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Analysis of routing mechanisms using QoS metrics in Data Aggregation for Wireless Sensor Network – A Survey

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Abstract - The main objective to use wireless sensor network (WSN) is to collect data from various nodes and send this data to sink for processing. This is typically the scenario in any real time application of WSN. The proposed paper discusses the issues in routing for data aggregation with respect to QOS metrics. The paper presents literary on various existing solutions for these issues highlighting the key features, pros and cons, compares the results and performance of protocols with respect to QoS metrics and pitches the research challenges to be solved.

Keywords- Wireless sensor network (WSN); routing protocols; QoS; data aggregation

1. Introduction

Wireless sensor network is an ad-hoc network where the nodes are dynamic. Due to this, design of an efficient routing algorithm is much needed. Another important factor to be considered is various QoS metrics while deploying any routing technique. These QoS metric should be designed to overcome the following challenges.

Resource constraints: Limitation on resources include energy, bandwidth, memory, processing power and transmission range

Dynamic traffic: Flow of traffic from large number of sensors to aggregator node may cause congestion.

Dealing with failures: Any node failures or link failures is a major challenge for QoS support.

Major routing challenges and design issues

Node deployment: As WSN is an ad-hoc network, node deployment can be random or organized depend on the application or context.

Energy consumption without losing accuracy: Energy consumption influences the overall working of WSN. Employing direct communication mechanism would lead to more energy consumption than multi-hop communication.

Data delivery model: This depends on the context of deploying WSN and its usage. It can be reporting an occurrence of an event or just sending data to source.

Fault tolerance: Node failure should not affect the network performance. The routing protocols and methods should form new link dynamically to keep the network up.

Network dynamics: Since the nodes in WSN are mobile, the route calculation is a challenge and frequent updates in the changing routes should be maintained.

Connectivity and Coverage: These two parameters are interlinked as some of the nodes may go out of the communication range or may experience low energy life.

The objective of this survey work being carried out is to discuss the routing challenges in data aggregation and its methods. The paper also highlights the various routing protocols and methods adopted in aggregation. This paper also classifies different mechanisms of routing based on QoS metrics and list out the open issues.

2. Existing routing methods and protocols in wsn

The routing method in WSN is classified into three categories:

Data centric routing: A mechanism whereby nodes can request and advertise data and disseminate that data to interested parties. Direct diffusion comes under this method where task of the network is known prior the deployment.

Cluster based routing: In this mechanism the imbalanced energy consumption among nodes is the key factor affecting the network lifetime. In order to balance the energy consumption among nodes, clustering algorithms for networks with uniform node distribution tend to construct uniformly distributed cluster heads, so that the clusters have the approximate number of members and coverage areas. Thus, the intra-cluster energy consumption of cluster heads is approximate and the energy consumption of cluster heads can be balanced.

Location based routing: Location awareness is an important factor in WSN. Data transmission can be more efficient if the locations of nodes are known by employing GPS technology. This location information is used to estimate the energy consumption. In this method, the geographical information is used for packet routing.

The above table 1 lists out the main features of each protocol and its operating network architecture.

The above table 2 lists out the methods adopted in various routing protocol for data aggregation highlighting the QoS metrics used in each method.

3. Open Research Issues

- In the presence of resource constraints, the network QoS may suffer from the unavailability of computing and/or communication resources. For instance, a number of nodes that want to transmit messages over the same WSN have to compete for the limited bandwidth that the network is able to provide. As a consequence, some data transmissions will possibly experience large delays, resulting in low level of QoS
- Identifying and specifying services crucial for exploiting SOA in WSNs for QoS provisioning
- The communication protocols for WSNs should be designed to perceive the service requirement of each type

of traffic so that it can be guaranteed a specific service level

- Cross-layer design has proved to be effective in optimizing the network performance and hence may be incorporated in the development of QoS-aware communication protocols for WSNs
- Designing a framework that can be resilient to the advent of faulty nodes using the principle of immunology and convergence
- Designing dynamic routing scheme independent of the increasing in nodes
- Mechanisms to be designed to deal with routing hole issue.

