A Comparative Study on Network structure based Routing Protocol and its Variants in Wireless Sensor Networks: A Survey

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ABSTRACT
Nowadays Wireless sensor network is one of the fastest growing and emerging area in the scientific and engineering world .Its basic objective is to sense the crucial data and send it Base station so that it take corrective actions further. Sensor nodes interact with each other via various Routing protocols. This paper surveys various network structure and network operation based routing protocols, and explains the current developments of each protocol pursued .The three basic categories of routing techniques explored here are Data centric, hierarchical and location based protocol. Afterward, various QOS protocols are also surveyed with their recent research work. Further, in this paper, ongoing research and future directions in routing are discussed.

Keywords
WSN, LEACH, SPEED, PEGASIS, GBR, SPIN.

1. INTRODUCTION
Recent advancements in the field of computing, sensing and communications have attracted Researchers from various quarters for making huge investments in the field of WSN. However, WSN are still in research period and deployed in various applications like monitoring of environment, crop , wildlife, air pollution, urban traffic, volcanic eruption, heritage buildings and detections of landslides, tsunami , emplaced an IED, Healthcare [2].WSN is self organized group of multiple nodes (motes) that can sense the surrounding environmental condition such as humidity, illumination, temperature. Each node senses the data and transmits it to BS for performing specific application [1].Maximum battery energy of motes is consumed in data transmission and reception. Thus, it is essential for routing protocols to prolong sensor node‘s lifetime by utilizing energy properly, route data via paths that can evade low energy sensor nodes and reduces transmission power in order to maximize WSN’s lifetime. This paper provides the various routing protocols which gives possible solutions to the problems.

The rest of the paper is structured as follows. Section 1 exhibits the various routing techniques in WSN. A classification and comprehensive survey of routing protocols based on network structure and network operation and its descendents is presented in Section 2. Here we summarize past and current developments in each categorized protocol. Section 3 highlights the ongoing research and future directions in routing. We conclude with final remarks in Section 4.

2. DIFFERENT ROUTING TECHNIQUES
There are basic two routing techniques that are Network structure and Network operations [1] as shown in Fig 1. Further, they are divided into three categories as data centric, hierarchical and location based on the basis of the structure of the network. However, on the basis of operations of network, QoS based protocols and their current developments are discussed.

- Data centric Routing-Data centric routing is query based where data are requested through queries. It depends on the naming scheme for the data which eliminates redundant transmissions. Attribute based naming is used for specifying characteristics of data. Here, Sensor node chooses the desired information and then sends it to the base station only and thus reducing the number of transmissions. For example: SPIN was the first data centric protocol, TEEN, et.al.
- Hierarchical Routing-They are based on clusters. It is used to perform energy efficient routing, where higher energy nodes i.e. cluster head nodes (CH) can be used to process and send the information; low energy nodes i.e. non cluster nodes (non-CH) are used to perform the sensing in the area of interest and send to its CH. It contributes to the system’s lifetime, scalability and energy consumption and conserves network bandwidth. For examples: LEACH, PEGASIS, TEEN.
- Location based Routing-Location based routing protocols need some location information of the sensor nodes to relay data to the desired areas before communication. It can be obtained from GPS (Global Positioning System) signals, received radio signal strength etc. e.g. GAF.

2.1 Quality (QOS) based Routing Protocol-
In QOS-based routing Protocols, the network should have minimum delay, less control overhead, high throughput and efficient resource allocation. These protocols find an optimal path that meets certain end to end delay during that connection. It requires each node to maintain information about its neighbors and uses geographic forwarding to paths.SAR was the first routing protocol that introduces the concept of QOS in the routing decisions.

2.2 Data aggregation (D A)
It is a collection of data from multiple sensor nodes, which computes the desired information about the sensed environment and then send this combined information to the

Base Station. Nowadays the researcher's main focus is moved towards energy conservation. Its basic objectives are to improve network lifetime by decreasing the energy consumption and bandwidth of sensor nodes, whereas by increasing network lifetime, value of fault tolerance, data accuracy and security may degrades. So therefore, the design of an efficient data aggregation protocol is a very difficult task because the designer must take care of all metrics of WSN i.e. energy efficiency, fault tolerance, data accuracy and security.

