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A COMPARISON STUDY - BASED ON THE ROUTING CHARACTERISTICS OF HIERARCHICAL PROTOCOLS IN WIRELESS SENSOR NETWORKS

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Abstract
In this modern era, the many Wireless Sensor Network applications replace the human efforts in Environmental, Industrial & Machinery Monitoring and also in Defence Services. Since self-powered nodes are used in the WSNs application the success of the applications become high it has high life time. Extending the life of the WSNs applications is possible if the energy utilization done in the optimal way. Selection of the Routing algorithms is more important while implementing the applications. This Paper provide a state art review Hierarchical based Routing algorithms in Wireless Sensor Networks and the comparisons were made among the Classical Hierarchical based Routing with Bio Mimicked Hierarchical based routing in WSNs.

Keywords: Bio-Inspired, Wireless Sensor Networks (WSNs), Hierarchical Routing, Energy Efficiency.

Introduction
The routing protocol is a process to select suitable path for the data to travel from source to destination. The process encounters several difficulties while selecting the route, which depends upon, type of network, channel characteristics and the performance metrics. Basically the routing protocols are divided into two clauses based on the structure and the working nature of the network. In additional, the structure based protocols are sectioned into three subgroups as flat based routing, hierarchical based routing, and location-based routing. Another group is based on protocol operations, which are also stated to as property based protocols. Negation based routing, multi-path based routing, and query-based routing and coherent based routing are grouped into the property based routing. The classification of wireless sensor network routing protocols are mentioned in figure 1.

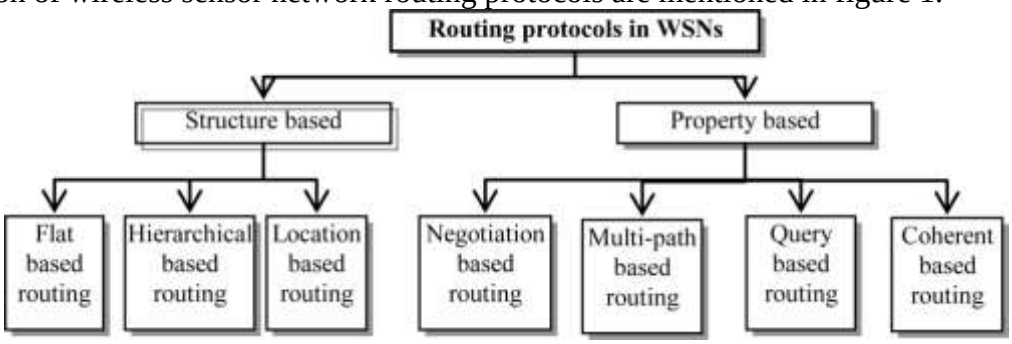

Figure.1: Classification of Wireless Sensor Network Routing Protocols

Hierarchical protocols
A hierarchical protocol is an approach to the balance between scalability and performance. A view of the architecture of the hierarchical network is as shown in figure 2. In hierarchical routing, energy consumption of sensor nodes is drastically minimized when the sensor nodes are involved in multi-hop communication in an area of the cluster and performing data aggregation and fusion so as to reduce the number of transmitted information to the sink. The clusters formation is based on the energy reserve of sensor nodes and its proximity to the cluster head [3].

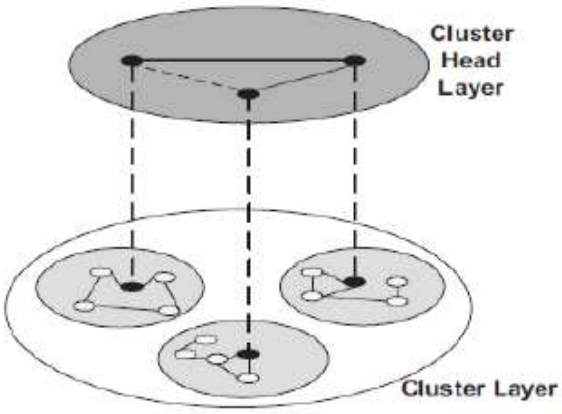

Figure 2. The architecture of the hierarchical network [1].

Normally in hierarchical routing, the sensed data broadcast from a lower clustered layer to upper region. The sensed data will be hopped from one node to another which covers larger distances, hence this method of moving the data more rapidly to the sink faster. Clustering provides inherent optimization capability at the cluster heads.

Literature Surgery

Low-energy adaptive clustering hierarchy:

Low-energy adaptive clustering hierarchy (LEACH) became the most popular and the first energy-efficient hierarchical algorithm proposed for power consumption reduction in sensor networks. The clustering task will be assigned on rotation to the participating nodes based on duration. Each cluster head communicates directly to the sink [3] [2]. The algorithm is also based on data aggregation or fusion techniques as the original data is combined and aggregated into the smaller size of data that carry only required information to all individual nodes. To balance the energy dissipation of nodes the cluster heads will be changed randomly over time. The protocol is completely distributed and requires no global knowledge of the network. As it uses the formation of cluster heads or dynamic clustering, it brings extra overheads, hence diminishing the gain in energy saving. It is also not friendly in a large network deployment.