Table 1: Routing protocols for data aggregation

Protocol	Architecture	Goals	Features / requirements
LEACH	cluster	Network lifetime: number of nodes that are alive, latency	Randomized cluster head rotation, non-uniform energy drainage across different sensors
SPIN	Flat Network	Disseminates all information at each node to every node in network where all the nodes in network are potential base stations	Uses query based routing
GEAR	Location-based	Takes advantage of the infinite energy of BS and adopts improved Dijkstra's algorithm to find the best scheme.	Uses the global topology and energy information to find the best scheme for every node transmitting data to base station.
MMSPEED	protocol operation	Provide multiple network-wide speed options	Uses QoS based routing (timeliness and reliability)

Table 2: The significant works done:

Model	Approach	Metrics	Outcome	Research Gap
Data aggregation approaches based on the routing protocols	Location Information	latency, data accuracy	Easy to manage & parse in embedded.	Lacks of formalism, Algorithms and Structuring
QoS based routing protocol for periodic and event-based data reporting	data forwarding happens according to the priority level assigned to each packet	packet delivery delay, total number of dropped packets	report the same event to the same sink	Data accuracy and congestion at sink
Data-centric routing	communication network density	End-end routing	complexity of optimal data aggregation is reduced	Node failure

4. Related Work

P.Anbumani et. al. [1] discusses various data aggregation approaches based on the routing protocols and the algorithm and also the performance measures in data aggregation in wireless sensor network. The authors discuss the various types of nodes and the involvement of each node in the whole process of data aggregation. The authors also discuss various merits and demerits of data aggregation in WSN. In the paper the authors consider various parameters such as energy efficiency, latency, data accuracy as a performance measure of data aggregation.

Mirela Fonoage et. al. [2] proposes a QoS based routing protocol for wireless sensor network applications that support both periodic and event-based data reporting. The authors also propose a routing protocol that performs data forwarding according to the priority level assigned to each packet. Event based packets are assigned a higher priority level. To address the issue of congestion, the authors propose a mechanism to capture and aggregate messages that report the same event to the same sink. The performance evaluation is done using the QoS metrics packet delivery delay and total number of dropped packets

BhaskarKrishnamachari et. al. [3] discusses data-centric routing and its performance with traditional end-to end routing schemes. The authors also discuss about the impact of source destination placement and communication network density on the energy costs and delay associated with data aggregation. They also point out the complexity of optimal data aggregation. The authors proposed and modeled performance of data aggregation in resource-constrained distributed event-based system.

Ram kumar.R et. al. [4] proposes an efficient data aggregation scheme using context aware mechanism by incorporating a packet attribute aware data aggregation scheme with potential based dynamic routing protocol. The authors make use of natural numbers to identify attributes and embed these numbers in the packet header. Each packet is sent to the neighbour in response to the amount of the same natural numbers as that of itself, so that the packets with the same attribute can attract each other and accumulate near the sink. The authors implement ant colony mechanism to construct dynamic routes. The average number of transmission per received packet and aggregation ratio is the QoS metrics used for performance evaluation.

Jiao Zhang et. al. [5] proposes a novel data aggregation with dynamic routing where the packets with the same attribute are gathered together. The authors also propose potential-based dynamic routing scheme which employs the concept of potential in physics and pheromone in ant colony to achieve an efficient attribute aware data aggregation mechanism. The authors use QoS metrics number of packet transmissions and communication overhead to achieve efficiency.

Fengyuan Ren et. al. [6] discuss concept of packet attribute, which identifies data sampled by different kinds of sensors or applications, and propose an attribute-aware data aggregation (ADA) scheme consisting of a packet-driven timing algorithm which uses dynamic routing protocol using the concepts of potential in physics and ant colony mechanism. The purpose of this algorithm is to consolidate

the packets with similar attribute. The average number of transmission per received packet and aggregation ratio is the QoS metrics used for performance evaluation.