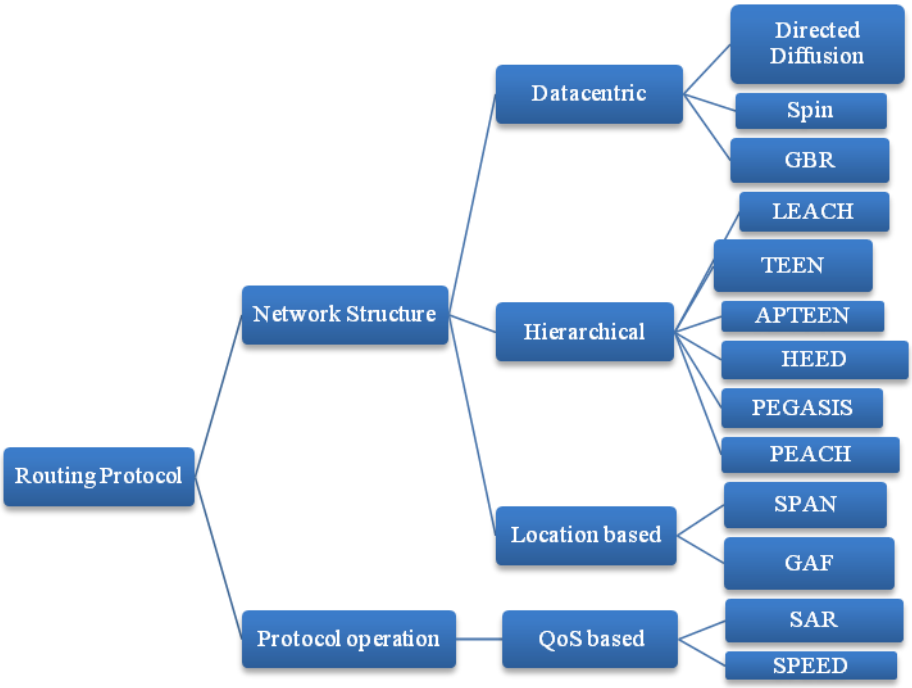

Fig 1: Classification of Routing Protocol

3. CLASSIFICATION OF ROUTING PROTOCOLS BASED ON ROUTING TECHNIQUE

Routing protocol & Author & Year & Routing technique	**Key features & Recent developments**
Direct Diffusion Intanagonwiwat, et al ,2000 Data-centric Routing	• Here, all communication is for named data. The basic idea aims at diffusion of data through sensor nodes by taking a naming scheme for the data into account. Its key features are sending interests, data dissemination and constructing gradients. Its big advantage is caching [3]. • FTSDD (Fault Tolerant and Storage Efficient Directed Diffusion), 2010-Using this updated protocol, flooding of interest, creating hop count and sending exploration and data are more reliable in the networks [4]. • DDBCI (Direct Diffusion based on clustering and inquiry), 2010-The CH nodes can avoid diffusing the interest messages into the cluster blindly. It reduces the redundant information spread and saves the energy of CH nodes and cluster member nodes [4]. • Improving DD to reduce average energy, 2011- Here, Authors tried to improve the network lifetime by reducing energy consumption [4].
LEACH: Low Energy Adaptive Clustering Hierarchy Heinzelman,2000 Hierarchical Routing	• Cluster based model (both centralized &distributed clustering) which also considers the Residual energy. • Two phased protocol: Setup Phase (Cluster Establishment) and steady phase (An actual data transfer takes place) [5]. • Authors modified LEACH and generates various descendents which gives better performance such as A-LEACH,S-LEACH,M-LEACH,LEACH-C, Multi-hop LEACH(Multihop LEACH), LEACH-F,LEACH-B, LEACH-E,TL-LEACH, Solar-aware LEACH (

