An Elaborative Study on Routing Protocols in Wireless Sensor Networks: A Survey

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***Abstract*— Wireless Sensor Networks have originated vast significance after the expansion of wireless technology. A Wireless Sensor Network is an amalgamation of enormous amount of sensing devices termed sensor nodes. In Wireless Sensor Networks (WSNs) due to the constraints the nodes, power and energy effectiveness is an essential point which should be well-thought-out at the instance of scheming of protocols. Wireless Sensor Networks in recent times move toward into distinction for the reason that they hold the impending to transform segment of our cost-cutting work out and existence with its broad applications. Several applications comprise like landslide detection, glacial monitoring, wildlife tracking, health care, military applications, environmental monitoring and a huge quantity of applications to robotics, internet of things etc. The articulation of information is based on the Routing Protocols which chooses the optimum route involving any number of nodes. Various types of Routing Protocols are useful to specific network surroundings. Routing Protocols for Wireless Sensor Networks are responsible for retaining the routes in the network and guarantee dependable multi-hop transmission beneath these situations. The paper reviews the WSNs Architecture and Design as well as Routing Protocols Taxonomy, Prime Routing Protocols and its further Research Areas in association with Wireless Sensor Networks.**

***Index Terms* Wireless Sensor Networks, Routing Protocols, Multi-hop Transmission.**

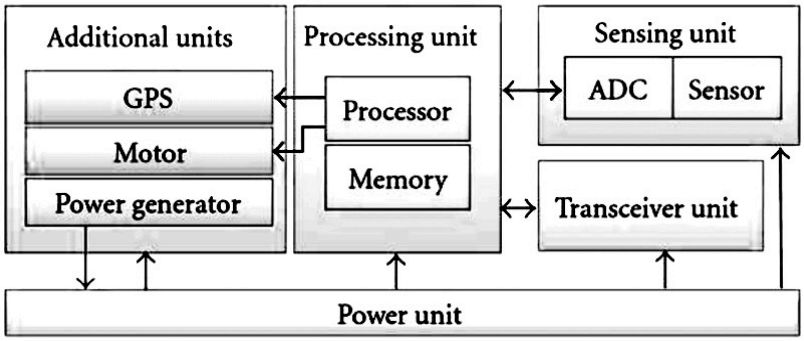
I. INTRODUCTION

The precedent few years has witnessed bigger importance in the prospective exercise of Wireless Sensor Networks (WSNs) in an extensive assortment of applications and it has developed into a burning line of investigation area. Wireless communication technology, Wireless Sensor Networks (WSNs) are appropriately increasingly striking for abundant application areas, such as military investigation, disaster management, security surveillance, habitat monitoring, medical and health, industrial automation, etc. [1]. A WSNs normally consists of a huge amount of low-priced, restricted energy, and multifunctional sensor nodes that correspond over small distances via wireless standard. These nodes by and large work together to carry out a frequent task that involve tracking, monitoring and controlling potential applications. Current development in WSNs is also paying attention on a number of Quality of Service (QoS) parameter such as energy, scalability, reliability, accuracy, adaptability, fault tolerance, and security. Routing in WSN is measured as one of the most significant challenges that exceedingly affect these parameters. This is due to the fact that quite a few network constraints may be present, these constrain curtail from the nature of the purpose, network architecture, and route establishment [2]. The WSNs formation consists of sensor nodes (SNs) and a sink node, usually called a base station (BS). Sensor nodes are positioned in the sensing field and Base Station is usually positioned further away to accumulate and scrutinize the sensing data. Usually, sensor nodes could send data to Base Station directly or indirectly via other intermediate SN(s). Since SNs usually function by means of restricted energy sources such as batteries, it is undesirable to substitute or recharge SNs due to high maintenance cost. In The case, Relay Stations (RSs) serve up a vital role to collect and forward data from SNs to BS such that the energy- restricted SNs can function for a preferred phase of the network existence. This allows arbitrary operation in unapproachable terrains or disaster relief operations [3].

Figure 1, illustrates the essential components of a sensor node, clearly a sensing unit, a processing unit, a transceiver unit and a power unit. The sensor node works as follows:

- Firstly, it senses the bodily surroundings being measured and converts the captured statistics into an electrical signal that feed to an Analog- to-Digital (A/D) converter with the aim of converting it into a suitable form to be used by the microprocessor.
- Secondly, the microprocessor converts the signal into digital facts depending on how it is planned.
- Finally, it sends the information to the system by using a transceiver.

The information is shared among additional sensor nodes and used as input for a distributed managing system [2].



