WIRELESS SENSOR NETWORK: APPLICATIONS AND ANALYSIS OF ROUTING PROTOCOLS

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September 2012

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This Thesis is submitted to the Department of Electrical and Electronics Engineering (EEE), In Partial Fulfillment of the Requirements for the Award of HIGHER DIPLOMA in Electrical and Electronics Engineering (HD-EEE).

16th September, 2012

Declaration

This is to certify the project entitled "WIRELESS SENSOR NETWORK: APPLICATIONS AND ANALYSIS OF ROUTING PROTOCOLS "is supervised by Mr Nafiz Imtiaz Bin Hamid. This project work has not been submitted anywhere for a degree or diploma.

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Dedicated

To our parents

Abstract

Wireless sensor networks consist of small nodes with sensing, computation, and wireless communications capabilities. Recent advances in wireless sensor networks have led to many new protocols specifically designed for sensor networks where energy awareness is an essential consideration. Most of our attention, however, has been given to the routing protocols since they might differ depending on the application and network architecture. A wireless sensor network (WSN) has important applications such as remote environmental monitoring and target tracking. This has been enabled by the availability, particularly in recent years, of sensors that are smaller, cheaper, and intelligent. These sensors are equipped with wireless interfaces with which they can communicate with one another to form a network. The design of a WSN depends significantly on the application, and it must consider factors such as the environment, the application's design objectives, cost, hardware, and system constraints.

This project surveys recent routing protocols for sensor networks and presents detailed account of various routing protocols. The project also talks about the basic network topologies in wireless sensor network. The basic network topologies include fully connected, mesh, star, ring, tree, bus etc. Again we have presented various system architectures, design issues and challenges in wireless sensor network. Solution to some of these challenges and the applications of wireless sensor networks are also provided. Lastly we conclude with open research issues in WSN.

Acknowledgement

First and foremost, we are very much indebted to Almighty Allah, the most Merciful without whose patronage and blessing this project report would not have been successfully completed.

We would like to express our sincere gratitude to our supervisor, Mr. Nafiz Imtiaz Bin Hamid Assistant Professor, Department of Electrical and Electronics Engineering (EEE) whose kind understanding, expertise, guidance, and patience, have considerably improved our graduate experience and know-how in our field of specialization. He provided us with immense guidance, technical support and constructive suggestions and in the course of time became more of a mentor than just a supervisor.

We are also grateful to him for the enormous time he has spent going through the various phases of our project work. His impressive commentaries, criticisms and observations throughout the several stages of our work have played a major role in enhancing both the quality and content of our humble work. It is thanks to his persistence, indulgence, understanding and kindness that we completed our project on time and at a very comfortable pace. We doubt that we will ever be able to convey him our appreciation fully, but we owe him our eternal gratitude.

Our special thanks goes to Prof. Dr. Md. Shahid Ullah Head of EEE Department without whose motivation and encouragement we would not have considered a graduate career in our field.

Last but not the least; we would like to thank our parents who have given us tremendous inspiration and support. Without their constant moral and financial support we would not have been able to complete our project work.

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5.1 Types of Wireless Sensor Network 53

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ABBREVIATIONS

BS	Base Station
BW	Bandwidth
QoS	Quality of Service
WSN	Wireless Sensor Network
GPS	Global Positioning System
Friday	Radio Frequency Identification
RF	Radio Frequency
MA	Mater Aggregator
LA Local	Local Aggregator
CH	Channel
HT	Hard Threshold
ST	Soft Threshold
RS	Random Sources
ER	Event Radius
WAN	Wide Area Network
LAN	Local Area Network
GUI	Graphical User Interface
UHF	Ultra High Frequency
CDMA	Code Division Multiple Access
TDMA	Time Division Multiple Access
EBAM	Energy-Based Activity Monitoring

CDM	Controlled Delimitation Material
LEACH	Low-Energy Adaptive Clustering Hierarchy
TEEN	Threshold sensitive Energy Efficiency Routing
AQUIRE	Active Query Forwarding in Sensor Networks
APTEEN	Adaptive Threshold sensitive Energy Efficiency Routing
PEGASIS	Power-Efficient Gathering in Sensor Information Systems
SPIN	Sensor Protocols for Information via Negotiation
SHIMMER	Intel Digital Health Group's Sensing Health with Intelligence, Modularity, Mobility, and Experimental Re-Usability
SID	Sudden Infant Death syndrome
CMOS	Complimentary Metal-Oxide Semiconductor

C H AP T E R 1

I n t r o d u c t I o n

Due to the recent advances in micro-electro-mechanical systems and low power a, highly integrated digital electronics have led to the development of micro sensor. These sensors have the ability to measure ambient conditions in the environment surrounding them and then transform these measurements into electric signals that can be processed. Processing such a signal reveals some properties about objects located and/or events happening in the vicinity of the sensor. A large number of these sensors can be networked in many applications that require unattended operations, hence producing a wireless sensor network (WSN). In fact, the applications of WSNs are quite numerous. For example, WSNs have profound effects on military and civil applications such as target field imaging, intrusion detection, weather monitoring, security and tactical surveillance, distributed computing, detecting ambient conditions such as temperature, movement, sound, light, or the presence of certain objects, inventory control, disaster management and health care. These systems process data gathered from multiple sensors to monitor events in an area of interest. For example, in a disaster management setup, a large number of sensors can be dropped by a helicopter. Networking these sensors can assist rescue operations by locating survivors, identifying risky areas and making the rescue crew more aware of the overall situation. Such application of sensor networks not only can increase the efficiency of rescue operations but also ensure the safety of the rescue crew In health, one promising application area is in the integration of sensing and consumer electronics technologies which would allow people to be constantly monitored. In- home pervasive networks may assist residents and their caregivers by providing continuous medical monitoring, memory enhancement, control of home appliances, medical data access, and emergency communication. Constant monitoring will increase early detection of emergency conditions and diseases for at risk patients and also provide wide range of healthcare services for people with various degrees of cognitive and physical disabilities. Not only the elderly and chronically ill but also the families in which both parents have to work will derive benefit from these systems for delivering high-quality care services for their babies and little children. Given the importance of the subject, there are already several applications and prototypes on the subject. For example, some of them are devoted to continuous monitoring for cognitive disorders like Alzheimer's, Parkinson's or similar cognitive diseases. Some focus on fall detection, posture detection and location tracking and others make use of biological and environmental sensors to identify patients' health status. There is also significant research effort in developing tiny wireless sensor devices, preferably integrated into fabric or other substances and be implanted in human body. However, sensor nodes are constrained in energy supply and bandwidth. Such constraints Combined with a typical deployment of large number of sensor nodes have posed many challenges to the design and management of sensor networks. These challenges necessitate energy awareness at all layers of networking protocol stack. The issues related to physical and link layers are generally common for all kind of sensor applications, therefore the research on these areas has been focused on system-level power awareness such as dynamic voltage scaling, radio communication hardware, low duty cycle issues, system partitioning, energy-aware MAC protocols. At the network layer, the main aim is to find ways for energy-efficient route setup and reliable relaying of data from the sensor nodes to the sink so that the lifetime of the network is maximized. Routing in sensor networks is very challenging due to several characteristics that distinguished these networks from other types of wireless networks like mobile ad hoc networks or cellular networks. First of all, it is not possible to build a global addressing scheme for the deployment of sheer number of sensor nodes. Therefore, classical IP-based protocols cannot be applied to sensor networks**.** Furthermore, sensor nodes that are deployed in an ad hoc manner need to be self-organizing as the ad hoc deployment of these nodes requires the system to form connections and cope with the resultant nodal distribution, especially as the operation of sensor networks is unattended. In WSNs, sometimes getting the data is more important than knowing the IDs of which nodes sent the data. Second, in contrary to typical communication networks almost all applications of sensor networks require the flow of sensed data from multiple regions (sources) to a particular sink. Third, sensor nodes are tightly constrained in terms of energy, processing, and storage capacities. Thus, they require careful resource management. Fourth, in most application scenarios, nodes in WSNs are generally stationary after deployment except for maybe a few mobile nodes. Nodes in other traditional wireless networks are free to move, which results in unpredictable and frequent topological changes. However, in some applications, some sensor nodes may be allowed to move and change their location (although with very low mobility). Fifth, sensor networks are application-specific (i.e., design requirements of a sensor network change with application). For example, the challenging problem of low-latency precision tactical surveillance is different from that of a periodic weather monitoring task. Sixth, generated data traffic has significant redundancy in it since multiple sensors may generate same data within the vicinity of a phenomenon. Such redundancy needs to be exploited by the routing protocols to improve energy and bandwidth utilization. Seventh, position awareness of Sensor nodes is important since data collection is normally based on the location. Currently, it is not feasible to use Global Positioning System (GPS) hardware for this purpose. Due to such differences, many new algorithms have been proposed for the problem of routing data in sensor networks. These routing mechanisms have considered the characteristics of sensor nodes along with the application and architecture requirements. Almost all of the routing protocols can be classified as data-centric, hierarchical or location based although there are few distinct ones based on network flow or quality of service (QoS) awareness. Data-centric protocols are query-based and depend on the naming of desired data, which helps in eliminating many redundant transmissions. Hierarchical protocols aim at clustering the nodes so that cluster heads can do some aggregation and reduction of data in order to save energy. Location based protocols utilize the position information to relay the data to the desired regions rather than the whole network. The last category includes routing approaches that are based on general network-flow modeling and protocols that strive for meeting some QoS requirements along with the routing functions. In our project, we will explore the network topologies, application of sensor network, different routing protocols for sensor networks developed in recent years. Each routing protocol is discussed in details. Our aim is to help better understanding of the current routing protocols for wireless sensor networks and point out open issues that can be subject to further research.

CHAPTER 2

Network Topologies, System architecture and design issue

2.1 Network Topologies:

A communication network is composed of nodes, each of which has computing power and can transmit and receive messages over communication links, wireless or cabled. The basic network topologies are shown in the figure and include fully connected, mesh, star, ring, tree, bus. A single network may consist of several interconnected subnets of different topologies. Networks are further classified as Local Area Networks (LAN), e.g. inside one building, or Wide Area Networks (WAN), e.g. between buildings.

