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A Survey on Sensor Network

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Abstract: Sensor networks are recently rapidly growing research area in wireless communications and distributed network. Sensor network is a densely deployed wireless network of small, low-cost sensors, which can be used in various applications like—health, environmental monitoring, military, home, gathering and sensing information in inhospitable locations etc. Wireless sensor networks monitor and control physical environments from remote locations. Sensor nodes suffer various energy and computational constraints for their low cost feature and ad hoc deployment method. Different application areas of sensor networks consist different technical issues and researchers are currently shedding their lights to resolving these issues. The prominent deficiencies are: energy efficient routing, protocols, localization algorithms and system design. This survey paper will cover up all these open research issues as well as their solutions and will point out and depicts all important fields of sensor networks.

Index Terms: Applications, Routing Protocols, Sensor, Sensor Network.

1 INTRODUCTION

A sensor network is a communication infrastructure or group of specialized transducers to monitor, record and respond to any phenomena or diverse locations [1]. Sensors can generally monitor temperature, humidity, pressure, wind direction and speed, illumination intensity, vibration intensity, sound intensity, power-line voltage, chemical concentrations, pollutant levels and vital body functions. Sensor network's communication infrastructure and protocols are different and challenging from recent Internet-based system because of their requirements and limitations [8].With the advancement of technology, sensor network is implemented with small, low cost, low power, multifunctional, distributed sensors [2]. Each sensor node has ability to perform a limited amount of processing. But when sensor nodes are coordinated with other nodes, they can perform some specific action. Before, sensor network was deployed only for small number of nodes, wired to a central processing station. But, now a days, the focus is going for wireless, distributed, sensing nodes. A sensor network consists of a large number of sensor nodes that are densely positioned inside or near to the occurrence. Energy of each sensor or energy efficiency is another issue for sensor network [3].

MANETS (Mobile Ad-hoc NETworkS) and sensor networks are two classes of the wireless Ad hoc networks with resource constraints [8]. MANETS usually consists devices that have high processing and power capabilities, mobile and can operate in coalitions. Both these wireless networks consists ad hoc nature and lack pre deployed infrastructure for computing and communication.

The differences between sensor networks and ad hoc networks are described below [2]:

- The number **of** sensor nodes in a sensor network can be several orders of magnitude higher than the nodes in an ad hoc network.
- Sensor nodes are densely deployed.
- Sensor nodes are prone to failures.
- The topology of a sensor network changes very frequently.
- Sensor nodes mainly use a broadcast communication technique, whereas most ad hoc networks are based on point-to-**point** communications.
- Sensor nodes are limited in power, computational capacities, and memory.
- Sensor networks are typically distributed in specific geographical regions for tracking, monitoring and sensing.
- Sensor nodes may not have global identification (ID) because of the large amount of overhead and large number of sensors.

The remainder of this paper is organized as follows. Section 2 contains components of sensor network, section 3 describes architecture of sensor network, section 4 contains protocol stack, section 5 depicts routing protocols and comparison of routing protocols and their design issues, section 6 presents applications of sensors networks in different areas, section 7 contains energy efficiency for sensor network and finally section 8 specifies the simulators used for sensor network followed by conclusion.

2 COMPONENTS OF SENSOR NETWORK

Sensors can be scaled from microsensors to larger scale .A sensor network consists sensor nodes which are small, lightweight and portable and these nodes form a network by communicating with each other directly or through other nodes. One or more nodes among them will serve as sink(s) that are responsible of communicating with the user either directly or through the existing wired networks.

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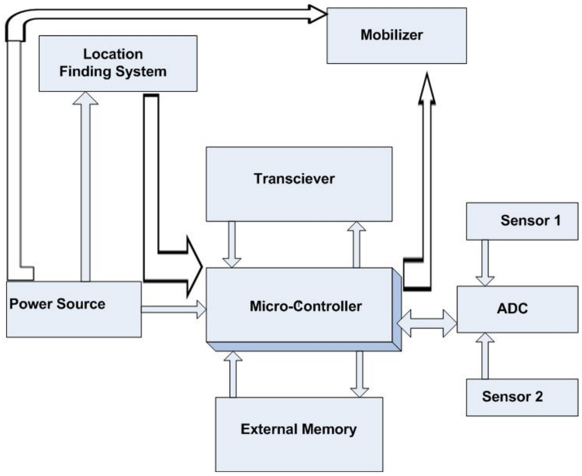

Fig. 1. The components of a sensor node.