Power-efficient gathering in sensor information systems:

Power-efficient gathering in sensor information systems (PEGASIS) is an improved version of Low-energy adaptive clustering hierarchy [5]. It avoids the formation of multiple clusters. Each node can transmit and receive data from a neighbor and only one node is selected from a chain at a time to communicate with the sink. Data is combined and moved from node to node, aggregated and sent to the sink. Unlike LEACH, it avoids the formation of a cluster and uses only a node in a chain to transmit to the sink rather than using multiple nodes. The protocol PEGASIS establishes an excessive delay for distant nodes on the chain and the single leader exhausts its energy as it involves regular communication. Lindsey et al. proposed an improved version of the PEGASIS, known as Hierarchical-PEGASIS. Its aim is to find a solution to the delay incurred during the transmission of packets to the sink, and as such proposed a solution to the data gathering problem by putting energy x delay metrics. It involves Code-division multiple access (CDMA) in its approach to deal with the problem of signal interference among the sensor nodes, and also allow only spatially separated nodes to transmit at the same time.

Hybrid energy-efficient distributed clustering:

Hybrid energy-efficient distributed clustering **(**HEED) is an extension of LEACH which uses node density and residual energy as a metric for cluster selection so as to balance the network energy [9]. The HEED execution process takes three phases as follows,

1. The initialization phase where cluster heads are selected based on their residual energy and intra-cluster communication cost

2. Repetition phase where the probability of selection of the cluster head is repeated due to some parameters if at the first stage it was not selected

3. Finalization phase where the selection of cluster head is finalized however the cluster selections consider some parameters, which may impose some drawback on the network, though it is suitable for prolonging network lifetime

Self-organizing protocol:

The Self-organizing protocol (SOP) involves basically the self-organization of the router nodes and creation of routing tables based on four phases.

Discovery phase - where the nodes in the neighborhood are discovered.

Organizing phase - where groups are formed and merged by forming a hierarchy of which nodes are addressed based on their position in the hierarchy.

Self-reorganizing phase - dealing with the situation when the partition of nodes fails, and group reorganization takes place.

Maintenance phase - where updating of routing tables and energy levels of nodes is made.

SOP adopts local Markov Loops algorithm which performs a random walk on spanning trees of a graph in dealing with fault tolerance and uses for broadcasting.

The algorithm is cost-effective in routing table maintenance, and consumes less energy in broadcasting messages than SPIN protocol, due to broadcast trees used in the algorithm. Due to the organization phase of the algorithm which is not on-demand, it introduces extra overhead.

Threshold sensitive energy efficient sensor network protocol:

Threshold sensitive energy efficient sensor network protocol (TEEN) is one of the types of a hierarchical protocol. The main aim of TEEN is to react to unexpected changes in the sensed attributes such as temperature [6]. The protocol combines the hierarchical technique in line with a data-centric approach. It then involves the formation of clusters along with cluster leaders which broadcast two thresholds to the nodes such as the hard and soft thresholds. Hard threshold has minimum values of an attribute for its sensor node to trigger the power on its transmitter to transmit to the cluster head. It is normally not suited in applications where continuous data is needed since it is threshold dependent.

Energy-aware routing for cluster-based sensor networks:

The Energy-aware routing for cluster-based sensor networks algorithm (EAR-CSN) was proposed based on three-tier architecture. In the EAR-CSN grouping of sensor nodes known as clusters, the cluster heads formation uses less energy constraint and tends to identify the location of other node and maintain the states of the sensors while setting up multi-hop routes for data collection [9]. It uses Time-division multiple access (TDMA) based MAC in communicating with the gateway or cluster heads. In the algorithm, sensor nodes in the cluster could be in any of the sensing only, relying only, sensing relaying or inactive states. A cost function is defined between any pairs of nodes in terms of delay optimization, energy consumption, throughput, and other performance parameters. The algorithm suffers in transmission range, and as the algorithm uses many cluster heads, it introduces more overheads and hence consumes much energy.

