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Classical and Computational Intelligence Based Routing Protocols for Wireless Sensor Networks- A Review

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Abstract *-Wireless Sensor Networks (WSNs) are capturing the imagination and enthusiasm of both academia and industry with its unique range of applicability as wide as Habitant Monitoring to Precision Agriculture; Battle Field Monitoring to Environment Checkups besides well knows applications in Fire Detection, Healthcare and Sea Life Exploration. In this paper we review some of the most vital contributions of CI in much explored area of routing for WSNs. We also explored some research issues which are vital for further investigations in WSNs and will guide scholars to focus on these research gaps in future. In this review , We observed that CI based techniques proved better in handlings the aspects of energy efficiency or adaptability but need more input in terms of issues like scalability, fault tolerance and adaptability.*
Keywords- *Wireless Sensor Networks, Computational Intelligence, Routing***.**

I. Introduction

Wireless Sensor Networks (WSNs) consist of large number of sensor nodes which sense, process and transmit the required collected data for a desired physical environment, collaboratively. Sensor nodes communicate not only with each other but also with a *Base Station* (BS) or *Sink* using their wireless radios, allowing them to disseminate their sensor data to remote processing, visualization and analysis [1]. A successful Wireless Sensor Network design must have several unique features: (1) low power consumption; (2) low cost; (3) greater availability; (4) robust network topology type; (5) good fault-tolerance; (6) flexible scalability; (7) high security; (8) enough data throughput; (9) low message latency and (10) mobility. The key area to achieve the above mentioned features lies in efficient data routing between sensor nodes and base station. Many researchers are currently engaged in developing architectures, routing protocols and schemes that fulfill the requirements of these key features. The main aim is to find ways for energy-efficient route setup and reliable relaying of data from the sensor nodes to the base station so that the lifetime of the network is maximized. There is always a trade off between computation and communication in each node when it makes the route decision and data aggregation. As the size of a WSNs grows, so does the complexity of the data routing. Therefore a key area of WSNs research is in developing new routing algorithms to meet the strict low-power limitations [2].

II. Approaches for WSN's Routing Protocols

The challenge of efficient data routing can have two broad approaches: (a) Classical Routing Protocol Approach and (b) Computational Intelligence (CI) based Routing Protocol Approach. Both the approaches are fined tuned to make the routing of data packets efficient and reliable. Both the approaches cater to the need of WSN's challenging nature and behaviour and try to provide some flexible solution to much addressed problems of WSN's. We now discuss various protocols under each of these above mentioned approaches in detail.

*A. **Classical Routing Protocols for WSN's***

Some of the most popular classical routing protocols are discussed below, which have addressed some of the most challenging aspects of the WSN's routing.

1) *Directed Diffusion (DD):* Taxonomy- Data Centric
In Directed Diffusion (DD) [17] events are diffused through sensor nodes by using a naming scheme for it. Attribute value pairs for the event is adopted while querying the sensors in an on demand basis. It is a popular data aggregation paradigm for WSNs. It is a data-centric and application aware paradigm in the sense that all data generated by the sensor nodes is named by attribute-value pairs. Creation of query is achieved by defining an interest using a list of attribute value pairs such as name of objects, duration of the event, and geographical location etc.[3]. DD is specific to some applications of sensor networks due to its query-driven data delivery model, since those requiring continuous data delivery to the sink will not perform efficiently.

2) Sensor Protocol for Information via Negotiation (SPIN): Taxonomy- Data Centric
In SPIN [18], three messages are defined to aid in data dissemination: ADV message for advertisement of data, REQ message for data request, and DATA message that carry the actual information. In SPIN, data are named using meta-data. The protocol meta-data negotiation helps in elimination of overlapping, redundant information and resource blindness. The advertisement method of SPIN does not guarantee the delivery of data as nodes that are interested in the data may be far away from the source node, and nodes in between the source and the sink may not be interested. In that case, such data will not get to the base station.

3) *Geographic and Energy-Aware Routing (GEAR)* **:** Taxonomy- Location Based
In GEAR [19], each sensor node is equipped with a GPS sensor for location identification. The protocol utilizes energy aware heuristics which is based on geographic information for the selection of nodes to route data to the sink, and uses geographically recursive forwarding algorithm for data dissemination within the target area. The main idea is to restrict the number of interests in directed diffusion by only considering a certain region rather than sending the interests to the whole network. By doing this, GEAR can conserve more energy than directed diffusion and proves to be a energy efficient routing protocol but GPS device add extraordinary cost to sensor [3].

4) Low-Energy Adaptive Clustering Hierarchy (LEACH) **:** Taxonomy- Hierarchical Protocol
LEACH [20] became the most popular and the first energy-efficient hierarchical algorithm proposed for power consumption reduction in sensor networks. LEACH rotates the clustering task among the participating nodes based on duration. Each cluster head communicates directly to the sink. The algorithm is also based on data aggregation or fusion techniques as the original data is combined and aggregated into smaller size of data that carry only required information to all individual nodes. Cluster heads change randomly over time so as to balance the energy dissipation of nodes. The protocol is completely distributed and requires no global knowledge of the network. As it uses formation of cluster heads, or dynamic clustering, it brings extra overheads, hence diminishing the gain in energy saving.

