A Survey on Advanced Data Routing and Aggregation Techniques

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Abstract—Sensor nodes are generally battery powered and low voltage devices. The main challenge in designing of the Wireless Sensor Network is to reduce energy consumption and construct effective route strategy to increase lifetime and reliability of the network. For various applications, Wireless Sensor Networks (WSNs) are getting deployed frequently, continuously and they are increasing day by day. Because of high density of WSN nodes there is high probability that redundant data will be sensed by surrounding nodes. Energy conservation is most affecting factor in building a network. It is not suitable to send data individually or separately by each node. Thus the data aggregation is required i.e. data will be collected or aggregated at particular node and then transmitted ahead towards sink node. Using this aggregation technique we can save cost and energy consumption in networking. Data routing in network aggregation is also called as DRINA. It provides a better solution like reduced number of message in routing tree, secure data aggregation, high aggregation rate, reliable, and transmission in wireless sensor network. In this survey, we highlights various approaches and algorithms for data routing and aggregation.

Keywords- routing, aggregation, WSNs.

1. WIRELESS SENSOR NETWORKS

Wireless Sensor Network is a collection or a group of specially designed transducers which is having communication infrastructure, which can be used for monitoring, measure ing or recording conditions at remote or diverse locations [12]. Generally measured parameters are temperature, pressure, speed, humidity, sound intensity, wind direction, illumination intensity, power-line voltage, vibration intensity, chemical con- centrations, pollutant levels and vital body functions. WSNs have variety of applications like Video surveillance, Industrial automation, Automated and smart homes, Air traffic control, Traffic monitoring, Medical device monitoring, Robot control,

Monitoring of weather conditions, and much more which may be critical to life safety and risk management.

A sensor network is made of multiple detection stations called sensor nodes, each of which is lightweight, small and portable. Each node consists of a transducer, power source, transceiver and microprocessor. Transducer generates electric current (signal) based on physical effects or phenomena sensed by it. Microprocessor (or controller) does processing on that signal and produces output. Transceiver transmits data or out- put to central database. The power for each node is generally derived from battery. This is the major limiting factor in WSN design Because of that protocols or algorithms designed for WSNs should consider energy low consumption and its management. Routing is an important process to finding out best path or shortest path in network. WSNs usually produces large amount of data which needs to be routed often in multi-hop fashion. WSNs provides connection between real physical and virtual world.

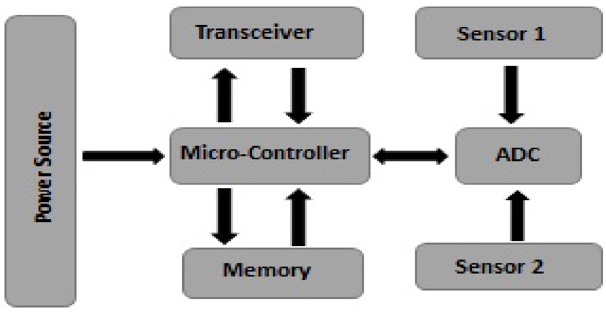

Fig. 1. Sensor Node Architecture

2. ROUTING IN WSNS

Wireless sensor networks are made up of small devices over the wireless link and it do not uses any fixed infrastructure for network formation. Because of small devices with limited transmission range requires, for communication between them it requires collaboration of intermediate data and intermediate forwarding nodes. Some devices acts as a router at the same time. Route discovery basically happened by simply flooding data in the entire network. Thus more efficient routing algorithms are necessary for such wireless networks.

Routing in wireless networks differs from the conventional fixed routing as there is no fixed infrastructure, the nodes may get fail in between and the links may become unreliable. As there are relatively large number of nodes, it is impossible to build a globally applicable addressing scheme for the deployment of such large number of sensor nodes since the complexity of ID maintenance is high. Thus traditional protocols are not suitable for wireless sensor networks. Sometimes it is more important in WSNs to get data than to know ID of the source node. Another major constrain is lifetime of the network. It needs to be taken care while designing of protocol.