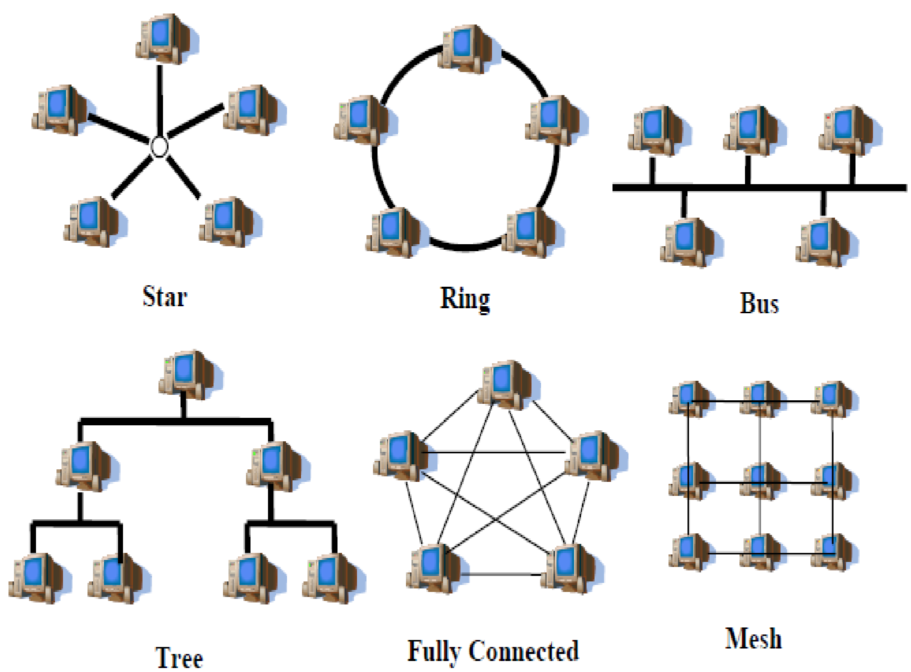

Fig 2.1 Basic Network Topologies

2.1.1 **Fully connected networks** suffer from problems of NP-complexity [Garey 1979]; as additional nodes are added, the number of links increases exponentially. Therefore, for large networks, the routing problem is computationally difficult even with the availability of large amounts of computing power

2.1.2 **Mesh Networks**, allow communication only between nearest nodes. The nodes in these networks are generally identical, so that mesh nets are also referred to as peer-to-peer nets. Mesh nets can be good models for large-scale networks of wireless sensors that are distributed over a geographic region, e.g. personnel or vehicle security surveillance systems. Note that the regular structure reflects the communications topology; the actual geographic distribution of the nodes need not be a regular mesh. Since there are generally multiple routing paths between nodes, these nets are robust to failure of individual nodes or links. An advantage of mesh nets is that, although all nodes may be identical and have the same computing and transmission capabilities, certain nodes can be designated as 'group leaders' that take on additional functions. If a group leader is disabled, another node can then take over these duties

2.1.3 **Star topology,** with the star topology all the nodes are connected to a single hub node. This hub requires greater message handling, routing, and decision-making capabilities than the other nodes. If a communication link is interrupted or cut, it only affects one node. However, if the hub is incapacitated (deprive of power) the network is destroyed

2.1.4 **Ring topology**, all the nodes perform the same function and there is no leader node. Messages generally travel around the ring in a single direction. The drawback of this topology is that if the ring is cut all the communication is destroyed. As a solution to this, a self –healing ring (SHR)

2.1.5 **Bus topology**, messages are broadcast on the bus to all nodes. Each node checks the destination address in the message header, and processes the messages addressed to it. The bus topology is passive in that each node simply listens for messages and is not responsible for retransmitting any messages.

2.1.6 Tree topology: tree network uses a central hub call a root node as the main communication router. One level down the Root node in hierarchy is a central hub. This lower level then forms a star network.

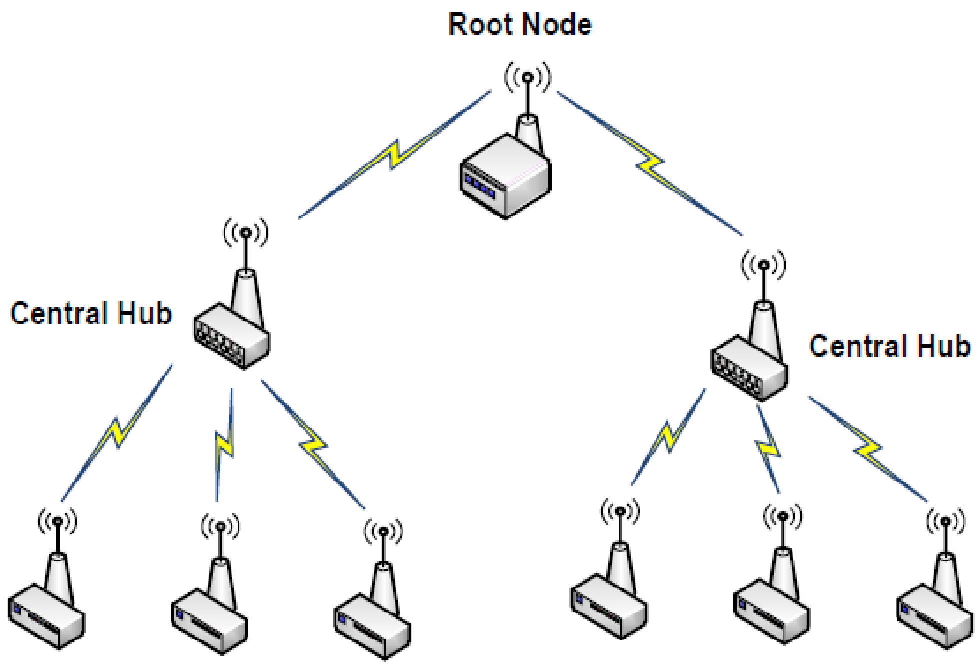

Fig 2.2Tree topology

2.2 System architecture and design issue

Depending on the application, different architectures and design goals/constraints have been considered for sensor networks. Since the performance of a routing protocol is closely related to the architectural model, in this chapter we will try to capture architectural issues and highlight their effect on WSN. Also we will talk about the limitations of wireless sensor networks (such as limited energy supply, limited computing power and limited Bandwidth of the wireless link connecting the sensor node) despite their numerous advantages. The design of routing protocols in WSNs is influenced by many challenging factors. These factors must be overcome before efficient communication can be achieved in WSNs. A summary of some of the system architecture, design issues and routing challenges are given as follows.

2.2.1 Node deployment:

Node deployment in WSNs is application-dependent and can be either manual (deterministic) or self organized. In manual deployment, the sensors are manually placed and data is routed through predetermined paths. However, in random (self organized) node deployment, the sensor nodes are scattered randomly, creating an ad hoc routing infrastructure. In that infrastructure, the position of the sink or the cluster-head is also crucial in terms of energy efficiency and performance. When the distribution of nodes is not uniform, optimal clustering becomes a pressing issue to enable energy efficient network operation.

2.2.1 Network dynamics:

Three main components are present in a sensor network. These are the sensor nodes, sink and monitored events. Aside from the very few setups that utilize mobile sensors, most of the network architectures assume that sensor nodes are stationary. However, in many applications both the BS or sensor nodes can be mobile. As such, routing messages from or to moving nodes is more challenging since route and topology stability become important issues, in addition to energy, bandwidth, and so forth. Moreover, the phenomenon can be mobile (e.g., target detection/ tracking application). On the other hand, sensing fixed events allows the network to work in a reactive mode (i.e., generating traffic when reporting), while dynamic events in most applications require periodic reporting to the base station

2.2.3 Node/link heterogeneity:

In numerous studies, all sensor nodes were assumed to be homogeneous (i.e., have equal capacities in terms of computation, communication, and power). However, depending on the application a node can be dedicated to a particular special function such as relaying, sensing and aggregation since engaging the three functionalities at the same time on a node might quickly drain the energy of that node. The enclosure of a heterogeneous set of sensors raises many technical issues related to data routing. For example, some applications might require a diverse mixture of sensors for monitoring temperature, pressure, and humidity of the surrounding environment, detecting motion via acoustic signatures, and capturing images or video tracking of moving objects. Either these special sensors can be deployed independently or the different functionalities can be included in the same sensor nodes. Even data reading and reporting can be generated from these sensors at different rates, subject to diverse QoS constraints, and can follow multiple data reporting models. For example, hierarchical protocols designate a cluster head node different from the normal sensors. These cluster heads can be chosen from the deployed sensors or be more powerful than other sensor nodes in terms of energy, bandwidth, and memory. Hence, the burden of transmission to the BS is handled by the set of cluster heads

2.2.4 Data aggregation:

Since sensor nodes might generate significant redundant data, similar packets from multiple nodes can be aggregated so that the number of transmissions would be reduced. Data aggregation is the combination of data from different sources by using functions such as suppression (eliminating duplicates), min, max and average. This technique has been used to achieve energy efficiency and data transfer optimization in a number of routing protocols. Data aggregation is also possible through signal processing techniques. In that case, it is referred as data fusion where a node is capable of producing a more accurate signal by reducing the noise and using some techniques such as beam forming to combine the signals.

2.2.5 Data reporting method:

Data delivery model (reporting method) in WSN is application dependent. Data reporting can be classified as either continuous, event driven, query-driven, or a hybrid of all these method. In the continuous delivery model, each sensor sends data periodically. In event-driven and query-driven models, the transmission of data is triggered when an event occurs or a query is generated by the sink. Some networks apply a hybrid model using a combination of continuous, event-driven and query-driven data delivery. The routing protocol is highly influenced by the data delivery model, in terms energy of energy consumption and route stability.

2.2.6 Energy considerations:

During the creation of a Network, the process of setting up the routes is greatly influenced by energy considerations. Since the transmission power of a wireless radio is proportional to distance squared or even higher order in the presence of obstacles, multi-hop routing will consume less energy than direct communication. However, multi-hop routing introduces significant overhead for topology management and medium access control. Direct routing would perform well enough if all the nodes were very close to the sink. Most of the time sensors are scattered randomly over an area of interest and multi-hop routing becomes unavoidable.

2.2.7 Fault tolerance:

In an event where a sensor nodes fails or blocked due to lack of power, physical damage, or environmental interference. The failure of sensor nodes should not affect the overall task of the sensor network. If many nodes fail, medium access control (MAC) and routing protocols must accommodate formation of new links and routes to the data collection BSs. This may require actively adjusting transmit powers

2.2.8 Connectivity:

High node densities in sensor networks prevent them from being completely isolated from each other. Therefore, sensor nodes are expected to be highly connected. This, however, may not prevent the network topology from being variable and the network size from being made smaller due to sensor node failures. Connectivity also depends on the random distribution of nodes.

2.2.9 Scalability:

The number of sensor nodes deployed in the sensing area may be on the order of hundreds or thousands, or more. Any routing scheme must be able to work with this huge number of sensor nodes. In addition, sensor network routing protocols should be scalable enough to respond to events in the environment. Until an event occurs, most sensors can remain in the sleep state, with data from the few remaining sensors providing coarse quality.

2.2.10 Coverage:

In WSNs, each sensor node obtains a certain view of the environment. A given sensor’s view of the environment is limited in both range and accuracy; it can only cover a limited physical area of the environment. Hence, area coverage is also an important design parameter in WSNs.

2.2.11 Quality of service:

There are some application in which data should be delivered within a certain period of time from the moment it is sensed, or it will be useless. Therefore, bounded latency for data delivery is another condition for time-constrained applications. However, in many applications, conservation of energy, which is directly related to network lifetime, is considered relatively more important than the quality of data sent. As energy is depleted, the network may be required to reduce the quality of results in order to reduce energy dissipation in the nodes and hence lengthen the total network lifetime. Hence, energy-aware routing protocols are required to capture this requirement.

C H A P T E R 3

Routing Protocols

Introduction to routing Protocols

Routing protocols in wireless sensor Network determine the appropriate path onto which data should be forwarded from one sensor node to another. The routing protocol also specifies how sensor node report changes and share information with the other sensor node in the network that they can reach. A routing protocol allows the network to dynamically adjust to changing conditions, otherwise all routing decisions have to be predetermined and remain static. Therefore the main objective of routing protocols is to sensed, processed and transmit the data to the base station (BS) where it can be interpreted by the user. However, routing protocols for wireless sensor networks are proliferating. In general, routing in WSNs can be divided into flat-based routing, hierarchical-based routing, and location-based routing depending on the network structure.

3.1 Flooding:

In flooding, each sensor receiving a data packet broadcasts it to all of its neighbors and this process continues until the packet arrives at the destination or the maximum number of hops for the packet is reached.

3.2 Gossiping:

Gossiping is a slightly enhanced version of flooding where the receiving node sends the packet to a randomly selected neighbor, which picks another random neighbor to forward the packet to and so on. These two systems have some disadvantages like if we see in the fig below

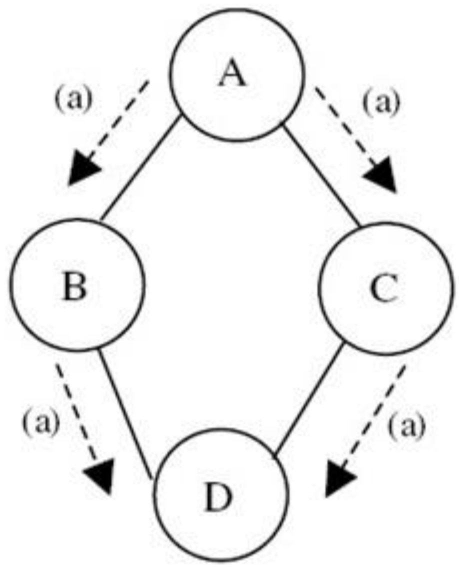

Fig 3.1 The implosion problem. Node A starts by flooding its data to all of its neighbors gets two same copies of data eventually which is not necessary.