5) Power-Efficient Gathering in Sensor Information Systems (PEGASIS): Taxonomy- Hierarchical Protocol
PEGASIS [21] is an improved version of LEACH. It avoids the formation of multiple clusters. Each node can transmit and receive data from a neighbour 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. However, the protocol introduces excessive delay for distant nodes on the chain. In addition, the single leader exhausts its energy as it involves regular transmission.

6) Energy-aware QoS Routing Protocol (EAQSR) : Taxonomy- QoS Based
Energy aware QoS routing [23] is a table driven multi-path routing protocol with embedded QoS in its routing decision. Its aim is to find an optimal path to the gateway in terms of energy consumption and error rate while meeting the end-to-end delay requirements. Both the paths that meet the requirements for real-time traffic, as well as well as maximizing the throughput for non-real time traffic were considered.

7) A Stateless Protocol for Real-Time Communication in Sensor Networks (SPEED): Taxonomy- QoS Based
SPEED [24] is a QoS routing protocol for sensor networks. The protocol involves three types of communication techniques: real-time unicast, real-time area-multicast and real-time area-anycast. It requires each node to maintain information about its neighbours and uses geographic forwarding in order to locate the paths. The protocol is aimed to be a stateless and localized algorithm with minimal control overhead. The protocol provides end-to-end soft real-time communication by maintaining a desired delivery speed across the sensor network through a novel combination of feedback control and nondeterministic geographic forwarding. SPEED is a highly efficient and scalable protocol for sensor networks where the resources of each node are scarce

B. ***Computational Intelligence (CI) based Routing Protocols for WSN's***

Routing in WSN's remain a challenge for researchers as various classical protocols lacks on energy efficiency , fault tolerance or on scalability. Researchers around the world have developed some robust protocols based on Computational Intelligence (CI), which provide optimal solutions to the above mentioned problems. Some of the CI based routing protocols are listed below:

1) *Pheromone Based Energy Aware Directed Diffusion (PEADD) :* Taxonomy- Data Centric

PEADD [7] is a variant of DD , based on ant colony optimization heuristic. The protocol is aimed at maximizing the lifetime of the sensor networks by involving nodes with higher energy in the information gathering process. In this algorithm ants increase the pheromone on a path
proportionally to the remaining energy levels of the nodes. Paths with larger residual energy are increased, while others are reduced i.e. the amount of pheromone decay with transmitting data because the pheromone is linked to the remaining energy. The pheromone level is updated based on the amount of transmitting data. The algorithm use the same route selection and updating as that of the general ant based routing as described above [3].

2)Comprehensive Routing Protocol (CRP) : Taxonomy- Data Centric
CRP [8] algorithm is an improved version of energy aware routing (EAR) and based on ant colony optimization, but in its routing decision, it uses probability of selection of which it considers the network lifetime and data packet arrival rate. The protocol argues that always using the path which is considered as the best and optimal path from the point of view might not be the best as it will lead to depletion of the path nodes energy and instead proposes the use of sub-optimal paths occasionally. The protocol has three phases: routing table setup, data communication, and route maintenance.

3)Sensor Driven and Cost-Aware Ant Routing (SC) : Taxonomy- Location Based
In SC [9], it is assumed that ants have sensors so that they 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. In addition to the sensing ability, each node stores the probability distribution and the estimates of the cost of destination from each of its neighbours. It suffers from misleading data when there is obstacle which might cause errors in sensing.

4)Ant Colony Clustering Algorithm (ACALEACH) : Taxonomy- Hierarchical Protocol
ACLEACH [11] is based on Ant Colony Clustering Algorithm, which is an ant colony based improved version of LEACH. The algorithm not only considers the node residual energy, but also the distance between the cluster heads was considered in selection of cluster heads. It applies the ACA into inter-cluster routing mechanism to reduce the energy consumption of cluster heads and finally prolong the lifetime of sensor networks. The protocol did not consider throughput and delay in its routing process, and hence may also be weak in energy efficiency due to overheads.

5)Ant Colony Based Multipath Routing Algorithm (ACMRA): Taxonomy- Hierarchical Protocol
ACMRA [12] discover disjoint multipath between the source nodes and sink node. In multipath routing, multiple paths between source and destination are established. The algorithm generates two types of ants: search ant (SANT) and reinforcement ant (RANT). SANT is used to collect information about paths and the intermediate nodes local information as they travel along the path. RANT is used to update the pheromone table along the reverse path, and bring information of path to source node, such as residual energy of node, path length and energy consumption of the current path. It is an on demand multipath protocol and adopts a two-phase routing process involving the constructing routing and data transmission phases. In the constructing routing phase, cluster head in the event region generates SANTs according to the number of neighbour nodes, and chooses the next node to move to according to probability of selection. While in the data transmission phase, the network lifetime relates to hop count, energy consumption and the minimum energy at a path [3].

