster based routing protocols, cross-layer routing protocols and cost-effective routing protocols.

TEMPERATURE BASED ROUTING

These routing protocols take temperature as routing metric. The main purpose of these protocols is to keep the temperature of node below the temperature safety level so that it does not harm human body [8]. Several protocols have been proposed which uses the temperature based routing.

A. Thermal Aware Routing Protocol (TARA)

TARA routes data to minimum thermal effects in a heat sensitive environment [12]. It was the first protocol that introduced temp erature as a routing protocol metric [8]. It works as follows: The tempe rature change of neighboring nodes is measured using packet count, power consumption. The node which exceeds a predefined threshold value us called as hotspot node. A withdrawal strategy is used in TARA. When the packets arrived at a node surrounded by hotspot nodes, they are sent back to sender and alternative path is followed to forward the packets to the sink node [7]. An example is shown in the Fig. 5.

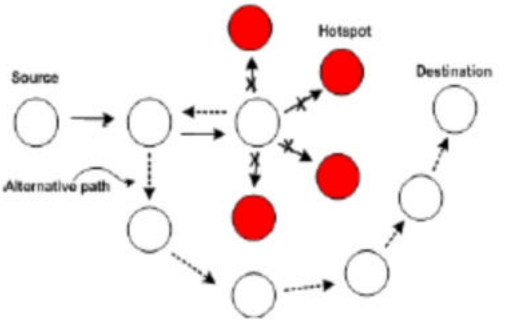

Fig. 5 An example of TARA [12]

TARA protocol is safe to use in in-body BANs and also the traffic congestion is less using this routing protocol. However, the number of transmissions is increased as alternative route is followed in case of hotspots and overall network temperature rises. Also, this strategy considers only temperature as a routing metric which leads to low network lifetime, high end-to-end delay, low reliability, high packet-lossratio. TARA does not consider link probability and power efficiency.

B. Least Temperature Routing(LTR)

LTR routing protocol is based on TARA protocol. This protocol defines hotspot node as the node which is having high temperature because of data communication focus. Every node has the information of the temperature of neighboring node similar to TARA. The node forwards the packet to the neighboring node having the least temperature. So the nodes forward data to the "coolest neighbor". A constraint is put on the number of hops so that the network bandwidth cannot increase much. The threshold value MAX_HOPS is defined and packet is discarded if this value is exceeded. To avoid getting into infinite loop, LTR keeps the track of nodes through which packets have passed. Fig. 6 shows the example of LTR routing.

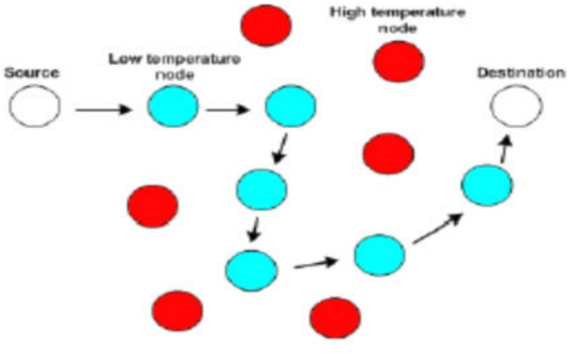

Fig. 6 An example of LTR [7]

However there are some drawbacks associated with this protocol. More bandwidth is wasted as most of the nodes are involved in routing. Overall temperature is increased and there is significant power consumption. Also, this protocol follows less optimal route towards destination.

C. Adaptive Least Temperature Routing (ALTR)

ALTR is an adaptive form of LTR. ALTR can adapt to particular topologies [13]. It is similar to LTR but a new parameter called as MAX_HOP_ADAPTIVE has been defined. The packets being routed must not exceed this value. For values lower than MAX HOP ADAPTIVE the packets are routed in same way as LTR but for values higher than MAX_HOP_ADAPTIVE the Shortest Hop Algorithm is used. The Fig. 7 shows an example of ALTR.

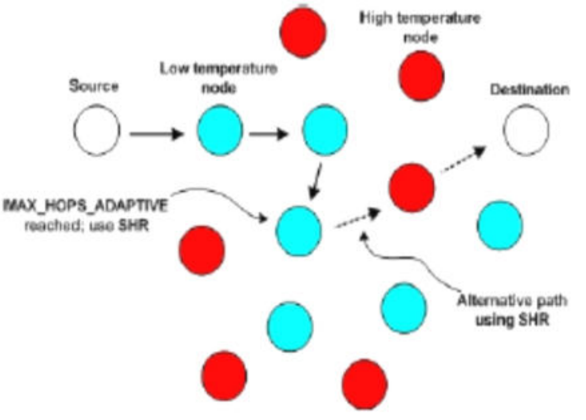

Fig. 7 An example of ALTR [8]

A mechanism called as "proactive delay" is used that cools down the temperature of the nodes which is increased due to following same path repeatedly. If a node receives a packet such that its coolest neighbor has relatively higher temperature, the node delays the packet by one unit before sending it to its coolest neighbor [8]. Though ALTR uses Shortest Hop Routing algorithm, the network bandwidth is wasted when it go through hotspots. Also ALTR leads to increase in op count and sensor temperature. Due to adaptive nature of ALTR, it has lower delay than LTR.