GPS: global positioning system
ADC: analog to digital converter

Figure 1: Generic Architecture of a WSN node [2]

One of the challenges of WSNs Routing Protocols is to accomplish maximal strength alongside path malfunction with minimum energy utilization. Many Routing Protocols have been designed and developed for WSNs because the routing in WSNs has many challenges which are not there in other form of networks. WSNs are enormously adaptable and can be deployed to carry a wide assortment of applications in many diverse situations, whether they are composed of motionless or mobile sensor nodes. The design in which the sensors are deployed depends on the environment of the relevance [4].

II. WSNs DESIGN

The WSNs design based on the architecture has various design strategies to fulfill the relevant purpose is elaborated below**.**

II.1 Design Strategies in WSNs: The process of discovering a suitable path among the source and the targets is called as routing. In a WSNs the form and utility of every network has a very ample distinction so the routing difficulty becomes relatively a challenge for the network design. Routing has to be in such a mode that the path pursued for data message should be the smallest amount with the slightest indulgence of energy. Routing Protocols formulate that the energy supplies are appropriately fulfilled. The most important purpose of any Routing Protocols is to make sure that the network remains associated for a large amount of the instance and the network life span is comprehensive to a significant degree [5]. Some crucial aspects of Design Strategies are:

- A very significant constraint is the position where the nodes are deployed. The constraint to a great level is reliant on the purpose.
- Smart operation of the force is the major blueprint limitation in every network. Energy optimization should not negotiate the correctness of the network.
- The nodes that are frequently deployed in any Wireless Sensor Networks are analogous nodes and varied nodes.
- An additional central design constraint is the area which is to be enclosed by a meticulous Wireless Sensor Network.
- The WSNs should be able to cope with a very large number of nodes.
- In the operations which engage authentic time data usage Quality of Service hold significance and thus can be measured a design concern [5].

The WSNs Design Strategies leads to various Designing Issues that need to be considered while designing a layout of WSNs.

II.2 Design Issues in WSNs: The subsequent significant design issues of the sensor network to be focused while developing a WSNs Design are as follows:

- Fault Tolerance: Fault tolerance is the capability to continue sensor network functionalities devoid of any interruption owing to sensor node failure.
- Scalability: The amount of sensor nodes utilized in the originating area possibly will be in the range of hundreds, thousands or additional to transmitting pattern must be adaptable enough to counter to procedures.
- Creation Costs: From the time when the sensor networks inhere of a large amount of sensor nodes, the rate of a particular node is very significant to validate the generally charge of the networks and consequently the rate of each sensor node has to be reserved low down.
- Working Environment: The sensor network can be position up in the core of huge equipment, at the floor of a deep-sea, in a geographically or artificial unhygienic turf, etc.
- Power Consumption: Sensor nodes are operational with some degree of power inception (<0.5 Ah 1.2V). Node duration is powerfully reliant on its battery life span..
- Data delivery models: It accomplish when the data composed by the node has to be forwarded. Appurtenant on the relevance of the sensor network, the data transmission model to the sink can be uninterrupted, Event- driven, Query-driven and Hybrid.
- Data Aggregation/Fusion: Since sensor nodes may produce considerable superfluous data, related packets from numerous nodes can be a quantity so that the amount of transposal would be condensed.

- Quality of Service (QoS): The quality of service defines the quality service necessary by the function, it could be the interval of life time, the data consistent, energy effectiveness, and position-awareness, collective processing. These factors will control the compilation of Routing Protocols for a meticulous function.
- Data Latency and Overhead: These are measured as the vital factors that control Routing Protocols plan.
- Node Deployment: Node deployment is function reliant and influences the work of the routing protocol. The operation is moreover deterministic or self-constructive [9].

  The organization or the classification of the Routing protocols fulfilling the designing strategies and overcoming all the key design issues is prime aspect of WSNs Design.

III. ROUTING PROTOCOLS TAXANOMY

In order to select the most suitable routing mechanism for a sensor application, it is required to classify all routing protocols according to a well-defined taxonomy as displayed in the Figure 2.