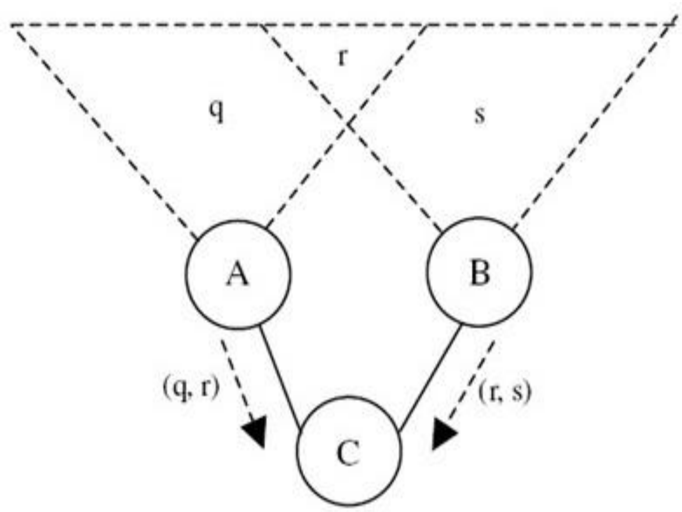

Fig 3.2 The overlap problem, two sensors cover an overlapping geographic region and C gets same copy of the data from these sensors.

This kind of disadvantages include implosion caused by duplicated messages sent to same node, overlap when two nodes sensing the same region send similar packets to the same neighbor and resource blindness by consuming large amount of energy without consideration for the energy constraints. Gossiping avoids the problem of implosion by just selecting a random node to send the packet rather than broadcasting. However, this cause delays in propagation of data through the nodes.

3.3 Directed diffusion:

Directed diffusion is a data-centric (DC) and application-aware paradigm in the sense that all data generated by sensor nodes is named by attribute-value pairs. The main idea of the DC paradigm is to combine the data coming from different sources en route (in-network aggregation) By eliminating redundancy, minimizing the number of transmissions, thus saving network energy and prolonging its lifetime. Unlike traditional end-to-end routing, DC routing finds routes from multiple sources to a single destination that allows in-network consolidation of redundant data. In directed diffusion, sensors measure events and create gradients of information in their respective neighborhoods. The BS requests data by broadcasting interests. An interest describes a task required to be done by the network. An interest diffuses through the network hop by hop, and is broadcast by each node to its neighbors. As the interest is propagated throughout the network, gradients are set up to draw data satisfying the query toward the requesting node (i.e., a BS may query for data by disseminating interests and intermediate nodes propagate these interests). Each sensor that receives the interest sets up a gradient toward the sensor nodes from which it receives the interest. This process continues until gradients are set up from the sources back to the BS. More generally, a gradient specifies an attribute value and a direction. Or Directed diffusion is a method of getting the data from the nodes. In this method we have nodes and a Sink. At the first step the sink is sending an interest to all the nods and the nodes if they have some data then the send back a Gradient to the Sink. Then again the Sink will select a path to that node which it had sent the Gradient and that node will select a reinforcement path to send the data to the Sink. See figures 3.3 below

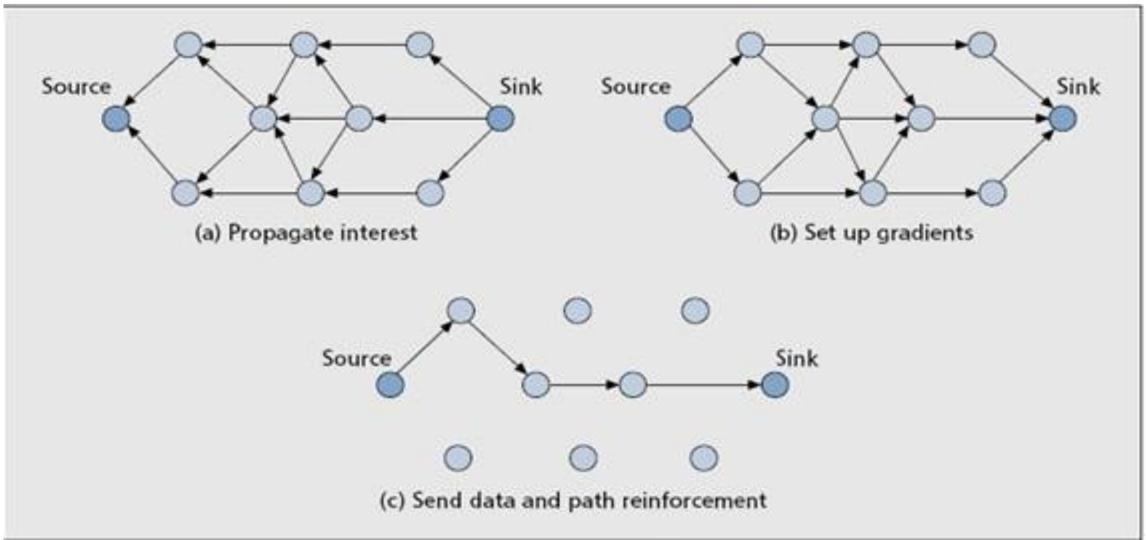

Fig 3.3 Directed Diffusion

The performance of data aggregation methods used in the directed diffusion paradigm is affected by a number of factors, including the positions of the source nodes in the network, the Number of sources, and the communication network topology. In order to investigate these factors, two models of source were placed. These models are called the event radius (ER) model and the random sources (RS) model. The average number of sources is approximately *S*2*n* in a unit area network with *n* sensor nodes. In the RS model, *k* of the nodes that are not BSs are randomly selected to be sources. Unlike the ER model, the sources are not necessarily clustered near each other. In both models of source placement, for a given energy budget, a greater number of sources can be connected to the BS. However, each one performs better in terms of energy consumption depending on the application. In conclusion, the energy savings with aggregation used in directed diffusion can be transformed to provide a greater degree of robustness with respect to dynamics in the sensed phenomena.

3.4 Sensor Protocols for Information via Negotiation (SPIN)

Heinzelman *et al* proposed a family of adaptive protocols called Sensor Protocols for Information via Negotiation (SPIN) that disseminate all the information at each node to every node in the network assuming that all nodes in the network are potential BSs. This enables a user to query any node and get the required information immediately. These protocols make use of the property that nodes in close proximity have similar data, and hence there is a need to only distribute the data other nodes do not posses. The SPIN family of protocols uses data negotiation and resource-adaptive algorithms. Nodes running SPIN assign a high-level name to completely describe their collected data (called meta-data) and perform metadata negotiations before any data is transmitted. The SPIN family is designed to address the deficiencies of classic flooding by negotiation and resource adaptation. The SPIN family of protocols is designed based on two basic ideas.

- Sensor nodes operate more efficiently and conserve energy by sending data that describe the sensor data instead of sending all the data; for example, image and sensor nodes must monitor the changes in their energy resources.
- Conventional protocols like flooding or gossiping-based routing protocols waste energy and bandwidth when sending extra and unnecessary copies of data by sensors covering overlapping areas. The drawbacks of flooding include implosion, which is caused by duplicate messages sent to the same node, overlap when two nodes sensing the same region send similar packets to the same neighbor, and resource blindness in consuming large amounts of energy without consideration for energy constraints.

Gossiping avoids the problem of implosion by just selecting a random node to which to send the packet rather than broadcasting the packet blindly. However, this causes delays in propagation of data through the nodes. SPIN’s meta-data negotiation solves the classic problems of flooding, thus achieving a lot of energy efficiency. SPIN is a three-stage protocol as sensor nodes use three types of messages. ADV, REQ, and DATA, to communicate. ADV is used to advertise new data, REQ to request Data and DATA is the actual message itself. The protocol starts when a SPIN node obtains. New data it is willing to share. It does so by broadcasting an ADV message containing metadata. If a neighbor is interested in the data, it sends a REQ message for the DATA and the DATA is sent to this neighbor node. The neighbor sensor node then repeats this process with its neighbors. As a result, the entire sensor area will receive a copy of the data. The SPIN family contains many Protocols but two of them are important i.e. SPIN1 & SPIN 2.They incorporate negotiation before transmitting data in order to ensure that only useful information will be transferred. Also, each node has its own resource manager that keeps track of resource consumption and is polled by the nodes before data transmission. SPIN-2 is an extension of SPIN-1 which incorporates a threshold-based resource awareness mechanism in addition to negotiation. When energy in the nodes is abundant, SPIN-2 communicates using the three-stage protocol of SPIN1. However, when the energy in a nod starts approaching a low threshold, it reduces its participation in the protocol; that is, it participates only when it believes it can complete all the other stages of the protocol without going below the low energy threshold. In conclusion, SPIN-1 and SPIN-2 are simple protocols that efficiently disseminate data while maintaining no per-neighbor state. These protocols are well suited to an environment where the sensors are mobile because they base their forwarding decisions on local neighborhood information. In SPIN system each node upon receiving new data, advertises it to its neighbors and interested neighbors, i.e. those who do not have the data, retrieve the data by sending a request message. Meta-data negotiation solves the classic problems of flooding such as redundant information passing, overlapping of sensing areas and resource blindness thus, achieving a lot of energy efficiency. There is no standard meta-data format and it is assumed to be application specific, e.g. using an application level framing.

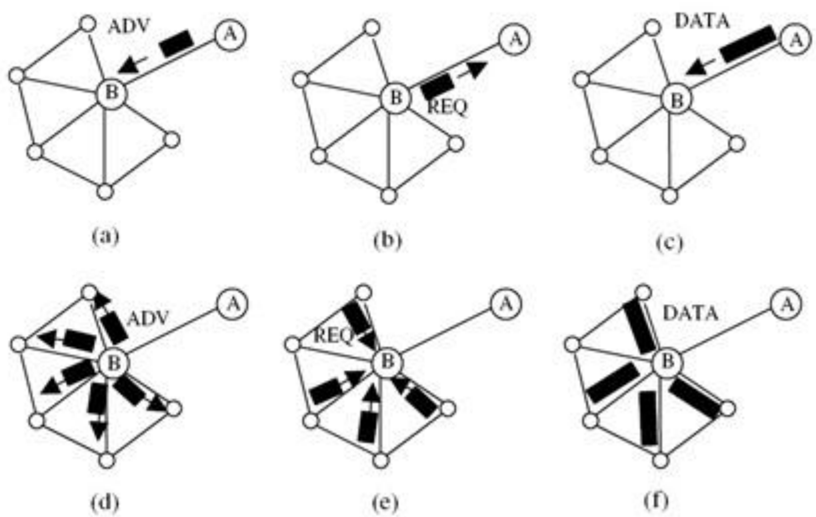

Fig 3.4 SPIN Protocols. Node **A** starts by advertising its data to node **B** (a), Node **B** responds by sending request to node **A** (b). After receiving the request data (c), node **B** then sends out advertisement to its neighbors (d), who in turn send request back to **B** (e-f) .

SPIN has some other types which I want to name them here.

- SPIN-BC: This protocol is designed for broadcast channels.
- SPIN-PP: This protocol is designed for point to point communication (i.e. hop-by-hop routing).
- SPIN-EC: This protocol works similar to SPIN-PP, but with an energy heuristic added to it.
- SPIN-RL: When a channel is loss, a protocol called SPIN-RL is used where adjustments are added to the SPIN-PP protocol to account for the loss channel.