D. Least Total Route Temperature (LTRT)

LTRT is a hybrid between LTR and Shortest Path routing algorithm. It is designed so that the route is selected with minimum temperature from source to destination and the numbers of hops are also less. The working of this algorithm can be explained as follows: The information about temperature of neighboring node is collected. Then all the possible routes are built and weights are assigned to the intermediate nodes and a graph is built. Then the shortest route from Source to destination is found such that the route is having least temperature. The example of LTRT is as shown in Fig. 8

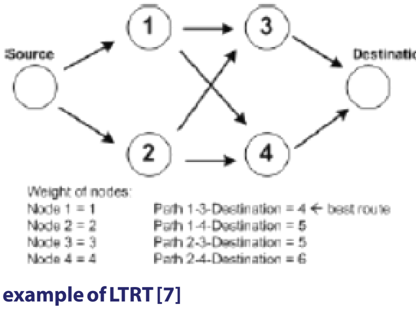

Fig. 8 An example of LTRT [7]

LTRT has lower average temperature rise and hop count as compared to LTRT and ALTR. The packet loss ratio of LTRT is nearly zero as it is designed such that no packets are dropped.

E. Hotspot Preventing Routing(HPR)

HPR is an improvement of LTR and ALTR this algorithm routes packets through the shortest path and avoids hotspot formation. Thus it reduces the average network delay.

The routing is done using two phases in HPR- setup phase and routing phase. In the setup phase the information about th temperature of the nodes and shortest path is calculated and a routing table is based on this information. In the routing phase as long as no hotspot occur shortest hop algorithm is used. The hotspots are calculated dynamically in HPR. If the temperature of next hop exceeds the summation of current temperature and threshold, the packet is forwarded to its neighbor with the least temperature. The threshold value is also calculated dynamically using this protocol.

HPR has low packet delivery delay and the temperature rise is avoided.

F. Thermal-Aware Shortest Hop Routing(TSHR)

TSHR has been proposed as an improvement over HPR. It also has two phases similar to HPR the setup phase and the routing phase. TSHR defines two threshold values- fixed threshold and dynamic threshold. The fixed threshold is defined for all nodes and is used whenever a node is transmitting a packet. It compares the temperature of node to the fixed threshold. If it exceeds the threshold the packet is buffered until next hop temperature is below threshold. The dynamic threshold is calculated for each node and is set based on temperature of the nodes and its neighbors. It is used to identify hotspots. If the next hop temperature exceeds this threshold, the sending node finds the coolest neighbor and forwards the packets. Also, no packets are dropped in TSHR. Packet delivery delay is more than in HPR but this protocol has lowest temperature rise.

G. Routing Algorithm for Network of Homogeneous and ID-less Biomedical Sensor Nodes(RAIN)

In RAIN the nodes are ID-less. Id-less does not mean it does not IDs at all. It uses a temporary ID. RAIN operates in three phases- setup phase, routing phase and status phase. In setup phase, a random number generator is used to generate a random number which is used as node-id of the node in the network. Al nodes distribute their IDs in the network. The routing phase is used to assign a unique packet ID to each packet. In this protocol sending of duplicate packets are prevented. It checks whether received packet ID is already in queue, if it is packet is discarded. A status update phase is used to maintain the energy of nodes. A mechanism is used to prevent "energy-hole". Sink node broadcast status update to its neighbors which contains packet id of received packets. This will prevent forwarding of duplicate packets.

CLUSTER-BASED ROUTING

A. Anybody

Anybody is the cluster-based routing protocol. Instead of making direct communication with the base station this protocol use clusters to gather data [11]. The clusters are chosen randomly. The cluster head collects all the data and send it to the base station. Anybody works as follows:

1. Neighbor Discovery- Each node broadcasts hello messages in this stage. Information about 2-hop neighboring nodes is collected and connectivity graph is made.

2. Density Calculation- Each node calculates its density, sends it throughout the network and receives the density of other nodes.

3. Contacting Clusterhead- In this stage the join messages are send. The join messages are continuously relayed until it reaches the node with highest density. Therefore cluster and cluster heads among local nodes are formed in this stage.

4. Setting up the backbone- In this stage some nodes will be chosen as gateways (GW) to connect the clusters with each other. GW nodes are used for communication among the clusters.

5. Setting up the routing paths- In this stage routing paths are formed. The path followed in anybody is sender node, sender's clusterhead, other clusterheads, sink's clusterhead and finally the sink.

An example is shown in Fig. 9.

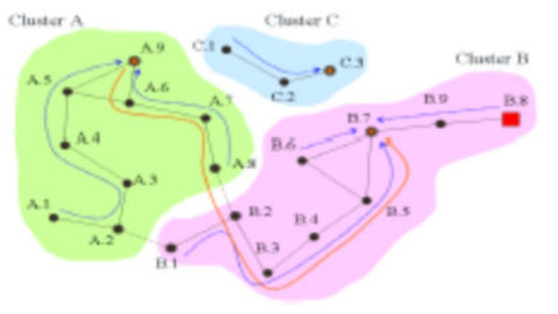

Fig. 9 An example of Anybody [7]

Anybody is not optimized for BANs and has high delay.