Elena Fasolo et. al. [7] discusses the challenges of data routing in in-network aggregation in wireless sensor networks and proposes the use of cross-layer design approach for optimizing the performance. The authors also talk about different aggregation methods and functions and their challenges.

Kumar Padmanabh et. al. [8] proposes an algorithm which uses both lossy and lossless techniques using the concept of context awareness to choose aggregation functions. This proposed algorithm also addresses buffer management which optimizes the QoS by minimizing the packet loss due to buffer over-flow. The authors also prioritize the packets based on the critical information which is sent first to sink.

Jamal N et. al. [9] discusses the challenges of data gathering and routing problem with in-network aggregation in WSNs and joint problem of optimal data routing. The authors propose Grid-based Routing and Aggregator Selection Scheme (GRASS) by which energy can be optimized without affecting the quality. The authors also proved that cluster-based algorithms with data aggregation and in-network processing can optimize energy consumption in WSN.

V. Akila et. al. [10] reviews the different data aggregation based routing protocols such as tree-based, cluster-based, chain-based and unstructured architecture for WSN and discusses the challenges in each method. In tree-based approach a spanning tree rooted at the sink is built. Then the sink generates queries and sends to this structure. In the next stage an in-network aggregation to form the complete tree. Cluster based approach consists of a hierarchical organization of the network. Nodes are divided and grouped to form clusters and cluster-heads are elected to perform data aggregation locally and send it to the sink. In chain based approach each sensor sends data only to its closest neighbour.

Preethi Y. R et. al. [11] proposes a Cluster Based Data Routing for In-Network Aggregation. The authors use the QoS metrics reduced number of messages for setting up a routing tree, maximized number of overlapping routes, high aggregation rate, and reliable data aggregation to justify that the proposed approach is efficient. The authors make use of a routing tree with the shortest path from source node to aggregator node which would maximize the data aggregation process.

Nilesh P et. al. [13] proposes an efficient data aggregation approach by using geographic location of the nodes. The routing path is chosen based on geographical distances between the nodes and sink to achieve better energy efficiency. The multipath routes are created from the source node using distance vector routing. The shortest routing path is chosen based on the geographical information and calculated as a Euclidian distance. The nodes which are closer to the sink node are selected as a cluster head in this approach. The performance evaluation for the proposed approach is done using QoS metrics communication cost and energy saved.

Kumaraswamy M et. al. [14] proposes a MAC layer protocol which improves network reliability and guaranteed packet delivery using collision avoidance mechanism. The authors employ some probability mechanism to calculate the optimal retransmission. The proposed protocol is mainly designed to maximize the delivery probability of the nodes and minimize the retransmission. The QoS metrics used for performance evaluation of this protocol are packet delivery probability and number of retransmission.

Bhaskar Bhuyan et. al. [15] surveys the various QoS aware routing techniques in WSNs. The authors also discuss the middleware approaches for QoS support in WSNs and also list some research challenges for providing QoS in WSNs. The authors highlight the various QoS metrics for WSN such as data accuracy, aggregation delay, coverage, fault tolerance and network lifetime. Some of the research challenges listed by the authors are limitation of resource, multiple copies of data in the aggregator node, different types of the sensor nodes, ad-hoc network topology, reliability, and untimed data arrival.

S. Jerusha et. al. [16] proposes a new cluster scheme for wireless sensor network by adding location information of each node to the K means clustering algorithm. The nodes form a cluster depending upon the highest residual energy and minimum distance from the base station. The location information of each sensor node is calculated with the help of Trilateration, a localization algorithm. The selection of Cluster head depend on the minimum distance between the cluster node's and the centroid. The performance evaluation for the proposed approach is done using QoS metric packet delivery ratio.