The main components of a sensor node as seen in the fig 1, are microcontroller, transceiver, external memory, power source and one or more sensors. Every sensor node consists transducer, microcomputer, transceiver and power source. The transducer (ADC—Analog to digital converter in fig 1) is responsible to generate electrical signals based on sensed phenomena and physical effects. The microcontroller's work is to process and store the sensor output. The transceiver receives command from a central computer or base station and transmits data to the computer or station. Sensor nodes are catered power by a battery. Some sensor nodes include external memory which may be on-chip memory of a microcontroller and Flash memory. Needs of memory of a sensor node are application specific. Each node may also belong to two extra components like: -Location finding system and Mobilizer. First one, location finding system is required since the user may in need of location with high accuracy and mobilizer may be needed to move sensor nodes to carry out the assigned tasks.

3 NETWORK ARCHITECTURE

As in fig 2, the sensor nodes are usually scattered in sensor field [2]. Each and every of these scattered sensor nodes are capable of collecting data and route back data to the sink. Data are routed back to the sink through a multi hop

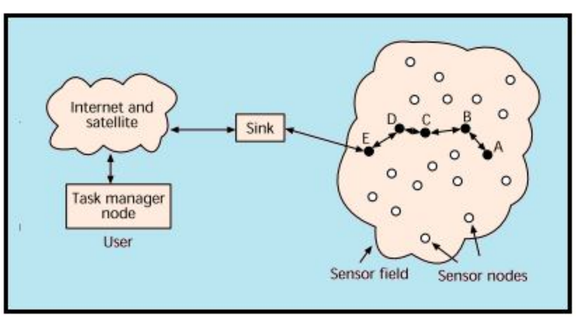

Fig. 2. Sensor network architecture

infrastructure less route or architecture as in fig 2.

The sink can communicate with the task manager node through Internet or Satellite technology. The design of sensor network are determined by various factors, like-- fault tolerance, scalability, small size, robust operations, production costs, operating environment, security, compatibility, flexibility, data aggregation, sensor network topology, hardware constraints, transmission media, quality of service (QoS),data latency and overhead and power consumption etc. [2],[6],[8].

In a multi hop sensor network, nodes are connected through wireless medium—infrared, radio, optical etc.

4 PROTOCOL STACK

The protocol stack used by the sink and sensor nodes as depicted in Fig 1, is given in Fig 3. This protocol stack incorporates power and routing awareness, integrates data with networking protocols, communicates power efficiently through the wireless medium, and promotes co-operative efforts of sensor nodes. The protocol stack consists application and energy driven point of view [4], the layers are -- the physical layer, data link layer, network layer, transport layer, application layer, power management plane, mobility management plane, and task management plane [2].

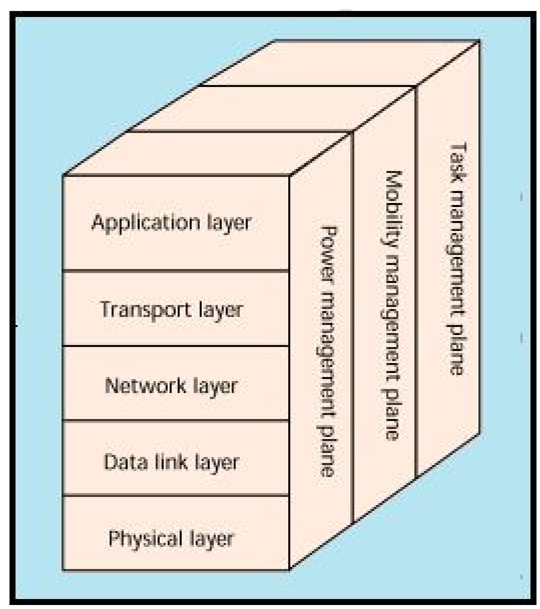

Fig.3. Protocol stack of sensor network.

Each layer of protocol stack is described below:-

4.1 Physical Layer

The physical layer is responsible for frequency selection, simple and robust modulation, signal detection, data encryption, transmission, and receive. This layer also addresses the needs of a modulation technics to affect the power requirements [4], [7]. In [7] this is considered as a largely unexplored area.

Open research issues: Design of simple and low power modulation schemes, strategies to overcome signal propagation effects and implementing the hardware in a very small volume.

4.2 Data Link Layer

This layer is responsible for creating the network infrastructure and sharing and access of communication media among sensor nodes [7]. Multiplexing of data streams, data frame detection, error control are also tasks of Data link layer.