One of the advantages of SPIN is that topological changes are localized since each node needs to know only its single-hop neighbors. SPIN gives a factor of 3.5 less than flooding (SPIN provides more energy savings than flooding, and metadata negotiation almost halves the redundant data) in terms of energy dissipation and meta-data negotiation almost halves the redundant data. However, SPIN_s data advertisement mechanism cannot guarantee the delivery of data. For instance, if the nodes that are interested in the data are far away from the source node and the nodes between source and destination are not interested in that data, such data will not be delivered to the destination at all.

3.5 Different between Directed Diffusion and SPIN:

Directed diffusion differs from SPIN in two aspects. First, directed diffusion issues data queries on demand as the BS sends queries to the sensor nodes by flooding some tasks. In SPIN, however, sensors advertise the availability of data, allowing interested nodes to query that data. Second, all communication in directed diffusion is neighbor to neighbor with each node having the capability to perform data aggregation and caching. Unlike SPIN, there is no need to maintain global network topology in directed diffusion. However, Directed Diffusion cannot be applied to all sensor network applications since it is based on a query-driven data delivery model. The applications that require continuous data delivery to the sink will not work efficiently with a query-driven on demand data model. Therefore, Directed Diffusion is not a good choice as a routing protocol for the applications such as environmental monitoring. In addition, the naming schemes used in Directed Diffusion are application dependent and each time should be defined a priori. Moreover, the matching process for data and queries might require some extra overhead at the sensors. So we can see in these subtitles below the advantage and disadvantages of Directed Diffusion .

3.5.1 Advantages of Directed Diffusion:

Since it is data centric, all communication is neighbor-to-neighbor with no need for a node addressing mechanism. Each node can do aggregation and caching, in addition to sensing. Caching is a big advantage in terms of energy efficiency and delay. In addition, Direct Diffusion is highly energy efficient since it is on demand and there is No need for maintaining global network topology.

3.5.2 Disadvantage of Directed diffusion:

Since it is based on a query-driven data delivery model, the applications that require continuous data delivery to the sink will not work efficiently then we can say that the Directed Diffusion is not a good choice for routing protocol.

3.7 Rumor Routing:

Rumor routing is a variation of directed diffusion and is mainly intended for applications where geographic routing is not feasible. In general, directed diffusion uses flooding to inject the query to the entire network when there is no geographic criterion to diffuse tasks.

However, in some cases there is only a small amount of data requested from the nodes; thus, the use of flooding is unnecessary. An alternative approach is to flood the events if the number of events is small and the number of queries is large. The key idea is to route the queries to the nodes that have observed a particular event rather than flooding the entire network to retrieve information about the occurring events. In order to flood events through the network, the rumor routing algorithm employs long-lived packets called *agents*. When a node detects an event, it adds the event to its local table, called an *events table*, and generates an agent. Agents travel the network in order to propagate information about local events to distant nodes. When a node generates a query for an event, the nodes that know the route may respond to the query by inspecting its event table. Hence, there is no need to flood the whole network, which reduces the communication cost. On the other hand, rumor routing maintains only one path between source and destination as opposed to directed diffusion where data can be routed through multiple paths at low rates. Simulation results showed that rumor routing can achieve significant energy savings compared to event flooding and can also handle a node's failure. However, rumor routing performs well only when the number of events is small. For a large number of events, the cost of maintaining agents and event tables in each node becomes infeasible if there is not enough interest in these events from the BS. See figure

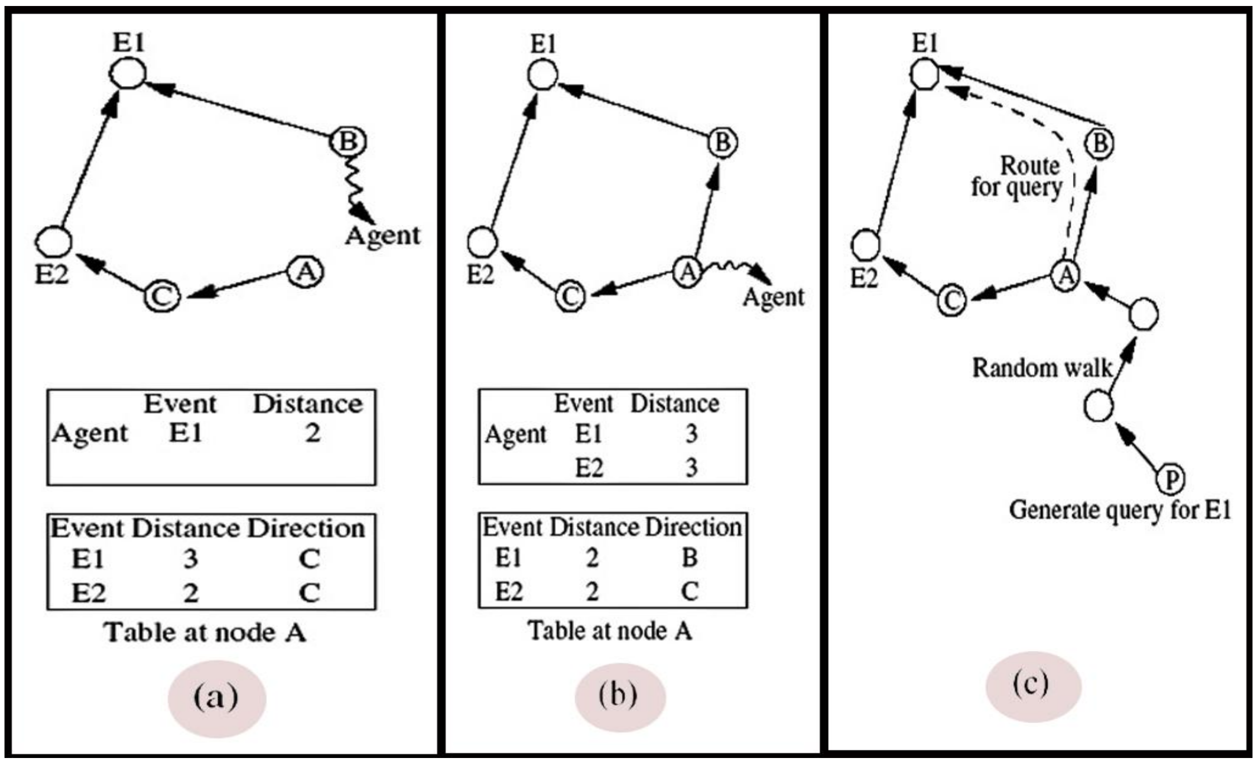

Fig 3.5 (a) The agent has initially recorded a path of distance 2 to event E1. Node A's table shows that it is at a distance 3 from event E1 and a distance 2 from E2. When the agent visits node A, it updates its own path state information to include the path to event E2. The updating is with one hop greater distance than what it found in A, to account for the hop between any neighbor of A that the agent will visit next, and A. It also optimizes the path to E1recorded at node A to the shorter path through node B. The updated status of the agent and node table is shown in Figure.

(b) When a query is generated at a sink, it is sent on a random walk with the hope that it will find a path leading to the required event. This is based on the high probability of two straight lines intersecting on a planar graph, assuming the network topology is like a planar graph, and the paths established can be approximated by straight lines owing to high density of the nodes. If a query does not find an event path, the sink time out and uses flooding as a last resort to propagate the query.

(c) Suppose a query for event E1 is generated by node P. Through a random walk, it reaches A, where it finds the previously established path to E1. Hence, the query is directed to E1 through node B, as indicated by A's table.

3.8 Gradient-based routing:

Another variant of directed diffusion, called gradient-based routing (GBR). The key idea in GBR is to memorize the number of hops when the interest is diffused through the whole network. As such, each node can calculate a parameter called the height of the node, which is the minimum number of hops to reach the BS. The difference between a node's height and that of its neighbor is considered the gradient on that link. A packet is forwarded on a link with the largest gradient. GBR uses some auxiliary techniques such as data aggregation and traffic spreading in order to uniformly divide the traffic over the network. In GBR, three different data dissemination techniques have been discussed.

- A stochastic scheme, where a node picks one gradient at random when there are two or more next hops that have the same gradient
- An energy-based scheme, where a node increases its height when its energy drops below a certain threshold so that other sensors are discouraged from sending data to that node
- A stream-based scheme, where new streams are not routed through nodes that are currently part of the path of other streams The main objective of these schemes is to obtain balanced distribution of the traffic in the network, thus increasing the network lifetime. Simulation results of GBR showed that GBR outperforms directed diffusion in terms of total communication energy.

3.9 COUGAR:

Network data aggregation to obtain more energy savings the abstraction is supported through an additional query layer that lies between the network and application layers. COUGAR incorporates architecture for the sensor database system where sensor nodes select a leader node to perform aggregation and transmit the data to the BS. The BS is responsible for generating a query plan that specifies the necessary information about the data flow and in-network computation for the incoming query, and sends it to the relevant nodes. The query plan also describes how to select a leader for the query. The architecture provides in-network computation ability that can provide energy efficiency in situations when the generated data is huge. COUGAR provides a network-layer-independent method for data query.

3.10 Active Query Forwarding in Sensor Networks (ACQUIRE).

Similar to COUGAR, ACQUIRE views the network as a distributed database where complex queries can be further divided into several sub queries. The operation of ACQUIRE can be described as follows. The BS node sends a query, which is then forwarded by each node receiving the query. During this, each node tries to respond to the query partially by using its preached information and then forwards it to another sensor node. If the preached information is not up-to-date, the nodes gather information from their neighbors within a look ahead of *d* hops. Once the query is resolved completely, it is sent back through either the reverse or shortest path to the BS. Note that directed diffusion may not be used for complex queries due to energy considerations as directed diffusion also uses a flooding-based query mechanism for continuous and aggregate queries. ACQUIRE can provide look ahead parameter *d*. When *d* is equal to network diameter, ACQUIRE behaves similar to efficient querying by adjusting the value of the flooding. However, the query has to travel more hops if *d* is too small.

3.11 Energy-Aware Routing:

Energy-Aware Routing protocol is a destination- initiated reactive protocol, is to increase the network lifetime. Although this protocol is similar to directed diffusion, it differs in the sense that it maintains a set of paths instead of maintaining or enforcing one optimal path at higher rates. These paths are maintained and chosen by means of a certain probability. The value of this probability depends on how low the energy consumption is that each path can achieve. By having paths chosen at different times, the energy of any single path will not deplete quickly. This can achieve longer network lifetime as energy is dissipated more equally among all nodes. Network survivability is the main metric of this protocol. The protocol assumes that each node is addressable through class-based addressing that includes the locations and types of the nodes. The protocol initiates a connection through localized flooding, which is used to discover all routes between a source/ destination pair and their costs, thus building up the routing tables. High cost paths are discarded, and a forwarding table is built by choosing neighboring nodes in a manner that is proportional to their cost. Then forwarding tables are used to send data to the destination with a probability inversely proportional to the node cost. Localized flooding is performed by the destination node to keep the paths alive. Compared to directed diffusion, this Protocol provides an overall improvement of 1.5 percent energy saving and a 44 percent increase in network lifetime. However, the approa2ch requires gathering location information and setting up the addressing mechanism for the nodes, which complicate route setup compared to directed diffusion.

3.12 Flat Routing

The first category of routing protocols is the multi hop flat routing protocols. In flat networks, each node typically plays the same role and sensor nodes collaborate to perform the sensing task. Due to the large number of such nodes, it is not feasible to assign a global identifier to each node. This consideration has led to data-centric routing, where the BS sends queries to certain regions and waits for data from the sensors located in the selected regions. Since data is being requested through queries, attribute-based naming is necessary to specify the properties of data. Early work on data centric routing (SPIN and directed diffusion) was shown to save energy through data negotiation and elimination of redundant data. These two protocols motivated the design of many other protocols that follow a similar concept. In the rest of this subsection, we summarize these protocols, and highlight their advantages and performance issues.