	sLEACH), I-LEACH,V-LEACH, Cell-LEACH and LEACH-SC. They studied the protocols in terms of the energy efficiency and throughput enhancement, which shows that sLEACH is providing maximum Quality of Service and Energy efficiency. sLEACH boosts the performance by using the energy harvesting techniques [5][6]. • Q-LEACH (Quadrature LEACH), 2013- It gives better coverage of the whole network by dividing it into quadrants which gives optimized network life time used in homogeneous WSN [7]. • MODLEACH, 2013-Here, Authors used efficient CH replacement scheme and dual transmitting power levels to minimize energy consumption and maximize network lifetime. They also introduced the concept of Hard and Soft threshold as in TEEN [8].
TEEN: Threshold sensitive Energy Efficient sensor Network A.Manjeshwar & D.P Agrawal, 2001 Hierarchical Routing	• Similar as LEACH but uses two types of threshold, i.e. soft threshold or hard threshold .If users don't get threshold, then they don't get any data and gives better performance. • It is suitable for time-critical applications. Real time data reaches the user almost instantaneously. • The soft threshold can be altered according to the target application and the criticality of the sensed attribute. Its smaller value gives a more accurate picture of the network, which results in more energy utilization [9]. reach
SPIN: Sensor Protocols for information via Negotiation J.Kulik et.al,2002 Data centric Routing	• Here, Authors used negotiation and resource adaptive algorithm to overcome the weaknesses of flooding. It reduces data redundancy [11]. • Three Stage Protocol and here, three types of messages ADV, REQ and DATA are used by sensor nodes for communication [11]. • It contains two building blocks: secure network encryption protocol (SNEP) and a TESLA protocol for security. SNEP gives data freshness, two-party data authentication and data confidentiality for node to base station communication. µTESLA offers authenticated broadcast [10]. • There are four different SPIN protocols, namely SPIN-PP for point to point transmission, SPIN-EC with an energy conservation heuristic added to it, SPIN-BC, which is used for broadcast transmission media and SPIN-RL which is a reliable version of SPIN-BC [12]. • M-SPIN (Modified SPIN)-It consists of three phases: Distance discovery phase, Negotiation phase & Data Transmission phase. It uses hop count values of motes. Number of messages needed for transmission is less which helps in energy savings as compared to SPIN [13].
PEGASIS: Power Efficient Gathering in Sensor Information System Lindsey and Raghavendra ,2002 Hierarchical Routing	• It is an improvement over LEACH protocol. The basic idea is that sensor nodes communicate with their closest neighbors only then further with the BS by taking their turns [14]. • Here, adjustment of dynamic topology is needed. It is able to prolong the network's lifetime, twice as compared to the LEACH protocol [14]. • Hierarchical PEGASIS -It reduces packet delay and resolves data gathering problem by taking energy X delay metrics into account [11]. • Energy Efficient PEGASIS Based (EEPB) - Here, the data chain of sensor nodes is formed using a greedy approach which caused very long distance between sensor nodes. Thus, energy utilization is very high at each node and they die very soon [15]. • Improved Energy Efficient PEGASIS Based (IEEPB)-It resolves the problem faced by EEPB. It takes very complicated and tentative threshold value during chain building which results in the formation of long chain. Hence it is very energy efficient and enhances the lifetime of the network [15]. • Modified Pegasis in WSN to increase Network Lifetime- Here, the authors modified the decision parameter, i.e. response which checks the response of nearby node before transmitting the data which leads the proliferation of live nodes so that more nodes will remain exist and hence increases the network lifetime [16].
HEED: Hybrid Energy Efficient Distributed O.Younis, and S.Fahmy, 2004,	• Distributed clustering used. The clustering process is divided into a number of rounds, and in each round, CH is selected on the basis of residual energy of nodes that are not covered by any cluster head which results in increasing its probability of becoming a cluster head almost twice.