MAC Protocol

For wireless multi-hop sensor network, MAC protocol has two goals:-- 1) Creation of the network infrastructure: thousands of Sensor nodes may be densely scattered in a sensor field ; for this the MAC scheme must be installed in communication links for data transfer to give the sensor network self-organizing ability. 2) Efficiently and fairly share communication resources between nodes. In a cellular system, the primary goal is the high quality of service (QoS) and bandwidth efficiency. Power conservation is a secondary goal, since the base station and the users have unlimited, dedicated power supply. This kind of strategy is impractical for sensor networks since there is no central controlling agent link base station. Moreover, power efficiency is most important for sensor network lifetime. As Bluetooth and mobile ad hoc network (MANET) may be the closest peers to sensor network, in contrast to them, sensor network have much larger number of nodes and transmission power and radio range are lower than them. Topology change is frequent in sensor network which imputed to node mobility and failure, falling in sleep, being blocked by environmental interference etc. [7]. Because of importance of power conservation to prolong network lifetime of a senor network, the existing Bluetooth and MANET MAC can be used directly for sensor network.

The protocols that are used for sensor network are [7]:-

Self-Organizing Medium Access Control for Sensor Networks (SMACS) and the Eavesdrop-And-Register (EAR) Algorithm — SMACS and EAR [9]:

SMACS is a distributed infrastructure-building protocol that achieves network startup and link-layer organization for the sensor nodes by enabling nodes to discover their neighbors and establish transmission / reception schedules for communication without the presence of global or local master nodes. The neighbor discovery and channel assignment phases are aggregated so that nodes hear all their neighbors and they can form a connected network. A communication link consists of a pair of time slots working at a randomly chosen, fixed frequency. Conserving power is achieved by using a random wake up during the connection phase and by turning the radio off during idle time slots [2], [7].

The EAR protocol [9] provides continuous service to the mobile nodes under both mobile and stationary conditions. EAR provides seamless connection of the mobile nodes, minimizes messaging overhead and is transparent to SMACS. The network is assumed to be static in this model or any mobile node is closed to number of stationary nodes.

CSMA-Based Medium Access

Traditional CSMA based MAC protocol is not appropriate for sensor network since they assume stochastically distributed traffic mainly for independent point-to-point flows [10]. On the other hand, the MAC protocol for sensor networks must be able to support variable but highly correlated and dominantly periodic traffic. CSMA based medium access protocol consists two important components: -- the listening and back off mechanism. Based on [10], this scheme uses constant listening periods for energy efficiency introduces random delays for robustness against repeated collisions.

An adaptive rate control (ARC) scheme is used in order to achieve medium access fairness [7], [10]. This can be done by balancing the rates of originating and route through traffic. This ensures that nodes that are nearer to the access point are not favored over inside into network. ARC controls the data origination rate of a node to allow the route-through traffic to propagate and attempts to reduce the problem of hidden nodes in a multi hop network by constantly tuning the transmission rate and changing phase so that periodic streams are repeatedly collide minimally.

Hybrid TDMA/FDMA- CSMA-Based Medium Access

TABLE 1
A QUALITATIVE OVERVIEW OF MAC PROTOCOLS FOR SENSOR NETWORKS

MAC protocol	Channel access mode	Sensor network specifics	Power conservation
SMACS and EAR	Fixed allocation of duplex timeslots at fixed frequency	Exploitation of large available bandwidth compared to sensor data rate	Random wake up during setup and turning radio off while idle
Hybrid TDMA/FDMA	Centralized frequency and time division	Optimum number of channels calculated for minimum system energy	Hardware-based approach for system energy minimization
CSMA-based	Contention-based random access	Application phase shift and pre transmit delay	Constant listening time for energy efficiency

In [11], this scheme is introduced as more energy efficient than time division multiple access (TDMA) or frequency division multiple access (FDMA). This work gives importance of hardware and physical layer for energy efficient protocol. Protocols throughout the protocol stack must be aware of the physical layer and hardware. To find the optimum number of channels to give lowest power consumption, an analytical formula is derived in [11]. The ratio of power consumption of the transmitter to that of receiver determines the optimum number of channels. A TDMA scheme is favored if the transmitter consumes more power, when the receiver consumes greater power, the FDMA is preferable.

An overview or comparison of salient features of MAC protocols for sensor network is depicted in Table 1 [2].

Open research issues: MAC for mobile sensor networks, Determination of lower bounds on the energy required for sensor network self-organization, Error control coding schemes, Power-saving modes of operation.