3.13 Routing protocols with random walks:

The objective of the random-walks-based routing technique is to achieve load balancing in a statistical sense by making use of multipath routing in WSNs In this protocol, it is assumed that sensor nodes can be turned on or off at random times. Furthermore, each node has a unique Identifier but no location information is needed. Nodes were arranged such that each node falls exactly on one crossing point of a regular grid on a plane, but the topology can be irregular. To find a route from a source to its destination, the location information or lattice coordination is obtained by computing distances between nodes using the distributed asynchronous version of the well-known Bellman-Ford algorithm. An intermediate node would select as the next hop the neighboring node that is closer to the destination according to a computed probability. By carefully manipulating this probability, some kind of load balancing can be obtained in the network. The routing algorithm is simple as nodes are required to maintain little state information. Moreover, different routes are chosen at different times even for the same pair of source and destination nodes. However, the main concern about this protocol is that the topology of the network may not be practical.

3.14 Hierarchical Routing:

Hierarchical routing is an efficient way to lower energy consumption within a cluster, performing data aggregation and fusion in order to decrease the number of transmitted messages to the BS. Hierarchical routing is mainly two-layer routing where one layer is used to select cluster heads and the other for routing. However, most techniques in this category are not about routing, but rather "who and when to send or process/ aggregate" the information, channel allocation, and so on, which can be orthogonal to the multi, hop routing function. Hierarchical or cluster based routing methods, originally proposed in wire line networks, are well-known techniques with special advantages related to scalability and efficient communication. As such, the concept of hierarchical routing is also utilized to perform energy-efficient routing in WSNs. In a hierarchical architecture, higher-energy nodes can be used to process and send the information, while low-energy nodes can be used to perform the sensing in the proximity of the target. The creation of clusters and assigning special tasks to cluster heads can greatly contribute to overall system scalability, lifetime, and energy efficiency.

3.15 Low Energy Adaptive Clustering Hierarchy (LEACH):

LEACH is a cluster-based protocol, which includes distributed cluster formation. LEACH randomly selects a few sensor nodes as cluster heads (CHs) and rotates this role to evenly distribute the energy load among the sensors in the network. In LEACH, the CH nodes compress data arriving from nodes that belong to the respective cluster, and send an aggregated packet to the BS in order to reduce the amount of information that must be transmitted to the BS. However, data collection is centralized and performed periodically. Therefore, this protocol is most appropriate when there is a need for constant monitoring by the sensor network. A user may not need all the data immediately. Hence, periodic data transmissions are unnecessary, and may drain the limited energy of the sensor nodes. After a given interval of time, randomized rotation of the role of CH is conducted so that uniform energy dissipation in the sensor network is obtained. The authors found, based on their simulation model that only 5 percent of the nodes need to act as CHs. The operation of LEACH is separated into two phases, the setup phase and the steady state phase. In the setup phase, the clusters are organized and CHs are selected. In the steady state phase, the actual data transfer to the BS takes place. The duration of the steady state phase is longer than the duration of the setup phase in order to minimize overhead. During the setup phase, a predetermined fraction of nodes, p, elect themselves as CHs as follows. A sensor node chooses a random number, r, between 0 and 1. If this random number is less than a threshold value, $T(n)$, the node becomes a CH for the current round. The threshold value is calculated based on an equation that incorporates the desired percentage to become a CH, the current round, and the set of nodes that have not been selected as a CH in the last $(1/P)$ rounds, denoted G. It is given by

$$T(n) = \frac{p}{1 - p(r \bmod (1/p))} \text{ if } n \in G,$$

Where G is the set of nodes that are involved in the CH election. All elected CHs broadcast an advertisement message to the rest of the nodes in the network that they are the new CHs. All the non-CH nodes, after receiving this advertisement, decide on the cluster to which they want to belong. This decision is based on the signal strength of the advertisement. The non-CH nodes inform the appropriate CHs that they will be a member of the cluster. After receiving all the messages from the nodes that would like to be included in the cluster and based on the number of nodes in the cluster, the CH node creates a TDMA schedule and assigns each node a time slot when it can transmit. This schedule is broadcast to all the nodes in the cluster. During the steady state phase, the sensor nodes can begin sensing and transmitting data to the CHs. The CH node, after receiving all the data, aggregates it before sending it to the BS. After a certain time, this is determined where a priori, the network goes back into the setup phase again and enters another round of selecting new CHs. Each cluster communicates using different CDMA codes to reduce interference from nodes belonging to other clusters. Although LEACH is able to increase the network lifetime, there are still a number of issues about the assumptions used in this protocol. LEACH assumes that all nodes can transmit with enough power to reach the BS if needed and that each node has computational power to support different MAC protocols. Therefore, it is not applicable to networks deployed in large regions. Furthermore, the idea of dynamic clustering brings extra overhead (head changes, advertisements, etc.), which may diminish the gain in energy consumption. Finally, the protocol assumes that all nodes begin with the same amount of energy capacity in each election round, assuming that being a CH consumes approximately the same amount of energy for each node. The protocol should be extended to account for non uniform energy nodes. See the table.

	SPIN	LEACH	Directed diffusion
Optimal route	No	No	Yes
Network lifetime	Good	Very good	Good
Resource awareness	Yes	Yes	Yes
Use of meta-data	Yes	No	Yes

Fig 3.6 comparison between SPIN , LEACH and Directed Diffusion .

The main theme of the proposed extension is to precede data transfers with high-level negotiation using meta-data descriptors as in the SPIN protocol discussed earlier. This ensures that only data that provides new information is transmitted to the CHs before being transmitted to the BS. Table 1 compares SPIN, LEACH, and directed diffusion according to different parameters. It is noted from the table that directed diffusion shows a promising approach for energy-efficient routing in WSNs due to the use of in-network processing.

3.16 TEEN:

These protocols were proposed for time-critical applications. In TEEN, sensor nodes sense the medium continuously, but data transmission is done less frequently. A CH sensor sends its members a hard threshold, which is the threshold value of the sensed attribute, and a soft threshold, which is a small change in the value of the sensed attribute that triggers the node to switch on its transmitter and transmit. Thus, the hard threshold tries to reduce the number of transmissions by allowing the nodes to transmit only when the sensed attribute is in the range of interest. The soft threshold further reduces the number of transmissions that might otherwise occur when there is little or no change in the sensed attribute. A smaller value of the soft threshold gives a more accurate picture of the network, at the expense of increased energy consumption. Thus, the user can control the tradeoff between energy efficiency and data accuracy. When CHs are to change new values for the above parameters are broadcast. See below figure. (TEEN)

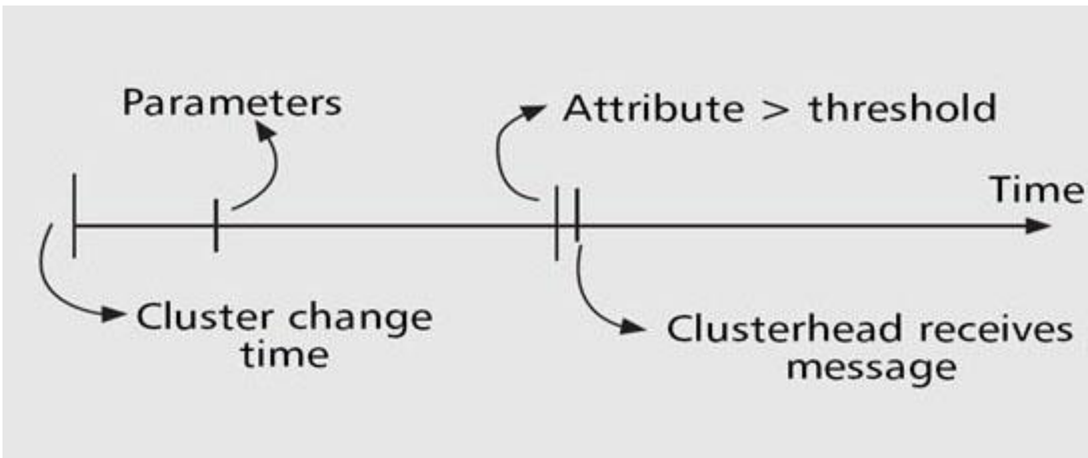

Fig 3.7 The main drawback of this scheme is that if the thresholds are not received, the nodes will never communicate, and the user will not get any data from the network at all.

The nodes sense their environment continuously. The first time a parameter from the attribute set reaches its hard threshold value, the node switches its transmitter on and sends the sensed data. The sensed value is stored in an internal variable called sensed value (SV). The nodes will transmit data in the current cluster period only when the following conditions are true.

- The current value of the sensed attribute is greater than the hard threshold.
- The current value of the sensed attribute differs from SV by an amount equal to or greater than the soft threshold.

The features of TEEN include its suitability for time-critical sensing applications. Also, since message transmission consumes more energy than data sensing, the energy consumption in this scheme is less than in proactive networks. The soft threshold can be varied. At every cluster change time, fresh parameters are broadcast, so the user can change them as required.

3.17 APTEEN:

APTEEN is a hybrid protocol that changes the periodicity or threshold values used in the TEEN protocol according to user needs and the application type. In APTEEN, the CHs broadcast the following parameters as shown in figure 3.8 (b)

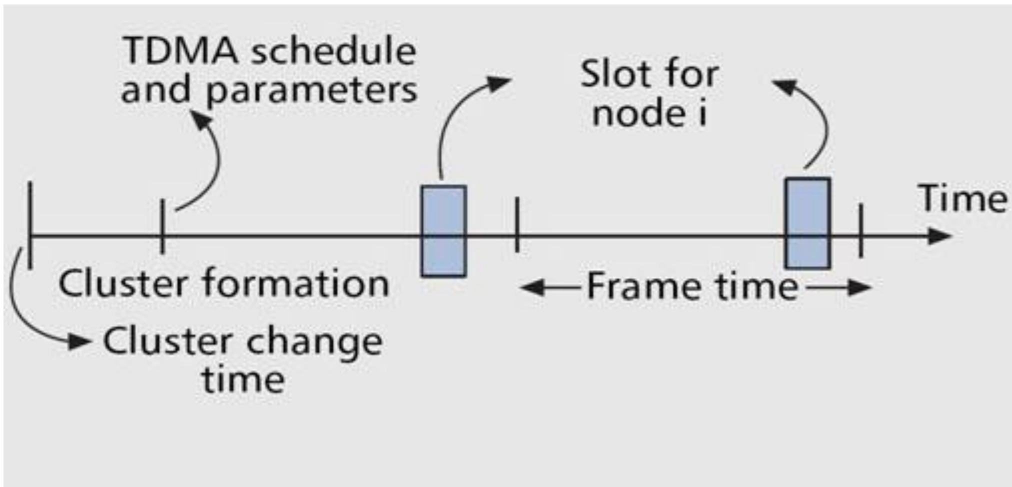

Fig 3.8

- Attributes (A): a set of physical parameters about which the user is interested in obtaining information.
- Thresholds: consists of the hard threshold (HT) and soft threshold (ST)
  Schedule: a TDMA schedule, assigning a slot to each node
- Count time (CT): the maximum time period between two successive reports sent by a node.

The node senses the environment continuously, and only those nodes that sense a data value at or beyond HT transmit. Once a node senses a value beyond HT, it transmits data only when the value of that attributes changes by an amount equal to or greater than ST. If a node does not send data for a time period equal to CT, it is forced to sense and retransmit the data. A TDMA schedule is used, and each node in the cluster is assigned a transmission slot. Hence, APTEEN uses a modified TDMA schedule to implement the hybrid network. The main features of the APTEEN scheme include the following. It combines both proactive and reactive policies. The main drawback of the scheme is the additional complexity required to implement the threshold functions and CT. Simulation of TEEN and APTEEN has shown that these two protocols outperform LEACH. The experiments have demonstrated that APTEEN's performance is somewhere between LEACH and TEEN in terms of energy dissipation and network lifetime.