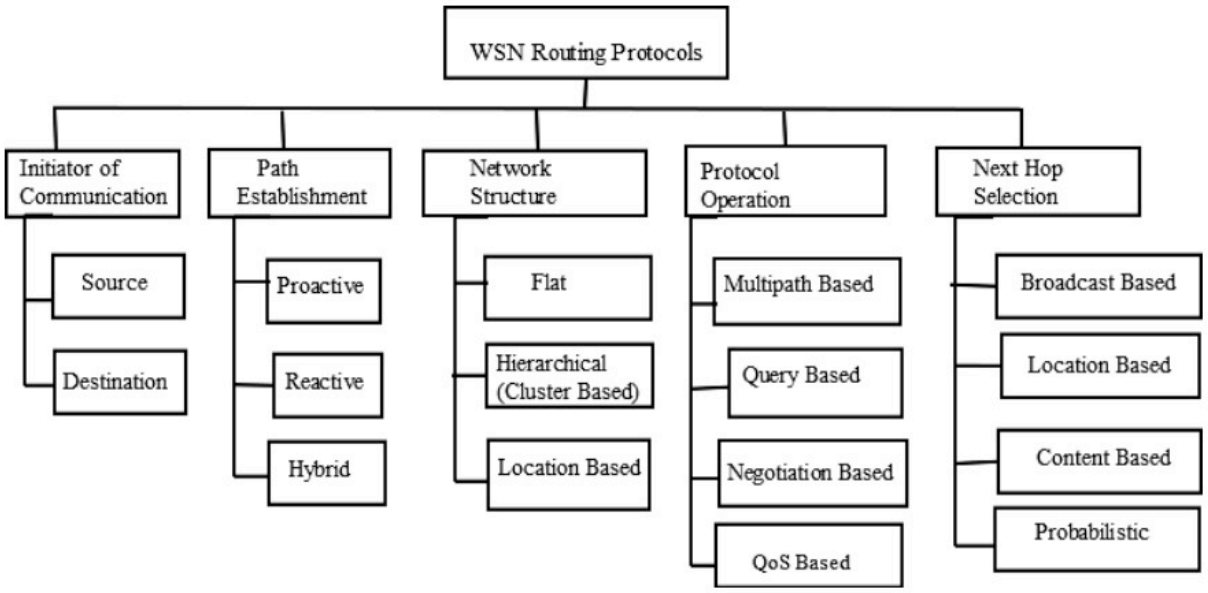


Figure 2 : Routing Protocols Taxanomy [6]

Focused on Routing Protocol Taxonomy the introspection can be performed to find the core Routing Protocols to be considered for any Research work.

IV. STRUCTURE AND OPERATION ORIENTED ROUTING PROTOCOLS

A range of Routing Protocols are considered to execute the deficiency of WSNs for effective data collection and dissemination of information. WSNS Routing Protocols can be partitioned into two broad groups, architecture (structure) based Routing Protocols and Operation /Property based Routing Protocols as shown below [11].

- **Structure Based**: It is network Structure oriented and comprises of Flat Based Routing, Hierarchical Routing and Location Based Routing as elaborated in the Table 1.

Table 1 : Structure based Routing Protocols [11]

Routing Protocol	Basic Principle	Advantages	Example
Flat-Based	Data-centric Routing Approach	Best suited for large amount of sensor nodes	SPIN,EAR,SAR,MCFA
Hierarchical Based	Cluster based Routing Approach	Energy efficient method, Increased network scalability and lifetime	TEEN,MECN,HPAR
Location Based	Nodes are located by means of GPS	Best Routing, Reduce energy consumption, optimize the whole network	GEAR,GEDIR,APS

- **Operation/Property Based:** It is protocol operation oriented and comprises of Negotiation Based Routing, Multi-path Based Routing, Query Based Routing and Coherent Based Routing as elaborated in Table 2.

Table 2: Operation/Property Based Routing Protocols

Routing Protocol	Basic Principle	Advantages	Example
Multipath Based	Multiple path selection	Decrease delay, Increase network performance	MMSPEED, SPIN
Query Based	Sending and receiving of queries for data	Self-adaptive, reduced average delay	COUGAR,DD,SPIN
Negotiation Based	Eliminate redundant data transmission	Efficient computation, scope of optimization	SPAN, SAR, DD
QoS Based	Balance approach for QoS	Better quality of service	SAR,SPEED,MMSPEED
Coherent	Minimum processing on raw data	Energy efficient routing	-

Other than these two categories of protocols there are many additional protocols that lead to necessity based research work.

V. PRIME ROUTING PROTOCOLS

There are several of Routing Protocols of WSNs based on the Taxonomy classification. The Routing Protocols are associated based on performance metrics. The performance metrics are Effectual Energy deployment and data accumulation, extraordinary scalability, fewer calculation overhead, good data distribution model, aggregate lifespan of a network, and well-organized optimum route with node flexibility. Some commonly Routing Protocols that can be considered in WSNs are as follows :

- Directed Diffusion (DD)
- Sensor Protocols for Information via Negotiation (SPIN)
- Sequential Assignment Routing (SAR)
- Rumor Routing (RR)
- Active Query forwarding in Sensor networks.(ACQUIRE)
- Constrained Anisotropic Diffusion Routing (CADR)
- COUGAR
- Gradient Based Routing (GBR)
- Low Energy Adaptive Clustering Hierarchy (LEACH)
- The Power-Efficient Gathering in Sensor Information Systems (PEGASIS)
- Self-Organizing Protocol (SOP)
- Threshold sensitive Energy Efficient Sensor Network (TEEN)
- Virtual Grid Architecture Routing (VGA)
- Hybrid Energy Efficient Distributed Clustering Protocol (HEED)
- Geographical and Energy Aware Routing (GEAR)
- Geographic Adaptive Fidelity (GAF) [8].