Sensor-driven and cost-aware ant routing:

Sensor-driven and cost-aware ant routing (SC)**,** the sensors are s assumed as ant shave sensors. In SC the sensors can smell where there is food at the beginning of the routing process so as to increase in sensing the best direction that the ant will go initially [10]. In addition to the sensing ability, each node stores the probability distribution and the estimates of the cost of destination from each of its neighbors. It suffers from misleading data when there is an obstacle which might cause errors in sensing. Assuming that the cost estimate is Q_n for neighbor n, the cost from the current node to the destination is 0 if it is the destination, otherwise,

$$\boldsymbol{C = min_{n\epsilon N}\ (C_n + Q_n)} \qquad (3)$$

where c_n is the local cost function The initial probability is calculated according to the expression:

$$\boldsymbol{P_n \leftarrow e^{(C-Qn)^{\beta}} \Big/ \in n \in N e^{(c-Qn)^{\beta}}} \qquad (4)$$

Self-organizing data gathering scheme:

Self-organizing data gathering scheme (SDG) protocol [4] aims to achieve scalability and reliability in sensor networks. In the protocol, a node uses another sink in case of sink failure. The

protocol queries the fact that with a single sink, a sensor network cannot tolerate energy depletion as once a node around the sink runs out of energy, the sink remains isolated and the sensor network becomes useless as packets can no longer be routed to the sink. In the protocol, in order to minimize the routing overhead, agents are only generated by sink nodes in the form of backward ants, which are broadcasted by sink nodes on a proactive basis. Sensor nodes communicate data and event information to their sink through the usual ant colony optimization techniques of stochastic forwarding.
Node clustering in the algorithm is inspired from eggs and larvae grouping behaviors observed in ant colonies. Ants repeatedly pick up and drop eggs according to their degree of similarity. Nodes at the borders of their cluster can dynamically change cluster membership according to a probabilistic mechanism that favors clusters with higher cluster pheromone. The protocol was evaluated in Network Simulator-2.34 with reliability metric. The algorithm consumes a significant amount of energy due to its proactive nature and hello packets exchange.

Multipath routing based on ant colony system (MACS):

Xiu-li et al. [8] proposed multipath routing based on ant colony system in wireless sensor networks which endure the ant with a new characteristic and searching method. The protocol tries to solve the problem of the basic ant colony system being trapped in the solution of global optimum, and also deal with the contingency problem as soon as possible. The protocol was simulated in Network Simulator-2.34 and found to perform better than Directed Diffusion and ant colony system in terms of average transmission delay.

Probabilistic, zonal and swarm-inspired system for wildfire detection:

Probabilistic, zonal and swarm-inspired system for wildfire detection (PZSWiD) aims at covering the speed of information propagation, the accuracy of the information being propagated and their liability of the network as a whole over a long period of time [7]. The protocol follows a data-centric approach whereby the system executes a swarm inspired routing and aggregation algorithm. The algorithm uses a probabilistic model for representing information in a data-centric sensor network. In PZSWiD, nodes perform two functions:

1. They respond to different queries generated by a sink node
2. They transport detected events

It works with both event and query-based applications. The sensor nodes can also generate periodic reports or emergency reports which depend on the urgency or criticality of sensed data and then transport to the sink in a proactive manner. The protocol is complex and the description of its parameters is rather vague. It assigns a probability to satisfy a query sent from sinks to each node in the network. The probability is assigned on the basis of, how closely the locally sensed data matches with the queried data and the amount of pheromone. The algorithm was simulated in NS-2.34 while analyzing its average energy dissipated and the average delay.

Findings:

Classical routing protocols and Bio-inspired routing protocols are compared based on the challenging characteristics such as energy efficiency, data aggregation, location awareness, routes selection, and query based. Table 1. show that the Hierarchical routing protocol that belongs to Bio-inspired are strong in energy utilization. Other classical protocols show that the not highly strong in energy utilization. Since Self-organizing data gathering scheme is proactive (SDG) protocol, which utilizes energy in an efficient manner with data aggregation and location awareness.

Probabilistic, Zonal and swarm-inspired system for wildfire detection protocol (PZSWiD) is reactive protocols uses the data aggregation and have very strong energy efficiency.

Routing Protocol	**Classification**	**Energy Efficiency**	**Data aggregation**	**Location Awareness**	**Route Selection**	**Query Based**
LEACH	Classical	Strong	Yes	No	Proactive	No
PEGASIS	Classical	Strong	Yes	No	Hybrid	No
HEED	Classical	Moderate	Yes	No	Hybrid	No
SOP	Classical	Weak	No	No	Reactive	No
TEEN	Classical	Strong	Yes	No	Reactive	No
EAR-CSN	Classical	Weak	Yes	Yes	Hybrid	No

SDG	Bio-Inspired	Highly Strong	Yes	No	Proactive	No
MACS	Bio-Inspired	Moderate	No	No	Proactive	No
PZSWiD	Bio-Inspired	Highly .Strong	Yes	No	Reactive	Yes

Table 1. Comparison of Hierarchical based routing protocols

Conclusion

This paper gives an analytical review on classical and bio-inspired hierarchical based routing protocols. This comparison extends novel idea of researchers in Designing of Enhanced Energy Efficient Routing Protocols with guaranteed bandwidth, reduce the delay, throughput and energy efficient path. At the same time, this comparison proved that adaptation of Bio inspired algorithms extends the optimality in routing protocols.

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