TEEN gives the best performance since it decreases the number of transmissions. The main drawbacks of the two approaches are the overhead and complexity associated with forming clusters at multiple levels, the method of implementing threshold-based functions, and how to deal with attribute-based naming of queries.

3.18 Self-organizing protocol:

In this system the sensors can be mobile or stationary. Some sensors probe the environment and forward the data to a designated set of nodes that act as routers. Router nodes are stationary and form the backbone for communication. Collected data are forwarded through the routers to the more powerful BS nodes. Each sensing node should be able to reach a router in order to be part of the network. A routing architecture that requires addressing of each sensor node has been proposed. Sensing nodes are identifiable through the address of the router node to which they are connected. The routing architecture is hierarchical where groups of nodes are formed and merge when needed. Sensor nodes can be addressed individually in the routing architecture; hence, it is suitable for applications where communication to a particular node is required. Furthermore, this algorithm incurs a small cost for maintaining routing tables and keeping a balanced routing hierarchy. It was also found that the energy consumed for broadcasting a message is less than that consumed in the SPIN protocol. This protocol, however, is not an on demand protocol, especially in the organization phase of the algorithm, and thus introduces extra overhead. Another issue is related to the formation of a hierarchy. It could happen that there are many cuts in the network, and hence the probability of applying reorganization phase increases, which is an expensive operation.

3.19 Sensor Aggregates Routing:

A sensor aggregate comprises those nodes in a network that satisfy a grouping predicate for a collaborative processing task. The parameters of the predicate depend on the task and its resource requirements. The formation of appropriate sensor aggregates in terms of allocating resources to sensing and communication tasks. Sensors in a sensor field are divided into clusters according to their sensed signal strength, so there is only one peak per cluster. Then local cluster leaders are elected. One peak may represent one target, multiple targets, or no target if the peak is generated by noise sources. To elect a leader, information exchanges between neighboring sensors are necessary. If a sensor, after exchanging packets with all its one hop neighbors, finds that it is higher than all its one-hop neighbors on the signal field landscape, it declares itself a leader. This leader-based tracking algorithm assumes that the unique leader knows the geographical region of the collaboration. Aggregates are formed when the process eventually converges. Second, Energy-Based Activity Monitoring (EBAM) estimates the energy level at each node by computing the signal impact area, combining a weighted form of the detected target energy at each impacted sensor, assuming that each target sensor has equal or constant energy level. EMLAM estimates the target positions and signal energy using received signals, and uses the resulting estimates to predict how signals from the targets may be mixed at each sensor. The distributed track initiation management scheme combined with the leader-based tracking Algorithm forms a scalable system. The system works well in tracking multiple targets when the targets are not interfering, and it can recover from inter target interference once the targets move apart.

3.20 Virtual grid architecture routing:

An energy efficient routing paradigm is proposed that utilizes data aggregation and in-network processing to maximize the network lifetime. A GPS free approach is used to build clusters that are fixed, equal, adjacent, and none overlapping with symmetric shapes. Data aggregation is performed at two levels: local and then global. The set of CHs, also called local aggregators (LAs), perform local aggregation, while a subset of these LAs are used to perform global aggregation. However, the determination of an optimal selection of global aggregation points, called master aggregators (MAs), is NP-hard. Illustrates an example of fixed zoning and the resulting virtual grid architecture (VGA) used to perform two-level data aggregation. Note that the location of the BS is not necessarily at the extreme corner of the grid; it can be located at any arbitrary place. The objective of all algorithms is to select a number of MAs out of the LAs that maximize network lifetime. For a realistic scenario, it is assumed that LA nodes form possibly overlapping groups. Members of each group sensei the same phenomenon; hence, their readings are correlated. However, each LA node that exists in the overlapping region will send data to its associated MA for each of the groups to which it belongs. It was noted that the problem of assigning MAs to LAs in CBAH is similar to the classical bin packing problem, a major difference being that neither the identities nor the amount of power each MA will be using for different LAs are known. In CBAH, the set of MAs are selected based on incremental filing of some bins with capacities. Besides being fast and scalable to large sensor networks, the approximate algorithms produce results not far from the optimal solution. See figure 3.9

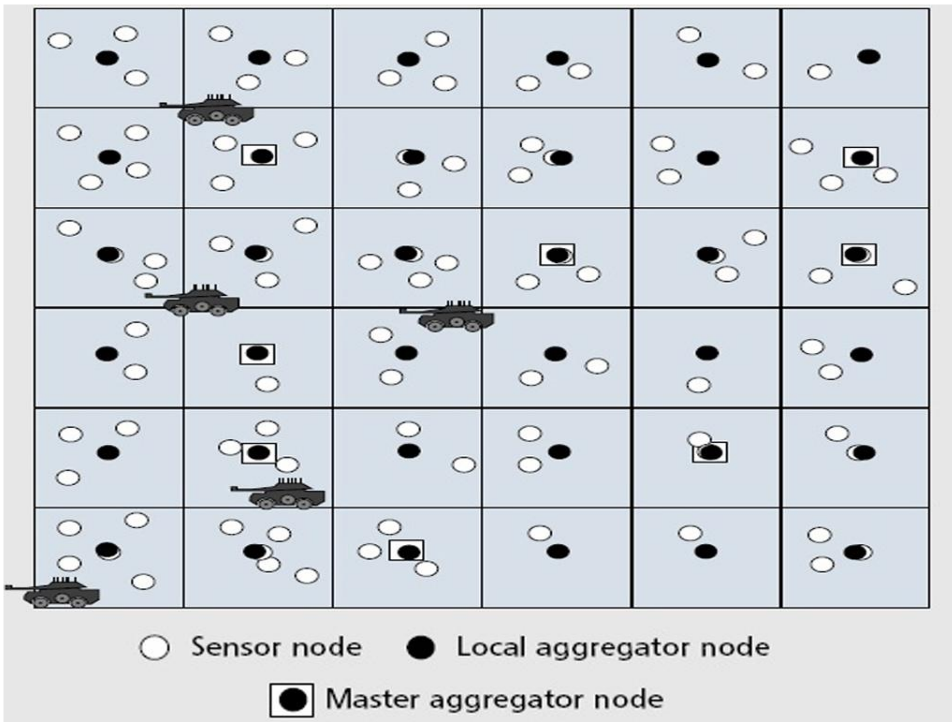

Fig 3.9 illustrates an example of fixed zoning and the resulting virtual grid architecture (VGA) used to perform two-level data aggregation.

3.21 Hierarchical power-aware routing:

The protocol divides the network into groups of sensors. Each group of sensors in geographic proximity are clustered together as a zone, and each zone is treated as an entity. To perform routing, each zone is allowed to decide how it will route a message hierarchically across the other zones such that the battery lives of the nodes in the system are maximized. Messages are routed along the path that has the maximum over all the minimum of the remaining power, called the max-min path. The motivation is that using nodes with high residual power may be more expensive than the path with the minimal power consumption. An approximation algorithm, called the *max-min zPmin* algorithm. The crux of the algorithm is based on the trade-off between minimizing the total power consumption and maximizing the minimal residual power of the network. Hence, the algorithm tries to enhance a max-min path by limiting its power consumption as follows. First, the algorithm finds the path with the least power consumption (*Pmin*) by using the Dijkstra algorithm. Second, the algorithm finds a path that maximizes the minimal residual power in the network. The proposed algorithm tries to optimize both solution criteria. This is achieved by relaxing the minimal power consumption for the message to be equal to *zPmin* with parameter *z* 1 to restrict the power consumption for sending one message to *zPmin*. The algorithm consumes at most *zPmin* while maximizing the minimal residual power fraction. Zone-base routing is a hierarchical approach where the area covered by the (sensor) network is divided into a small number of zones. To send a message across the entire area, a global path from zone to zone is found. The sensors in a zone autonomously direct local routing and participate in estimating the zone power level. Each message is routed across the zones using information about the zone power estimates. A global controller for message routing is assigned the role of managing the zones. This may be the node with the highest power. If the network can be divided into a relatively small number of zones, the scale for the global routing algorithm is reduced.

C H A P T E R 4

Applications of wireless sensor networks

WSN applications encompass but are not limited to environment monitoring, target tracking, search and rescue, and real-time monitoring of hazardous material. For environmental monitoring in disaster areas, manual deployment might not be possible. With mobile sensor nodes, they can move to areas of events after deployment to provide the required coverage. In military surveillance and tracking, mobile sensor nodes can collaborate and make decisions based on the target. Mobile sensor nodes can achieve a higher degree of coverage and connectivity compared to static sensor nodes. In the presence of obstacles in the field, mobile sensor nodes can plan ahead and move appropriately to obstructed regions to increase target exposure. Applications in WSN can be categorized into two (fig 4.1). They are monitoring and tracking. Monitoring applications include environmental monitoring, health and wellness monitoring, power monitoring, inventory location monitoring, factory and process automation, and seismic and structural monitoring. Tracking applications include tracking objects, animals, humans, and vehicles. While there are many different applications, below we describe a few example applications that have been deployed and tested in the real environment.

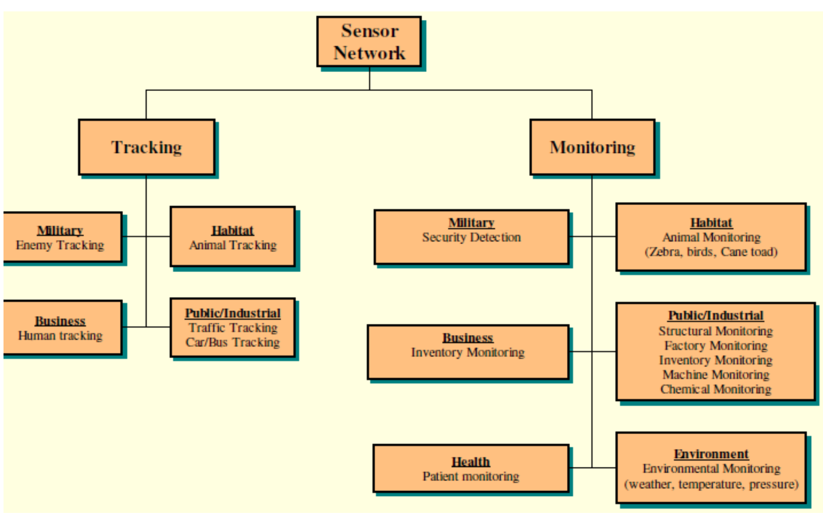

Fig 4.1Overview of sensor network and its application on different part of the life

4.1 Health monitoring applications and WSN prototypes:

There are several prototype and commercial applications for pervasive healthcare monitoring for the elderly, children and chronically ill people. When these applications are explored, it is observed that the main focus categories include (i) activities of daily living monitoring, (ii) fall and movement detection, (iii) location tracking, (iv) medication intake monitoring, and (v) medical status monitoring. In the first category, the applications try to identify and differentiate everyday activities of the patients and the elderly such as watching television, sleeping, ironing, and be able to detect odd conditions. Fall and movement detection applications are focused on the physiological conditions such as posture and fall detection for people that need special care like the elderly people who are susceptible to sudden falls which may lead to death, infants, or patients recovering from an operation. Location tracking and the medication intake reminder and monitoring systems can help cognitively impaired people to survive independently. Medical care applications make use of medical and environmental sensors in order to obtain comprehensive health status information of the patients, including ECG, heart rate, blood pressure, skin temperature, and oxygen saturation. In the following subsections we provide examples of applications belonging to each category.