4.3 Network Layer

Sensor nodes are scattered densely in a field and for this special wireless multi hop wireless routing protocols between the sensor nodes and the sink node are needed. Traditional ad hoc routing protocols cannot be used for sensor network. Design issues for the networking layer of sensor networks are: 1) Power efficiency 2) Data Centric 3) Data aggregation 4) Attribute-based addressing and location awareness [2].

Some important tasks of this layer are energy efficient route, data centric routing, data aggregation, provide internetworking with external networks such as other sensor networks, command and control systems, and the Internet.

An overview of the protocols proposed of network layerfor sensor networks is given in Table 2 [2]. The routing protocols are discussed in Section 5.

Open research issues: Depends on higher topology changes and higher scalability, the routing protocols may need to be improved.

4.4 Transport Layer

This layer is required when the system to be accessed through the Internet [2]. TCP with its transmission window mechanism does suit the characteristics of the sensor network environment. TCP splitting is needed to interact with other networks such as Internet. TCP connections are created between the sink and sensor node and communication between the user and the sink node is by UDP or TCP via the Internet or Satellite. As a sensor node has limited memory, the connection between sink and sensor nodes may be purely by UDP protocols. Unlike TCP protocols, which use global addressing, sensor networks use attribute-based naming to indicate the destination data packet. Moreover, for sensor network transport layer need to handle differently for the factors like-- power consumption and scalability, and characteristics like data-centric routing.

Open research issues: Based on the issues discussed above, each sensor node has limited storage, and acknowledgement is costly, the development of transport layer protocols is challenging and so TCP/UDP are used in the Internet or Satellite and UDP is used for sensor network.

4.5 Application Layer

For sensor network, three possible application layer protocols: Sensor Management Protocol (SMP), Task Assignment and Data Advertisement Protocol (TADAP), and Sensor Query and Data Dissemination Protocol (SQDDP), are used. All of these application layer protocols are open research issues.

TABLE 2

AN OVERVIEW OF NETWORK LAYER SCHEMES.

Network layer scheme	Description
SMECN	Creates a sub graph of the sensor network that contains the minimum energy path
Flooding	Broadcasts data to all neighbor nodes regardless if they receive it before or not
Gossiping	Sends data to one randomly selected neighbor
SPIN	Sends data to sensor nodes only if they are interested; has three types of messages (i.e., ADV, REQ, and DATA)
SAR	Creates multiple trees where the root of each tree is one hop neighbor from the sink; selects a tree for data to be routed back to the sink according to the energy resources and additive QoS metric
LEACH	Forms clusters to minimize energy dissipation
Directed diffusion	Sets up gradients for data to flow from source to sink during interest dissemination

SENSOR MANAGEMENT PROTOCOL--SMP

System administrators interact with sensor networks using SMP protocol. SMP needs to access the nodes by using attribute-based naming and location-based addressing [2]. Therefore, the soft wares will perform the following administrative tasks [12]:

- Introducing the rules related to data aggregation, attribute-based naming, and clustering to the sensor nodes
- Exchanging data related to the location finding algorithms
- Time synchronization of the sensor nodes
- Moving sensor nodes
- Turning sensor nodes on and off
- Querying the sensor network configuration and the status of nodes, and reconfiguring the sensor network
- Authentication, key distribution, and security in data communications.

TASK ASSIGNMENT AND DATA ADVERTISEMENT PROTOCOL--TADAP

Other important operation of a sensor network is interest dissemination and users send their interest to a sensor node, a subset of the nodes or the whole network for this. Another one is the advertisement of available data where the sensor nodes advertise the available data to the users and the users search the data in which they are interested.

SENSOR QUERY AND DATA DISSEMINATION PROTOCOL --SQDDP

This protocol provides user interfaces in applications to make queries, respond to queries and collect incoming replies. This query is not performed for particular nodes. Instead, attribute- or location-based naming is preferred.

Sensor query and tasking language (SQTL) [12] is proposed as an application that caters an even larger set of services. SQTL supports three types of events, these events are: receive, every, and expire. Receive means events generated by a sensor node when the sensor node receives a message; every defines events occurring periodically due to timer timeout; and expire defines events occurring when a timer is expired.

Open research issues: Although SQTL is proposed, other application layer protocols are still in need of development to provide a greater level of services. Research should also focus on TADAP and SQDDP, described above.

4.6 Power management plane

Power management plane is responsible to deal how a sensor node uses its power. A sensor node may turn off its receiving message from its neighbors to get duplicate messages. When the power level of a sensor is low, the node broadcasts the low power status to its neighbors and stop participating in routing. The redundant power is reserved for sensing task.

4.7 Mobility management plane

The mobility management plane detects and keep records the movement of sensor nodes. This results route back to the user and the sensor nodes can maintain their sensor nodes records that balance their power and task usage.