6)Energy Efficient Ant Based Routing (EEABR) **:** Taxonomy- QoS Based
EEABR [13] is based on Ant Colony Optimization (ACO) metaheuristic. In this protocol, each node in the network launches a forward ant at a regular interval with the aim of finding a route to the destination (sink). In the protocol, each ant only carries the address of the last visited nodes which means intermediate nodes carries the records of received and forwarded ants in the tables. The table content of each node contains the previous node, forward node, ant identification, and timeout value. Each time a node receive a forward ant, it looks up its table to search for any possible loop. If no loop exists, the node saves into its table the information of the ant and restarts a timer and forwards it to the next hop. When the forward ant reaches its destination, it is converted to backward ant with the mission to update the pheromone trail of the path traversed by the forward ant.

7)A Bee-Inspired Power Aware Routing (Beesensor) : Taxonomy- QoS Based
Beesensor [16] is an algorithm based on the foraging principles of honey bees with an on-demand route discovery (AODV). The algorithm works with three type of agents; packers, scouts and foragers. Packers locate appropriate foragers for the data packets at the source node. Scouts are responsible for discovering the path to a new destination using the broadcasting principle. Foragers are the main workers of BeeSensor which follow a point-to-point mode of transmission and carry the data packets to a sink node. When a source node detects an

event and does not have a route to the sink node, it launches a forward scout and caches the event. A forward scout is propagated using the broadcasting principle to all neighbours of a node. Each forward scout has a unique id with the detected event in its payload. Intermediate nodes at a distance of two hops or less always broadcast the forward scout while rest of the nodes stochastically decide whether to broadcast it further or not. The forward scouts do not create a source header in which complete sequence of the traversed nodes up to the sink node is saved. Hence their size is fixed and is independent of the length of the followed path. The approach is based on the interactions of scouts and source routing in which small forwarding tables are built during the return of a scout.

III. Comparison OF Classical and CI Based Routing Protocols

Now we present a brief comparison of Classical routing protocols and CI based routing protocols based on various parameters like Energy Efficiency, Data Aggregation, Localization and Query Based Approach. (See Table I.). It has been observed that Data Centric, classical routing protocols are weak in energy efficiency and localization but exhibit data aggregation while CI based Data Centric protocols are very energy efficient in nature. The Location based Classical Protocols possess moderate energy efficiency but with localization while Location based CI protocols exhibit strong energy efficiency with no localization.

The Hierarchical based Classical as well as CI based Protocols are excellent in terms of energy efficiency and data aggregation but lacks in Localization. The QoS based Classical and CI based protocols do not offer data aggregation and localization but are good in terms of energy efficiency. It has been observed that the choice of the routing protocol will depend on the type of application, dynamics of the network, various environment parameters and data to be collected for desired application.

Table I. Comparison of Classical and CI Based Routing Protocol

Approach	Routing Protocol	Taxonomy	Energy Efficiency	Data Aggregation	Localization	Query Based
Classical Routing Protocols	*DD*	Data Centric	Weak	Yes	No	Yes
	SPIN	Data Centric	Weak	Yes	No	Yes
	GEAR	Location Based	Moderate	No	Yes	No
	LEACH	Hierarchical	Strong	Yes	No	No
	PEGASIS	Hierarchical	Strong	Yes	No	No
	HEED	Hierarchical	Strong	Yes	No	No
	EAQSR	QoS Based	Strong	No	No	Yes
	SPEED	QoS Based	Weak	No	No	Yes
Computational Intelligence (CI) based Routing Protocols	*PEADD*	Data Centric	Strong	Yes	No	Yes
	CRP	Data Centric	Very strong	No	No	No
	SC	Location Based	Strong	No	No	No
	EBAB	Hierarchical	Strong	Yes	No	No
	ACALEACH	Hierarchical	Very Strong	Yes	No	No
	ACMRA	Hierarchical	Moderate	No	No	No
	EEABR	QoS Based	Very Strong	No	No	No
	E-D ANTS	QoS Based	Strong	No	No	No
	AR and IAR	QoS Based	Strong	No	No	No
	Beesensor	QoS Based	Very Strong	No	No	No

IV. Conclusion

From the review of routing protocols it is clearly seen so far that, significant efforts have been made in addressing the techniques to design effective, and efficient routing protocols for WSNs. Classical as well as CI based approaches shows good potential but are application specific .The performance of the protocols is promising in terms of energy efficiency, in both the approaches. Further research would be needed to address issues like scalability, fault tolerance and security, so that WSN's can be applied to real time applications and scenarios.

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