4.2 Fall and movement detection application:

Although falls and body movements are specific cases of activity classification, there is a significant research effort focusing on fall detection and body posture and gait analysis. This is due to the fact that accidental falls are among the leading causes of death over 65. Most of the studies in the literature make use of accelerometers and gyroscopes for identifying sudden falls. There are only a few studies that propose the use of unobtrusive ambient video cameras, because of the privacy issues. On the other hand, in the Information Technology for Assisted Living at Home (ITALH) project proposes the use of video camera enabled phone only under emergency conditions. It is a fall detection system based on accelerometer data for elderly people. The sensor node's processor is capable of analyzing the accelerometer data in real-time and classifying events such as falls or other normal and abnormal events. When a fall is detected, the mote opens a connection to a Bluetooth capable camera phone and the sensor data is streamed to the phone. The phone makes a call to an emergency center if the user does not respond to the initial request made by the phone. In this way, the system provides rich visual information about the user when an abnormal situation is detected and he/she is unable to respond. In a more typical application, a human activity monitor and fall detection uses a single 3-axes accelerometer to identify human activities by using signal processing techniques. The base station mote gathers the accelerometer data and relays the data to the server computer for processing. The mobile mote carried by the user gives accurate results as 81% correct detection of a fall while running and resting when the mote is worn on the chest rather than on the wrist. This is not surprising when the identification is done by only a single acceleration sensor since the higher amplitudes will provide more distinguishable acceleration data.

Another issue in fall identification with acceleration data is differentiating a fall from other fall-like situations like jumping, lying or sitting down quickly on a chair. Moreover, the fall detection systems should be robust against different types of falls. Wang et al propose a fall-detecting system placing an accelerometer on the head level and using an algorithm to distinguish between falls and daily activities. The proposed algorithm can distinguish eight kinds of falling postures and seven kinds of daily activities including standing, sitting down, lying down, walking, jumping, going up (down) stairs, and jogging. Their algorithm tries to find the difference between the initial time when the body contacts the ground and the time the body is at rest. According to this difference, a fall decision is made. In another study, all propose to make fall decisions according to the position of the users after a large acceleration is observed. Large accelerations are not classified as falls as long as the position is upright or the accelerometer detects activity. This simplifying assumption of being inactive after a fall situation may not be realistic, since the person may be suffering pain and making the movements because of the pain.

4.3 Location tracking application:

Location tracking for pervasive healthcare systems may serve both indoor and outdoor applications. In an indoor scenario, the location tracking system can be integrated for increasing the context-awareness of the systems and or efficiency. In an outdoor setting, it can be used for assisting people with cognitive disabilities or identifying the locations of people when an alarm situation has occurred like an epilepsy seizure. Since GPS is the most robust and widely available technique for outdoor location tracking and it does not properly work indoors, the development of indoor localization techniques is more worthy. To begin with, Chang et al, propose an RFID based way finding system for cognitively impaired patients. The system works by placing passive RFID tags in important locations where patients need to make decisions about the next action to take, such as turning right or left. Patients have to carry PDAs that have built-in RFID readers to identify the location by reading passive RFID tags and provide just-in-time directions to guide the patients to the destination also providing with spatial photos. The visited positions are tracked and logged and in case of anomalies, alarms are raised. This prototype application may suffer from the tag-reader communication problems due to shadowing effects and scalability of the system is limited because it necessitates the association of the places with the tags. Yet, in a hospital setting it can provide assistance to the patients who are having difficulties finding certain places. The Ultra Badge System is another location tracking application that is used in a hospital setting. In Ultra Badge, a 3D tag system designed to realize the location of the patients. When a patient is in a specific area where a fall is most likely to occur, the system alerts the caregivers beforehand. The Ultra Badge System consists of ultrasonic receivers embedded in the environment and wireless ultrasonic emitters placed on objects as depicted in figure below.

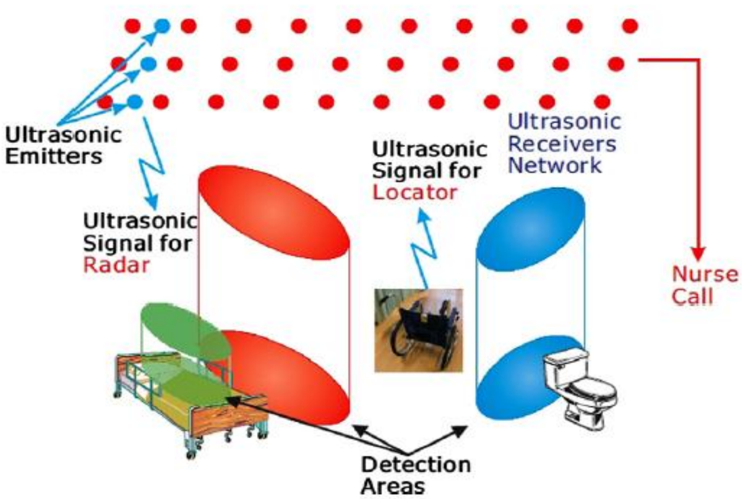

Fig 4.2 Schematic diagram of the Ultra Badge system, In here we can see theme have control of each of the things that we use for a patient.

ALMAS project integrates location tracking technology with video analysis and wireless multimedia technologies to create an environment that provides healthcare for the elderly. It consists of the following physical components: A wireless wearable unit and a RFID tag attached to the patient, which store and transmit the patient's vital signs and location, wireless transceivers, which communicate with the RFID tags and the wearable units worn by the patients to track and locate them, video cameras, which constantly monitor the patients' activities and record them when a problem is detected by the tracking system, a PC with video capture capability, to which all the hardware are connected and on which all the software run, and a PDA capable of receiving alerts, video clips, and vital signs of the patient. The patient's location is determined by the relative strength of the radio frequency (RF) signals received by the RFID transceivers. ALMAS' video cameras continuously record the activities of the patient and automatically detect if there is a situation that requires attention by the healthcare professional. Examples of such situation include the room or hallway towards an unauthorized area or patients that are found in unusual conditions like lying on the floor for an extended period of time. If such motion is detected and the patient is perceived to be crossed the line between the room and the common area, the second camera begins to monitor patient's activity and generates signals to alert the healthcare professional. The alerts and associated video clips are wirelessly transmitted to the healthcare professional's PDA. The healthcare professional responds to the event by monitoring the video clip and taking appropriate action.

4.4 Medication intake monitoring:

Medication noncompliance is common in elderly and chronically ill especially when cognitive disabilities are encountered. Therefore, medication intake monitoring is essential. One of the early prototypes developed by Moh et al was aim to control the medicine intake of the elderly with the combined use of sensor networks and RFID. It consists of three subsystems: The Medicine Monitoring Subsystem is used for medicine bottle identification using high frequency (HF) RFID tags and the amount of the medicine removed by the user is tracked by a weight scale. The system is able to determine when and which bottle is removed or replaced by the patient and the amount of medicine taken. The patient wearing an Ultra High Frequency (UHF) RFID tag is identified and located by the Patient Monitoring Subsystem and the system is able to alert the patient to take the necessary medicines. Finally, the Base Station Subsystem is responsible for message relay to the Base Station Personal Computer (PC). The Base Station software tasks include simulating a display and its GUI for the patient; determining when medicine is required; and maintaining various interactions between the Medicine Mote and the Patient Mote.

The iCabiNET solution makes use of the smart RFID packaging that can record the removal of a pill simply by breaking an electric flow into the RFID's integrated circuit. iCabiNET is an indoor application that is also interfaced to a residential network, in this way, the medicine intake can be monitored over the residential network by using the RFID readers at home. The system is capable of monitoring the drugs that are bought by the user and when the presence at home is detected the smart appliances, such as TV, can be used to inform the patient about the usage and dosage. Furthermore, an interactive TV application can also be integrated with the system that allows the purchase of the new packet of the drugs when the supply is decreased. As an alternative scenario, the iCabiNET system can be integrated with the cellular network or ordinary telephone network in order to remind the patients to take their medication correctly.

Another intelligent packaging prototype is proposed and developed by Pang et al. The system is capable of both remote medication intake monitoring and vital signs monitoring. The intelligent package prototype, called the iPackage, is different from RFID attached intelligent packages in that it uses an array of Controlled Delimitation Material (CDM) films and its control circuits are added. The CDM film is a three-layer foil composed of aluminum bottom and top layers and an adhesive middle layer made of electrochemical epoxy. When a voltage higher than a particular threshold is applied on the bottom layer and top layer, an electrochemical reaction occurs in the middle layer. When the voltage is applied for a certain amount of time, the epoxy layer is destroyed and delaminated. Therefore, the iPackage sealed with a CDM film can only be opened by the special control appliance which also enables the control of the dosage. The identification of the correct pill is accomplished by RFID. The prototype design of CDM and tagged capsule package in fig 4.3

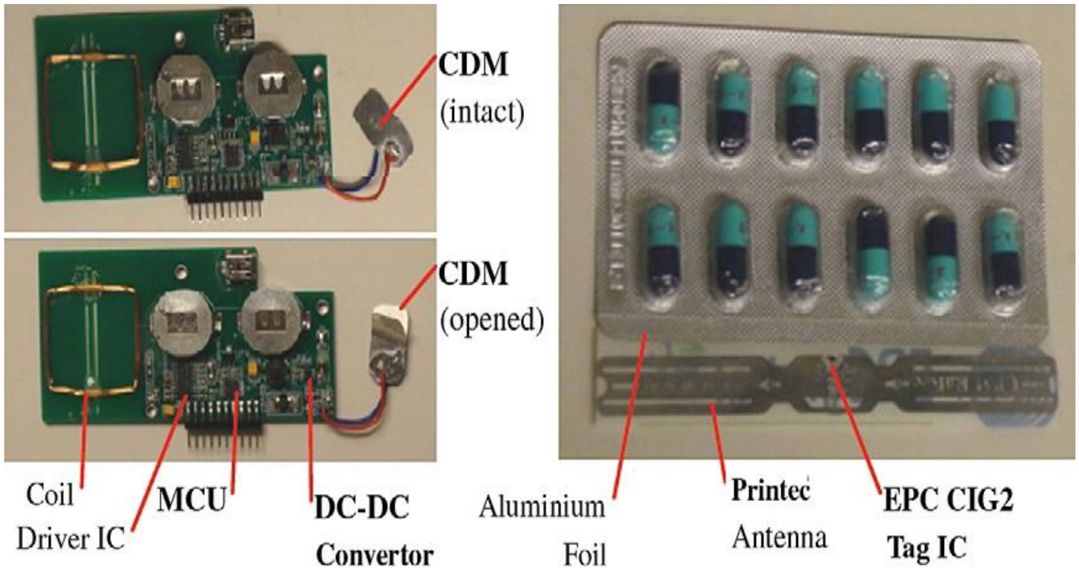

Fig 4.3 WSN as made as capsules

Some of the application of WSN in health such as infant monitoring, deaf, blood a pressure used five prototypes functioning in two motes; T-mote sky devices and SHIMMER (Intel Digital Health Group's Sensing Health with Intelligence, Modularity, Mobility, and Experimental Re-usability) Owing to the fact that many infant die from sudden infant death syndrome (SIDS) each year, Sleep Safe is designed for monitoring an infant while they sleep. It detects the sleeping position of an infant and alerts the parent when the infant is lying on its stomach. Sleep Safe consists of two sensor motes. One SHIMMER mote is attached to an infant's clothing while a T-mote is connected to base station computer. The SHIMMER node has a three-axis accelerometer for sensing the infant's position relative to gravity. The SHIMMER node periodically sends packets to the base station for processing. Based on the size of the sensing window and the threshold set by the user, the data is processed to determine if the infant is on their back. Baby Glove prototype is designed to monitor vitals. Baby Glove is a swaddling baby wrap with sensors that can monitor an infant's temperature, hydration, and pulse rate. A SHIMMER mote is connected to the swaddling wrap to transmit the data to the T-mote connected to the base station. Like Sleep Safe, an alert is sent to the parent if the analyzed data exceeds the health settings

4.5 Fire Line: application:

It is a wireless heart rate sensing system. It is used to monitor a fire fighter's heart rate in real-time to detect any abnormality and stress. Fire Line consists of a Tmote, a custom made heart rate sensor board, and three re-usable electrodes. All these components are embedded into a shirt that a fire fighter will wear underneath all his protective gears. The readings are taken from the T-mote is then transfer to another T-mote connected to the base station. If the fire fighter's heart rate is increasing too high, an alert is sent. Heart@Home is a wireless blood pressure monitor and tracking system. Heart@Home uses a SHIMMER mote located inside a wrist cuff which is connected to a pressure sensor. A user's blood pressure and heart rate is computed using the oscillometric method. The SHIMMER mote records the reading and sends it to the T-mote connected to the user's computer. A software application processes data and provides a graph of the user's blood pressure and heart rate over time.