4.8 Task management plane

This plane schedules and balances the sensing tasks given to a specific region. Based on the power level, not all sensor nodes in a region are needed to perform the sensing task at the same time. This management plane is required because --sensor nodes can work together in a power efficient way, route data in a mobile sensor network, and share resources between sensor nodes.

5 ROUTING PROTOCOLS

Generally, routing in WSNs can be divided into flat-based routing, hierarchical-based routing, and location-based routing, depending on the network structure [5]. Depending on the protocol operation routing protocols can be classified into multipath-based, query-based, negotiation-based, QoS-based, or coherent-based routing techniques. Additionally, routing protocols can be classified into three categories, namely, proactive, reactive, and hybrid protocols depending on how the source finds a route to the destination.

Here is the brief description of these protocols:--

5.1 Architecture Based Routing Protocols

i) Flat-Based Routing

When huge amount of sensor nodes are required, flat-based routing is needed where every node plays same role. Since the number of sensor nodes is very large therefore it is not possible to assign a particular ID to each and every node. This leads to data-centric routing approach in which Base station sends query to a group of particular nodes in a region and waits for response. Attribute-based naming is necessary to specify the properties of data because data is being requested through queries. Examples of Flat-based routing protocols are: [5].

- Energy Aware Routing (EAR)
- Directed Diffusion (DD)
- Sequential Assignment Routing (SAR)
- Minimum Cost Forwarding Algorithm (MCFA)
- Sensor Protocols for Information via Negotiation (SPIN)
- Active Query forwarding In sensor network (ACQUIRE)

ii) Hierarchical-Based Routing

When network scalability and efficient communication is needed, hierarchical-based routing is the best match. It is also called cluster based routing. Hierarchical-based routing is energy efficient method in which high energy nodes are randomly selected for processing and sending data while low energy nodes are used for sensing and send information to the cluster heads. This property of hierarchical-based routing contributes greatly to the network scalability, lifetime and minimum energy. Another reason of energy efficiency is by performing data aggregation and fusion in order to decrease the number of transmitted messages to the Base Station.

Examples of hierarchical based routing protocols are: [5, 13]

- Hierarchical Power-Active Routing (HPAR)
- Threshold sensitive energy efficient sensor network protocol (TEEN)
- Power efficient gathering in sensor information systems
- Minimum energy communication network (MECN)

iii) Location-Based Routing

In this kind of network architecture, sensor nodes are scattered randomly in an area of interest and mostly known by the geographic position where they are deployed. Alternatively, the location of nodes may be available directly by communicating with a satellite, using GPS (Global Positioning System), if nodes are equipped with a small low power GPS receiver. To save energy, some location based schemes demand that nodes should go to sleep if there is no activity. More energy savings can be obtained by having as many sleeping nodes in the network as possible. The distance between nodes is estimated by the signal strength received from those nodes and coordinates are calculated by exchanging information between neighboring nodes.

Location-based routing networks are: [13, 14]

- Sequential assignment routing (SAR)
- Ad-hoc positioning system (APS)
- Geographic adaptive fidelity (GAP)
- Greedy other adaptive face routing (GOAFR)
- Geographic and energy aware routing (GEAR)
- Geographic distance routing (GEDIR)

5.2 Operation Based Routing Protocol Classification

i) Multipath Routing Protocols

As its name implies, protocols included in this class provides multiple path selection for a message to reach destination thus decreasing delay and increasing network performance. Network reliability is achieved due to increased overhead. Since network paths are kept alive by sending periodic messages and hence consume greater energy. Multipath routing protocols are: [14]

- Multi path and Multi SPEED (MMSPEED)
- Sensor Protocols for Information via Negotiation (SPIN)

ii) Query Based Routing Protocols

This class of protocols works on sending and receiving queries for data. The destination node sends query of interest from a node through network and node with this interest matches the query and send back to the node which initiated the query. The query normally uses high level languages. Query based routing protocols are: [14]

- Sensor Protocols for Information via Negotiation (SPIN)
- Directed Diffusion (DD)
- COUGAR

iii) Negotiation Based Routing Protocols

This class of protocols uses high level data descriptors to eliminate redundant data transmission through negotiation. These protocols make intelligent decisions either for communication or other actions based on facts such that how much resources are available. Negotiation based routing protocols are [14]:

TABLE 3
Classification and Comparison of routing protocols in WSNs

Routing Protocols	Classificacation	Power Usage	Data Aggregation	Scalability	Query Based	Overhead	Data delivery model	QoS	Mobility	Multipath	Position Awareness	State Complexity	Localization	Negotiation based
SPIN	Flat	Limited	Yes	Limited	Yes	Low	Event Driven	No	Possible	Yes	No	Low	No	Yes
Directed diffusion	Flat	Unlimited	Yes	Limited	Yes	Low	Demand Driven	No	Limited	Yes	No	Low	Yes	Yes
Rumor Routing	Flat	N / A	Yes	Good	Yes	Low	Demand Driven	No	Very Limited	No	No	Low	No	No
GBR	Flat	N / A	Yes	Limited	Yes	Low	Hybrid	No	Limited	No	No	Low	No	No
MCFA	Flat	N / A	No	Good	No			No	No	No	No	Low	No	No
CADR	Flat	Limited	Yes	Limited	Limited	Low	Continuously	No	No	No	No	Low	No	No
COUGAR	Flat	Limited	Yes	Limited	Limited	High	Query Driven	No	No	No	No	Low	No	No
ACQUIRE	Flat	N / A	Yes	Limited	Yes	High	Complex Query	No	Limited	No	No	Low	No	No
EAR	Flat	N / A	No	Limited	Yes			No	Limited	No	No	No		No
LEACH	Hierarchichal	Maximum	Yes	Good	No	High	Cluster head	No	Fixed BS	No	No	CHs	Yes	No
TEEN & APTEEN	Hierarchichal	High	Yes	Good	No	High	Active Threshold	No	Fixed BS	No	No	CHs	Yes	No
PEGASIS	Hierarchichal	Max	No	Good	No	Low	Chains Based	No	Fixed BS	No	No	Low	Yes	No
MECN & SMECN	Hierarchichal	Max	No	Low	No			No	No	No	No	Low	No	No
SOP	Hierarchichal	N / A	No	Low	No	High	Continiously	No	No	No	No	Low	No	No
HPAR	Hierarchichal	N / A	No	Good	No			No	No	No	No	No	No	No
VGA	Hierarchi	N / A	Yes	Good	No	High	Good	No	No	Yes	No	CHs	Yes	Yes

	chichal													
Sensor Aggregate	Hierarchichichal	N/A	Yes	Good	Possible			No	Limited	No	No	Low	No	No
TTDD	Hierarchichichal	Limited	No	Low	Possible			No	Yes	Possible	Yes	Moderate	No	No
GAF	Location	Limited	No	Good	No	Mod	Virtual grid	No	Limited	No	No	Low	No	No
GEAR	Location	Limited	No	Limited	No	Mod	Demand Driven	No	Limited	No	No	Low	No	No
SPAN	Location	N/A	No	Limited	No	High	Continiously	No	Limited	No	No	Low	No	Yes
MFR, GEDIR	Location	N/A	No	Limited	No			No	No	No	No	Low	No	No
GOAFR	Location	N/A	No	Good	No				No	No	No	Low	No	No
SAR	Data Centric	N/A	Yes	Limited	Yes	High	Continuously	Yes	No	No	No	Moderate	No	Yes
SPEED	Location/ Data Centric	N/A	No	Limited	Yes	Less	Greographic	Yes	No	No	No	Moderate	No	No

- Sensor Protocols for Information via Negotiation (SPAN)
- Sequential assignment routing (SAR)
- Directed Diffusion (DD)

iv) QoS Based Routing Protocols

In this type of routing, network needs to have a balance approach for the QoS of applications. In this case the application can delay sensitive so to achieve this QoS metric network have to look also for its energy consumption which is another metric when communicating to the base station. So to achieve QoS, the cost function for the desired QoS also needs to be considered. Example of such routing are: [14, 15]

- Sequential assignment routing (SAR)
- SPEED
- Multi path and Multi SPEED (MMSPEED)

v) Coherent Data Processing Routing Protocol

Coherent data processing routing is used when energy-efficient routing is required. In this routing scheme, nodes perform minimum processing (typically, time-stamping, suppression etc.) on the raw data locally before sending for further processing to other nodes. Then it is sent to other nodes called aggregator for further processing known as aggregation [14].

Data processing in non-coherent processing involves three phases. In first phase target detection, its data collection and preprocessing of its data takes place. Then for the cooperative function the node needs to enter in phase 2 where it shows its intention to neighboring nodes. Here all neighboring nodes must be aware of the local network topology. Finally, in step 3 a center node is selected for further refined information processing. Therefore central node must have enough energy resources and computation abilities [14].