Marwa Sharawi et. al. [17] reviews soft computing based routing models for efficient network life time. Reinforcement learning algorithm maximizes the system performance by using simple reward feedback for the agent to learn its behaviour and could be used to maximize the power level and minimize the distributed system latency. Swarm Intelligence could be used to calculate the optimal shortest path between sender and receiver nodes based on energy aware methods to maximize the network lifetime

Faiza Nawaz et. al. [18] proposes a mechanism which integrates gradient based routing scheme and LEACH protocol to develop an effective strategy for routing and data aggregation. This proposed method uses clustering approach and node energy is measured while selecting the cluster head. The authors consider data load and network lifetime as the QoS metrics to prove that this method is more efficient than the existing ones. The authors also employ context awareness by implementing a cost aware node with respect to link to the sink.

Leandro A. Villas et. al. [19] propose a routing protocol called Dynamic and Scalable Tree (DST), to address the challenge of load balancing. The proposed protocol reduces the number of messages necessary to set up a routing tree, maximizes the number of overlapping routes, and selects routes with the highest aggregation rate. This routing protocol is independent of events. Further the authors compared with their proposed protocol with existing methods using the QoS metrics communication costs, overhead and aggregation rate.

G. Rekha et. al. [20] proposes a routing technique to reduce redundant data size and recovers the cluster head failure thus improves energy conservation in cluster nodes. In this method the aggregation is performed interior nodes reducing size and number of messages transferred to the sink and across the network. The cluster head is selected based on the energy level of the node. Failure node detection is done by timed acknowledgement. The authors use packet delay and packet delivery ratio as QoS metric for the performance evaluation of the proposed protocol.

5. Comparative Performance Analysis: Leach Vs Spin

The simulation of LEACH protocol and SPIN protocol is done using the same node setup with respected to QoS metrics delay and throughput. Below are the graphs and result analysis.

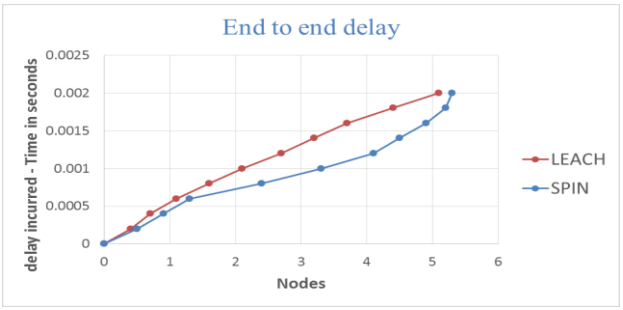

Fig. 1: Average end to end delay

A. Comparative analysis of end to end delay:

From the above fig 1, the average end to end delay for SPIN is much lesser than LEACH. By this an inference can be made that SPIN protocol has a better performance than LEACH for the same number of nodes.

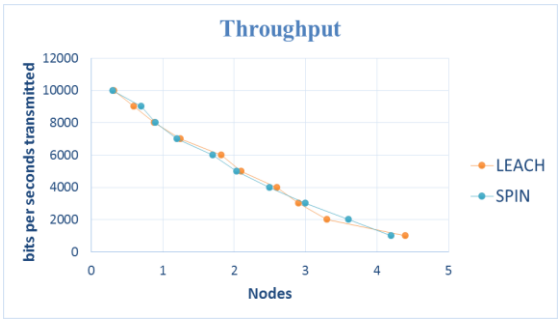

Fig 2: Throughput attainment

B. Comparative analysis of throughput:

From the above fig 2, an observation can be made that the throughput for LEACH and SPIN is almost similar with the same node setup and throughput reduces as the number of nodes increases.

6. Conclusions

Efficient routing in wireless sensor network is big challenge but its rapid growing area of research. This paper surveys the routing protocols of WSN and a comparative analysis is made based on QoS metrics. This paper also lists out some open research issues amongst which implementing a cross layer design with context aware computing is much required for many research applications and scenarios.

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