4.6 LISTSENset:

It enables the hearing impaired to be informed of the audible information in their environment. A user carries the base station T-mote with him. The base station T-mote consists of a vibrator and LEDs. Transmitter motes are place near objects (e.g., smoke alarm and doorbell) that can be heard. Transmitter motes consist of an Omni-directional condenser microphone. They periodically sample the microphone signal at a rate of 20 Hz. If the signal is greater than the reference signal, an encrypted activation message is sent to the user. The base station T-mote receiving the message actives the vibrator and its LED lights to warn the user. The user must press the acknowledge button to deactivate the alert

4.7 WSN in a petroleum facility:

In a petroleum facility, WSN can reduce cost and improve efficiency. The design of this network is focused on the data rate and latency requirement of the plant. The network consists of four sensor node and an actuator node. The sensor nodes are based on T-mote sky devices. Two AGN1200 pre-802.11N Series MIMO access points are used to create an 802.11b 2.4 GHz wireless local area network. In this multi-hop WSN, the T-mote sky devices send their radio packets to the base station which is forwarded to a crossbow star gate gateway. The crossbow star gate gateway translates the radio packets and sends it along the Ethernet MIMO to a single board TS-3300 computer. The single board TS-3300 computer outputs the sensor data to the distributed control system. The distributed control system can also submit changes to the actuator. In this study, results of network performance, RSSI and LQI measurement and noise were gathered. Results show that the effect of latency and environmental noise can significantly affect the performance of a WSN placed in an industrial environment.

4.8 Volcanic monitoring:

This can help accelerate the deployment, installation, and maintenance process. WSN equipments are smaller, lighter, and consume less power. The challenges of a WSN application for volcanic data collection include reliable event detection, efficient data collection, high data rates, and sparse deployment of nodes.

4.9Macros cope of redwood:

It is a case study of a WSN that monitors and records the redwood trees in Sonoma, California. Each sensor node measures air temperature, relative humidity, and photo-synthetically-active solar radiation. Sensor nodes are placed at different heights of the tree. Plant biologists track changes of spatial gradients in the microclimate around a redwood tree and validate their biological theories.

4.10 Cyclops:

This is a small camera device that bridges the gap between computationally-constrained sensor nodes and complimentary metal-oxide semiconductor (CMOS) imagers. This work provides sensor technology with CMOS imaging. With CMOS imaging, humans can (1) exploit a different perspective of the physical world which cannot be seen by human vision, and (2) identify their importance. Cyclops attempts to interface between a camera module and a lightweight sensor node. Cyclops contains programmable logic and memory circuits with high speed data transfer. It contains a micro-controller to interface with the outside world. Cyclops is useful in a number of applications that require high speed processing or high resolution images.

4.11Semiconductor plants and oil tanker application:

In this case report is focus on preventive equipment maintenance using vibration signatures gathered by sensors to predict equipment failure. Based on application requirements and site survey, the architecture of the network is developed to meet application data needs. Two experiments were carried out: the first was in a semiconductor fabrication plant and the second on an on board oil tanker in the North Sea. The goal was to reliably validate the requirements for industrial environments and evaluate the effect of the sensor network architecture. The study also analyzed the impact of platform characteristics on the architecture and performance of real deployment.

4.12 Under water monitoring:

This is the use of underwater sensor networks for long term monitoring of coral reefs and fisheries. The sensor network consists of static and mobile underwater sensor nodes. The nodes communicate via point-to-point links using high speed optical communications. Nodes broadcast using an acoustic protocol integrated in the Tiny OS protocol stack. They have a variety of sensing devices, including temperature and pressure sensing devices and cameras. Mobile nodes can locate and move above the static nodes to collect data and perform network maintenance functions for deployment, re-location, and recovery. The challenges of deploying sensors in an underwater environment were some key lessons from this study.

4.13 MAX application:

MAX is a system for human-centric search of the physical world. MAX allows people to search and locate physical objects when they are needed. It provides location information reference to identifiable landmarks rather than precise coordinates. MAX was designed with the objectives of privacy, efficient search of a tagged object, and human-centric operation. MAX uses a hierarchical architecture that requires objects to be tagged, sub-stations as landmarks, and base-station computers to locate the object. Tags on objects can be marked as private or public which is searchable by the public or owner only. MAX is designed for low energy and minimal-delay queries. The implementation of MAX was demonstrated using Connection-less sensor-based tracking system using witness (CenWitsis): It is a search-and-rescue system designed, implemented, and evaluated using Berkeley Mica2sensor motes. The system uses several small radio frequencies (RF)-based sensors and a small number of storage and processing devices. CenWits is not a continuously-connected network. It is designed for intermittent network connectivity. It is comprised of mobile sensors worn by subjects (people), access points that collect information from these sensors and GPS receivers, and location points to provide location information to the sensors. A subject will use the GPS receivers and location points to determine its current location. The key concept is the use of witnesses to convey a subject's movement and location information to the outside world. The goal of CenWits is to determine an approximate small area where search-and-rescue efforts can be concentrated.Other examples of wireless sensor networks are provided below. The mall: In the mall the following applications are possible using wireless sensor network.

- Many heterogeneous devices can be present at the same time for example Laptops, PDAs, cell phones, Wireless sensors, Smart tags and RFIDs.
- Proactive and reactive advertisements for example special offer, directions, latest news etc. also it can be used for user required information on the mall (e.g. for specific shops)

Fig 4.4

C H A P T E R 5

Types of wireless sensor networks

Presently, WSNs are deployed on land, underground, and underwater. Depending on the environment, a sensor network faces different challenges and constraints. There are five types of WSNs: terrestrial WSN, underground WSN, underwater WSN, multi-media WSN, and mobile WSN.

5.1 Types of wireless sensor networks

5.1.1 Underground WSNs:

This type of sensor nodes consist a number of sensor node buried underground or in a cave or mine used to monitor underground conditions. Additional sink nodes are located above ground to relay information from the sensor nodes to the base station. An underground WSN is more expensive than a terrestrial WSN in terms of equipment, deployment, and maintenance. Underground sensor nodes are expensive because appropriate equipment parts must be selected to ensure reliable communication through soil, rocks, water, and other mineral contents. The underground environment makes wireless communication a challenge due to signal losses and high levels of attenuation. Unlike terrestrial WSNs, the deployment of an underground WSN requires careful planning and energy and cost considerations. Energy is an important concern in underground WSNs. Like terrestrial WSN, underground sensor nodes are equipped with a limited battery power and once deployed into the ground, it is difficult to recharge or replace a sensor node's battery. As before, a key objective is to conserve energy in order to increase he lifetime of network which can be achieved by implementing efficient communication protocol.

5.1.2 Terrestrial WSNs:

This category of sensor network consists of hundred or thousand of sensor node deployed in particular area, either in ad hoc or preplanned manner. In ad hoc deployment, sensor nodes can be dropped from a plane and randomly placed into the target area. In pre-planned deployment, there is grid placement. The sensor nodes in this case are inexpensive compared with the underground WSNs. Terrestrial sensor nodes must be able to effectively communicate data back to the base station. While battery power is limited and may not be rechargeable, terrestrial sensor nodes however can be equipped with a secondary power source such as solar cells. In case, it is important for sensor node to conserve energy. This can be done using multi hop optimal routing, short transmission range, eliminating data redundancy and minimizing delays.

Underwater WSNs**:** In this case the sensor node consist vehicles deployed underwater. As opposite to terrestrial WSNs, underwater sensor nodes are more expensive and fewer sensor nodes are deployed. Autonomous underwater vehicles are used for exploration or gathering data from sensor nodes. Compared to a dense deployment of sensor nodes in a terrestrial WSN, a sparse deployment of sensor nodes is placed underwater. Typical underwater wireless communications are established through transmission of acoustic waves. A challenge in underwater acoustic communication is the limited bandwidth, long propagation delay, and signal fading issue. Another challenge is sensor node failure due to environmental conditions. Underwater sensor nodes must be able to self-configure and adapt to harsh ocean environment. Underwater sensor nodes are equipped with a limited battery which cannot be replaced or recharged. The issue of energy conservation for underwater WSNs involves developing efficient underwater communication and networking techniques.

5.1.3 Multi-media WSNs:

This type of network has been proposed to enable monitoring and tracking of events in the form of multimedia such as video, audio, and imaging. Multi-media WSNs consist of a number of low cost sensor nodes equipped with cameras and microphones. These sensor nodes interconnect with each other over a wireless connection for data recovery, process, correlation, and compression. Multi-media sensor nodes are deployed in a pre-planned manner into the environment to guarantee coverage. Challenges in multi-media WSN include high bandwidth demand, high energy consumption, quality of service (QoS) provisioning, data processing and compressing techniques, and cross-layer design. Transmission techniques that support high bandwidth and low energy consumption have to be developed. QoS provisioning is a challenging task in a multi-media WSN due to the variable delay and variable channel capacity. It is important that a certain level of QoS must be achieved for reliable content delivery. In-network processing, filtering, and compression can significantly improve network performance in terms of filtering and extracting redundant information and merging contents. Similarly, cross-layer interaction among the layers can improve the processing and the delivery process.

5.1.4 Mobile WSNs:

It comprises of a group of sensor nodes that are capable to move on their own and interact with the physical environment. Mobile nodes like static node have the ability sense, compute, and communicate information. A key difference is mobile nodes have the ability to reposition and organize itself in the network. A mobile WSN can start off with some initial deployment and nodes can then spread out to gather information. Information gathered by a mobile node can be communicated to another mobile node when they are within range of each other. Another key difference is data distribution. In a static WSN, data can be distributed using fixed routing or flooding while dynamic routing is used in a mobile WSN. Challenges in mobile WSN include deployment, localization, self-organization, navigation and control, coverage, energy, maintenance, and data process.

C H A P T E R 6

Conclusion

Routing in sensor networks is a new area of research, with a limited but rapidly growing set of research results. In our project we present a comprehensive survey of routing techniques in wireless sensor networks that have been presented in the literature. They have the common objective of trying to extend the lifetime of the sensor network while not compromising data delivery.

Although the performance of these protocols is promising in terms of energy efficiency, further research would be needed to address issues such as quality of service posed by video and imaging sensors and real-time applications. Energy-aware QoS routing in sensor networks will ensure guaranteed bandwidth (or delay) through the duration of connection as well as providing the use of most energy efficient path. QoS routing in sensor networks have several applications including real time target tracking in battle environments, emergent event triggering in monitoring applications etc. Currently, there is very little research that looks at handling QoS requirements in a very energy constrained environment like sensor networks. Another interesting issue for routing protocols is the consideration of node mobility. Most of the current protocols assume that the sensor nodes and the sink are stationary. However, there might be situations such as battle environments where the sink and possibly the sensors need to be mobile. In such cases, the frequent update of the position of the command node and the sensor nodes and the propagation of that information through the network may excessively drain the energy of nodes. New routing algorithms are needed in order to handle the overhead of mobility and topology changes in such energy constrained environment. Other possible future research for routing protocols includes the integration of sensor networks with wired networks (i.e. Internet). Most of the applications in security and environmental monitoring require the data collected from the sensor nodes to be transmitted to a server so that further analysis can be done. On the other hand, the requests from the user should be made to the sink through Internet. Since the routing requirements of each environment are different, further research is necessary for handling these kinds of situations. Lastly we also brief account of network topologies, system architecture, design issue, application of wireless sensor network in various domain and types of wireless sensor networks.

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