Table 3 represents Classification and Comparison of routing protocols in WSNs [2], [8].Table 4 depicts routing protocols selection for particular applications in WSNs [8].

6 Applications of Sensor Network:

Wireless sensor networks have wide variety of applications with wide variety of requirements and characteristics. Applications are considered according to the deployment, mobility, resources, cost, energy, heterogeneity, modality, infrastructure, topology, coverage, connectivity, size, lifetime and QoS. Some applications are: Great Duck (bird observation on Great Duck island), Zebra Net, Glacier (glacier monitoring), Herding (cattle herding), Bathymetry, Ocean (ocean water monitoring),Grape (grape monitoring), Cold Chain (cold chain management), Avalanche (rescue of avalanche victims), Vital Sign (vital sign monitoring), Power (power monitoring), Assembly (parts Assembly (parts assembly), Tracking (tracking military vehicles), Mines (self-healing mine field) and sniper (sniper localization) ,Disaster Relief, Emergency Rescue

TABLE 4
ROUTING PROTOCOLS SELECTION FOR PARTICULAR APPLICATIONS IN WSNS

Application type	Project	Node deployment	Topology	Size	Routing protocol
Habitat monitoring	Great Duck	Manual one time	Cluster Head	10-100	SPAN , GAF
Environment monitoring	PODS Hawaii	Manual one time	Multi-hop Multi-path	30-50	DD
	Food Detection	Manual	Multi-hop	200	COUGAR, ACQUIRE
Health	Artificial Retina	Manual one time	Cluster Head	100	LEACH
	Vital Sign	Manual	Star	10-20	GBR,SAR,SPEED
Military	Object Tracking	Random	Multi-hop	200	GAF
Home/Office	Aware Home	Manual Iterative	Three Tiered	20-100	APTEEN, GEAR
Production/ Commercial	Cold Chain	Manual, Iterative	Three Tiered	55	SAR

operation, Military, Habitat Monitoring, Health Care, Environmental monitoring, Home networks, detecting chemical, biological, radiological, nuclear, and explosive material etc [8], [16] .

These current research projects are (Project name): SensorNet, WINS, SPINS, SINA, mAMPS, LEACH, SmartDust, SCADDS, PicoRadio, PACMAN, Dynamic Sensor Networks, Aware Home, COUGAR and Device Database Project DataSpace [16]

Some applications for different areas are shown in table 5 [8], [16].

7 ENERGY EFFICIENCY

Energy efficiency is a dominant consideration for sensor network no matter what the problem is. Because sensor nodes only have a small and finite source of energy. Many solutions, both hardware and software related, have been proposed to optimize energy usage [16].

Sensors must be in idle state and save energy by between interesting events. Sensors can consume energy by defining the latency to active time of the network according to the user's specific demands. By considering the network as a single entity and collaborative communications protocols remove redundancies in computation and communication, maintain and consume spatial distribution of energy. Nodes with infinite lifetime can be harvested using environmental energy transformed into useful energy electrical energy. This energy harvesting techniques gather energy from vibrations, blasts of radio energy, and the like, self-powered circuitry is a very real possibility. As a result, a battery less infinite-lifetime sensor network is possible.

Sensor nodes can be used in ubiquitous computing for its availability of computational power in anywhere, anytime.

In [18], an energy-efficient distributed clustering approach for ad-hoc sensor networks was described. In this hybrid clustering approach, heads are randomly selected based on their residual energy and nodes are joined in clusters in a cost effective way.

From [13], we can get the improvement of the energy consumption of sensor nodes in large networks. A new "bio-morphic" paradigm is proposed to import solutions to existing engineering problems from the biological world to enhance the durability of battery power of sensor nodes. This paradigm provides better solutions through the introduction of an additional type of sensor nodes and allowing the network to self-organize and "learn".

From [19], in order to maximize operational lifetime wireless sensor networks must minimize overall power consumption. Here a mixture of higher-powered IP-speaking nodes and lower-powered non-IP nodes are used and Graph-theoretic techniques are used to investigate heuristics for guaranteeing full network connectivity in networks consisting of sensors with differing transmission ranges. Reactive routing protocols and sleep mode operation are used for adaptive power control in IP networks, reactive routing-protocols with topology-based Adaptive Power Control improve energy-usage in sensor networks, and reactive-routing was compatible with sleep-mode operation— all these are described in [19].

In [20], an architecture for large scale low power sensor network with mobile agents (SENMA) is proposed. Mobile agents in SENMA are powerful hardware units, with their communication and processing capability and in their ability to traverse the sensor network. Examples of mobile agents are manned/unmanned aerial vehicles; ground vehicles equipped with sophisticated terminals and power generators, or specially designed light nodes that can hop around in the network [20].