B. Hybrid Indirect Transmission (HIT)

This protocol uses parallel multihop indirect transmissions both within the cluster and among multiple clusters. HIT has small network delay and high network lifetime. It works as follows: Initially the cluster heads are formed. They send their status throughout the network. Then upstream and downstream clusters are formed. Then, from a cluster to the cluster head multiple routes are formed and each node calculates its blocking set. Blocking set of a node is the set of nodes which are not allowed to transmit simultaneously with that node. Then using TDMA schedule is computed.

COST EFFECTIVE ROUTING

A. Opportunistic Routing

In opportunistic routing the moving nature of body is considered. The packet is delivered whenever there is a direct contact between source and destination. It ensures high communication probability with sink at all times. A simple model is used in this protocol. Sink node is placed on wrist and moves forward and backward while doing activities like running and walking [9]. Sensor node is placed at chest and relay node at waist. The data is sent to relay node and then sink node if the wrist is at back of body and non line of sight communication is there. When line of sight communication exists wrist is in front and there exists a direct communication between sink and the sensor node.

The energy is preserved to increase the network lifetime. By placing relay nodes and sink nodes at appropriate places energy consumption can be decreased.

B. Randomized routing

In randomized routing, packets are randomly routed using hot-potato logic [10]. In this type of routing no direct communication exists between node and the destination. The packet is forwarded by the node to another node chosen randomly. The packet is forwarded randomly to the connected neighbors until the destination is reached. This way it uses a random node to forward the packet to destination. The probability known as forwarding probability is calculated and then the forwarding matrix is made based on the observed link states.

The average packet hop count is more in this case as compared to opportunistic routing.

C. Utility based routing

In randomized routing, the connectivity of a node with other node is not considered while a packet is forwarded [10]. In utility based routing protocols, the packet is forwarded to the neighbor with the latest encounter with the destination. The utility value is assigned to each node based on the latest encounter with the destination node. The packet is forwarded to the node having highest value. Utility represents how fast the data can be delivered to the destination. It is implemented using timers. Hello messages are used for exchanging the utility values.

Average delay in this case is less as compared to opportunistic and randomized protocol.

D. Probabilistic Routing with Multi-scale Postural local ity(PRMPL)

PRMPL routing uses postural link cost (PLC). For on-body sensors the packets are forwarded in same way as in Utility based routing but utility values are replaced by the PLCs. When the posture of the body changes with the activity f the human, the PLCs are automatically adjusted. The values are adjusted such that the packets are forwarded to the hops which will provide end-to-end path with minimum buffering or storage delay [10]. When the link is conn ected the PLC is increased at a constant rate. The difference between current value of PLC and its maximum value is 1. The link remains constant for a long time and the PLC value reaches maximum value of 1. When the link is disconnected PLC decreases to 1 at a constant rate.

PRMPL achieves better delay than other protocols because of its ability to capture multi-scale topological localities in human body.

VI. ROUTING CHALLENGES

BANs are used in various medical and non-medical applications including health-care, gaming, military and many more. As the BANs applications include different technological requirements, constraints and architectures, there are different challenges associated with BANs. This section covers the challenges associated.

1) Postural body movements- The link quality between nodes in BANs varies as a function of time due to postural body movements [7]. So the algorithm should be adaptive to the changes in the topology.
2) Limitation of sources- This is one of the important challenges as the nodes have limited energy and bandwidth. The protocol should be aware of the energy, quantity of the sources, memory available and network control otherwise the Quality of Service (QoS) may get affected.
3) High redundancy of data- Though redundancy of data in BAN helps in increasing reliability but the energy consumption may be more.
4) Dynamism of network- The degree of dynamism of network is increased due to certain factors such as environmental conditions, node mobility and destruction of communication. This increase of dynamism results in increased complexity of the network.
5) Energy consumption- To increase the network lifetime, energy consumption should be balanced so that no subset consumes higher energy [11]. Reliability on one route should not be there.
6) Heterogeneous environment- The nodes in BANs can be heterogeneous. As the power of calculation, memory and power consumption can be different for different nodes, it imposes the challenges on QoS.
7) Several Sink Nodes- There can be several sink nodes in BANs. QoS should be designed keeping in mind that it should support all levels.

VII. CONCLUSION

BANs are used in various medical and non-medical applications. The advantages, hardware and network challenges are described in this paper. The architecture of BAN along with the requirements is explained. BANs are used in various medical applications for cancer detection, patient monitoring, glucose level monitoring, cardio vascular disease and many more. Apart from medical applications Body area Networks are used in various non-medical applications as well. These include interactive gaming, defense and military applications, sports training. Routing in WBANs has gained importance in recent years. The routing can be classified on the basis of the metric used. It can be Temperature based routing, cost effective routing, cluster based routing. Various other types of routing algorithms have been proposed. Some of the routing challenges have been overcomed but a lot more of work has to be done.

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