Hierarchical Routing	• H-HEED (Heterogeneous Hybrid Energy Efficient Distributed), 2010-Different levels of heterogeneity are used which increases the energy, throughput and number of packets in the network and decreases the delay [17]. • RHEED- It modified the clustering phases (setup and steady phase) so that it gives maximum energy efficiency. Idea: To rotate the role of the CH between nodes in the same group until the residual energy of at least one cluster head fall below a particular threshold [18].
PEACH: Power Efficient and Adaptive Clustering Hierarchy Sangho Yi,2007 Hierarchical Routing	• Here, the cluster is formed by using overhearing features. It is applicable for both location unaware & aware WSN. It minimizes energy consumption & enhances the lifetime of the network [19].
APTEEN: Adaptive Periodic Threshold–sensitive Energy Efficient sensor Network A.Manjeshwar and D.P.Agrawal,2009 Hierarchical Routing	• The architecture is same as in TEEN. A Hybrid clustering based protocol that alters the periodicity used in TEEN. • Here, Cluster head broadcasts Attributes, Thresholds (Hard and Soft), Count Time, and Schedule [11]. • APTEEN supports three different query types, namely a) historical query, to analyze past data values b) one-time query, for taking a network snapshot view c) endless queries, for examining an event for a particular time period [20]. • Energy dissipation will be lower and a large number of sensors alive in APTEEN. It aims at both capturing periodic data collections and reacting to real time events [20].
SPAN Benjie Chen,Kyle Jamieson, Hari Balakrishnan, and RobertMorris,2002 Location based Routing	• Randomized, distributed algorithm where nodes take decisions locally regarding either to sleep, or to join a forwarding backbone as a coordinator. It reduces power consumption in multi-hop ad hoc wireless networks [21]. • It is a topology management protocol which divides the sensor nodes into equivalent classes by using their geographic properties. • Integration of SPAN with IEEE 802.11 improves communication latency, system lifetime and capacity [21]. • E-SPAN- Distributed Protocol and facilitates the sources within an event region to perform data aggregation. The Mean lifetime of sensor nodes is higher as compared to the Directed Diffusion. It also maintains a low average packet transfer delay and a high packet delivery ratio [22].
SPEED, Tian He, John A Stankovic et. al 2003 QoS Routing	• Stateless and Localized Protocol, basically meant for real time applications. It maintains the desired level of speed across wireless sensor network. It provides soft real-time end to end guarantees and avoids Network Traffic. It maintains neighbor's information of nodes and finds the path using forwarding [23]. • MMSPEED (Multipath Multi SPEED) - It extends the SPEED protocol [23] by introducing multiple speed levels to guarantee timeliness packet delivery. Cross-layer design approach between MAC layer and network layer. It provides probabilistic QoS differentiation in terms of timeliness and reliability domains. It allows sending packets by considering end delay parameter which is required by the applications in order to avoid congestion and reduce the packet loss rate [24].
GAF(Geographical Adaptive Fidelity), Y. Xu, J. Heidemann,D.Estrin 2001 Location based Routing	• It is a topology management protocol like SPAN originally developed for mobile ad hoc networks (MANETs) but realized to be useful for sensor networks. Second order radio model (Type I) and virtual grids are used. It associates nodes to the grids according to their location information [25]. • Idea: node serves as a leader, which conveys data to other nodes in each grid area [25]. • HGAF (Hierarchical GAF) expanded the grid size of GAF. It synchronizes the relative position of active nodes in each virtual grid using the idea of sub-grid and addressed the problem of routing hole to some extent [26]. • GAF-Co (GAF with COnnectivity-awareness)-It employs hierarchical hexagonal cells to avoid local minimums in WSNs. Basic Idea: Scheduling redundant nodes into energy-saving mode and maintaining the network connectivity. It also addresses the problem of routing hole and boosts the performance of network as compared to GAF and HGAF [26].