8 SIMULATORS FOR SENSOR NETWORKS:

Some prominent simulators for sensor networks are used today are [3]:

1. **NS-2**: This is mother of all simulators and has facilities to conduct both wireless and wired simulations. This is written in oTCL and easier to add new modules for its object-oriented features. It facilitates of extensive documentation.

2. **GloMoSim**: GLobalMObile Information systems SIMulator is a scalable simulation environment for wireless and wired network systems. It is written both in C and Parsec. It is capable of parallel discrete-event simulation. GloMoSim currently supports protocols for a purely wireless network. A basic level of Parsec knowledge and thorough C knowledge is sufficient to carry out simulations [3].

3. **SensorSim**: is a simulation framework for sensor networks. It is an extension to the NS simulator. It provides the following: Sensing channel and sensor models, Battery models, Lightweight protocol stacks for wireless micro sensors, Scenario generation and Hybrid simulation. It is geared very specifically towards sensor networks and is still in the pre-release stage. It does not have proper documentation.

9 CONCLUSION

In this paper, all important aspects of sensor network is described including sensor nodes, network architecture, protocols and protocol stack, applications, way of energy efficiency etc. Characteristics of sensor networks like: - flexibility, fault tolerance, high sensing fidelity, low cost, and rapid deployment, create many new and exciting application areas for remote sensing. However, realization of sensor networks needs to satisfy the constraints introduced by factors such as fault tolerance, scalability, cost, hardware, topology change, environment, and power consumption.

Sensor network is an evolving research area and lots of underdeveloped research scopes related to senor network are waiting for researchers.

A lot of researchers are currently developing technologies related to different layers of the sensor network protocol stack.

Along with the current research projects, more insight into the problems related to protocols are required to motivate a search for solutions to the open research issues described in this paper. Energy constraint nature captivates the necessary to look at more energy efficient design and operation. Moreover, media access control, security and privacy and efficient routing protocols are also necessary to give attention for future work.

TABLE 5

SOME APPLICATIONS FOR DIFFERENT AREAS

Area	**Applications**
Military	• Military situation awareness • Sensing intruders on bases, detection of enemy units movements on land/sea, chemical/ biological threats and offering logistics in urban warfare • Battlefield surveillances • Command, control, communications, computing, intelligence, surveillance, reconnaissance, and targeting systems.
Emergency situations	• Disaster management. • Fire/water detectors. • Hazardous chemical level and fires • Monitoring disaster areas.
Physical world	• Environmental monitoring of water and soil. • Habitual monitoring. • Observation of biological and artificial systems • Monitor and control the physical world: deployment of densely distributed sensor/actuator networks for a wide range of biological and environmental monitoring applications, from marine to soil and atmospheric contexts; observation of biological, environmental, and artificial systems; environmental monitoring of water and soil, tagging small animals unobtrusively, and tagging small and lightweight objects in a factory or hospital setting.
Medical and health	• Sensors for blood flow, respiratory rate, ECG (electrocardiogram), pulse oxymeter, blood pressure and oxygen measurement. • Monitoring people’s location and health condition. • Monitor patients and assist disabled patients
Industrial	• Factory process control and industrial automation. • Monitoring and control of industrial equipment • Manufacturing monitoring
Home networks	• Home appliances, location awareness (blue tooth). • Person locator
Automotive	• Tire pressure monitoring. • Active mobility. • Coordinated vehicle tracking.
Location	• Location awareness (LR-WPAN and Bluetooth). • Person locator.
Mobile wireless low-rate networks for precision location	Tracking of assets, people, or anything that can move in various environments, including industrial, retail, hospital, residential, and office environments, while maintaining low-rate data communications for monitoring, messaging, and control.
Physical world	Monitor and control the physical world: deployment of densely distributed sensor/actuator networks for a wide range of biological and environmental monitoring applications, from marine to soil and atmospheric contexts; observation of biological, environmental, and artificial systems; environmental monitoring of water and soil, tagging small animals unobtrusively, and tagging small and lightweight objects in a factory or hospital setting.
Public safety	• Sensing and location determination at disaster sites
Airports	• Smart badges and tags. • Wireless luggage tags. • Passive mobility (e.g., attached to a moving object not under the control of the sensor node)
Agriculture	Sensing of soil moisture, pesticide, herbicide, pH levels.
Rotating machinery Seismic Commercial	• Warning systems. • Managing inventory, monitoring product quality
Ocean	Monitoring fish

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