Table 3: Shows the comparison between the above Routing Protocols based on the performance metrics as Query Based, Usage Power, Scalability, Network Lifetime, Optimal Route, Data Overhead, QOS, Data Aggregation and Delivery Model. [8]

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Name of the Protocol	Category	Query Based	Usage Power	Scalability	Network Lifetime	Optimal Route	Data Overheads	QoS	Data Aggregation	Delivery Model
DD	Data Centric	Yes	Limited	Limited	Long	Yes	Low	Low	Yes	Demand Driven
SPIN	Data Centric	Yes	Limited	Good	Good	No	Yes	Low	Yes	Event driven
SAR	Data Centric	Yes	High	Limited	Good	Yes	High	Yes	Yes	Continuously
RR	Flat	Yes	Low	Good	Good	Yes	Low	No	Yes	Demand driven
ACQUIRE	Flat	Yes	Low	Limited	Good	No	Low	No	Yes	Complex query
CADR	Flat	Yes	Limited	Yes	Moderate	No	Low	No		Continuously
COUGAR	Flat	Yes	Limited	Limited	Limited	No	High	No	Yes	Query driven

GBR	Flat	Yes	Low	Limited	Good	No	Low	No	Yes	Hybrid
LEACH	Hierarchical	No	High	Good	Very Good	No	Low	High	No	Cluster Head
PEGASIS	Hierarchical	No	High	Good	Very Good	Yes	Moderate	Low	No	Chain Based
SOP	Hierarchical	No	Low	Good	Limited	No	High	No	No	Continuously
TEEN	Hierarchical	No	High	Good	Limited	No	Yes	High	No	Active Threshold
VGA	Hierarchical	No	Low	Good	Limited	No	High	No	Yes	Good
HEED	Hierarchical	No	Limited	Good	Good	No	Low	Moderate	Yes	Weight Based
GEAR	Location Based	No	Limited	Limited	Long	No	Moderate	No	No	Demand driven
GAF	Location Based	No	Limited	Good	Good	No	Moderate	Moderate	No	Virtual Grid

The understanding from the above comparison can lead to reflection of many challenges that can be considered as focused research issues in WSNs.

VI. WSNs RESEARCH ISSUES

While designing routing algorithms, WSNs researchers face many challenges due to limited resources of these networks. Some Routing challenges are listed below which are focused while designing WSNs [10].

- Node Deployment: Nodes can be deployed in manual (predefined) order or in random manner depending upon the application. When nodes are manually deployed, data are sent through predetermined routing paths.
- Energy Consumption: There can be directed or multi-hop routing depending upon the distance between source and sink. Directed routing consumes less energy if the distance between source and sink be less. However, when sink is far away from sensing nodes then multi-hop routing performs better because it balances load and network resources. Routing Protocols should effectively manage energy to enhance network lifetime.
- Scalability: Normally sensor nodes are deployed in huge quantity for monitoring an area. Therefore, routing schemes should respond to huge number of events sensed through sensors in the environment. If the event does not occur for specific time, then sensors should go to sleep mode to minimize energy usage.
- Network Dynamics: In case when nodes are moving, routing data from/to such mobile nodes are challenging task because there arise important issues like stability of routing data, energy and bandwidth consumption etc.
- Time Delay: also called as latency means how much time a data packet requires reaching from sensing node to BS or vice versa.
- Data Collection and Aggregation: Data collection methods are very important while designing routing algorithms to avoid the collection and aggregation of same data from multiple nodes to optimize energy consumption.
- Connectivity while designing routing algorithms high connectivity is required to avoid isolation in the Wireless Sensor Networks.
- Security: Researchers intend to provide secure aggregation while developing Routing Protocols to make them resilient to intruder devices.
- Transmission media Sensor nodes communicate over wireless medium. So wireless channel may face problems like higher rate of error and fading which can disturb the operation of network [10].

VII. CONCLUSION

Routing protocols in WSNs is still an area of research as sensor nodes are finding newer and newer applications with time but however rapidly growing set of research results. In the paper the WSNs core domain, comprehensive Design strategies and issues are highlighted. The Taxonomy, Classification of Routing Protocols based on Network Structure and Protocol Operation are also presented. A prime Routing protocols detailed comparison based on the performance metrics as Query Based, Usage Power, Scalability, Network Lifetime, Optimal Route, Data Overhead, QOS, Data Aggregation and Delivery Model is discussed. The reflected Research key areas are underlined in form of challenges and that focus on the further and future Research directions of the researcher endeavoring research in WSNs and its allied domain.

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