SAR(Sequential Assignment Routing),K.Sohrabi,J.Pottie,2000 QoS based routing	• First protocol, which considers QoS with energy efficiency. Routing is done on the basis of QoS, energy resources and priority level of each packet [27]. • Table driven multipath protocol that minimizes the average weighted QoS Metric. It gives the affirmation of fault-tolerance and easy recovery [27].
GBR (Gradient based Routing), C. Schurgers and M.B. Srivastava, 2001. Data centric Routing	• Route a query using natural information gradient in WSN. It considers the minimum hop count and remaining energy of each node while relaying data from source node to the sink. It prolongs the network lifetime by optimizing energy consumption [28]. • Establishment of optimal routes independently with our protocol. Back-off waiting scheme is implemented to tackle with the explosive message flooding problem in routing establishment stage [28]. • EEOGRP (energy-efficient optimal gradient-based routing protocol) 2014- Here, the author used look ahead algorithm within an elliptical region in addition to gradient based routing [29]. • A new gradient-based routing protocol for load-balancing (GLOBAL, 2014) with a new gradient model to maximize the lifetime of the network. Here, least-loaded path which also evades the most overloaded sensor node is selected for forwarding [30].

4. ONGOING RESEARCH AND FUTURE DIRECTIONS IN ROUTING

In the future, authors can focus more on energy efficiency because we have inadequate resources of energy. Energy efficiency is considered to be the true bottleneck in current wireless sensor networks. The European research project EYES is developed for designing the new schemes for the network architecture, routing protocols and algorithms at various layers of WSN. It will be self organized in a hierarchical manner by routing protocols, which makes data communication possible between the sensor nodes that are not within the range of one another [31].

Energy harvesting establishes a major change to the basic criteria of designing routing protocols in WSN. Nowadays, key objective of WSN has been to enhance the performance of the network by harnessing already existing energy in spites of energy efficiency. In future authors will focus on developing such a cross layer routing protocol by considering the concept of harvesting the energy with energy efficiency. Multi-metric cross layer protocols are used to develop to conserve energy. Various technologies such as wind, mechanical and solar energy, have been developed to enable sensor nodes to harness energy from their surroundings [32].

The area of sensor network QoS largely remains an unexplored research area. Designing QoS based routing protocols to integrate WSN with other network like cellular, LANs and IP is still the biggest hurdle in WSN. Researchers may focus on this issue while designing energy aware QoS routing protocol.

In the future, wireless sensor networks will be used extensively in sensitive applications, where security of the network will be of prime significance. I expect the current work in security protocols will make the sensor network a more attractive option like in SPIN. Current routing protocols optimize for the limited capabilities of the nodes and the application specific nature of the networks, but do not take security into an account. Although security is not the major target of these protocols but it is important to evaluate the properties of security. Nowadays, researchers are highly geared towards data aggregation, which is the main aspect of WSN that complicates the design of secure routing protocol [33].

Another interesting issue for routing protocols is the consideration of node mobility. Many of the current routing protocols believe that the Base Stations and the Sensor nodes are stationary. However, there might be situations such as battle environments where the BS and possibly the sensors need to be mobile. In such cases, new routing protocols are required in order to handle the overhead of mobility and topology changes in such energy constrained environment.

Other possible future research for routing protocols includes Internet of things which integrates the wireless sensor networks with existing 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 through the internet so that further analysis can be done. Since the routing requirements of each environment are different, further research is needed for handling such types of situations [34].

5. CONCLUSION

Due to remarkable development of WSN, Routing plays an essential role. In this paper, we studied previous and recent work on various routing protocols based on the structure and operation of network. A brief study of various improved versions of protocols has been done. Few other protocols such as SAR, SPEED followed the QOS methodology and its descendents are also surveyed. We also included in the table, whether the protocol is utilizing data aggregation or not, since it is an important consideration for routing protocols in terms of energy saving and network congestion optimization. We highlighted their key features. Although many of these protocols look promising such as LEACH, PEGASIS, GBR et.al but still many challenges that need to be solved. This paper would be helpful to work and study about various routing protocols for future researches. Recent trends in various routing techniques might focus on different directions, but all have the common objective of enhancing network lifetime. It is concluded from given survey that there is need to explore a highly reliable, robust and energy efficient routing protocol in future. Here, we highlighted various challenges to the routing and pinpointed future research directions in this regard.

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