3. ROUTING CHALLENGES AND DESIGN ISSUES IN WSNS

Some of the design issues and routing challenges are as,

A. Deployment of Node

Node deployment is application specific and it directly affects the performance of the protocol. The deployment may be in predefined or in randomized manner. In predefined deployment, routing is done through already defined paths. In random deployment, the sensor nodes are placed randomly and it creates infrastructure in ad hoc manner. This directly affects the energy efficiency.

B. Energy Efficiency with precise Accuracy

Sensor nodes have only limited supply of energy for transmitting and computations of information in a wireless network. Lifetime of the node is strongly depends on its battery lifetime. If a particular node fails due to power failure then there will be significant topological changes and this will reduce reliability and data accuracy of the network.

C. Data Reporting

Sensor node continuously senses, monitors data and reports it to the sink node. This data reporting of sensor nodes may be continuous or on demand i.e. query driven. Node have to react any sudden or drastic changes in the data such as time critical applications.

D. Heterogeneity of nodes

Sensor node in many times are considered as homogeneous i.e. same architecture within the nodes I terms of energy consumption, data processing and communication infrastructure. But depending on applications it may have different architecture or capacity. For examples certain application requires continuous monitoring, some are security alarms, some have to withstand the environmental extreme conditions. Thus due to heterogeneity of nodes design complexity increases.

E. Error Tolerance

During operation few of the nodes may get fail due to extreme environmental conditions, physical damage or external interference. This particular failure should not be cause failure of network. Thus routing techniques should take care of this failure node and recovery of the network after such failure. In case of node failure routing algorithm should able to establish new paths or links and data rate has to be maintain.

F. Network Scalability

The wireless sensor nodes may be in order of few to thou- sands or even more. So the routing technique should able to work with such large number of nodes and it must be scalable sufficient for responding events happening in environment.

G. Mobility of Nodes

Many network architecture considers sensor nodes to be stationary, but application may demand mobility of nodes. Routing paths formation and updating such routing tree is major challenge while designing. In fixed architecture routing can be static but dynamic routing is necessary in case of movable nodes.

H. Connectivity

Nodes in sensor network precludes themselves form com- plete isolation from others. Thus, sensor nodes are expected connectivity on large scale. Connectivity depends on distribution of nodes.

I. Coverage

Wireless sensor networks, every node computes certain information from environment. Every node has limited scope of vision or range. It generally covers only certain limited area. Thus while designing of WSNs coverage is also one of the major parameter need to take care.

4. DATA AGGREGATION

The most prominent technique for optimization of routing task is to use available processing capacity along with the routing paths. This is known as in-network data aggregation. Aggregation simply means combination. Dictionary meaning of aggregation is the act of collecting together. In networking concepts aggregation means summarizing multiple route into one route.

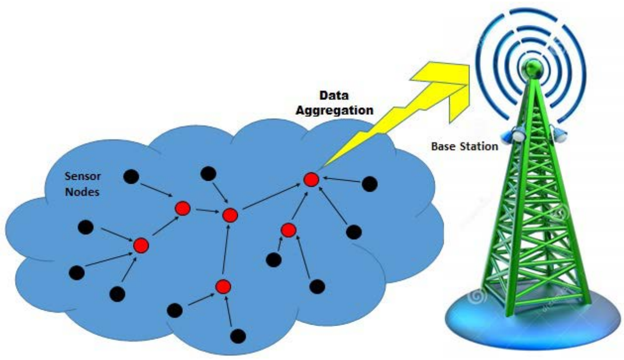

Fig. 2. Data Aggregation

In simple words, data aggregation is simply the combination of data which is originated from different sources. Main function of data aggregation is to suppress the duplication [3]. Let two sources source A and source B. Both sends same data to node C, now node C will send one of these forward, saving cost of data transmission. Data Aggregation aware routing protocol design is the main challenge for in-network data aggregation [1].

In this technique a number of sensor nodes act as a group which collects data or information from target region. Traditionally nodes send data individually when base station demands for network. Instead of that there is a special node called as aggregator which collects information from its neighboring nodes, aggregates them and sends that combined data to base station in multichip pattern. As shown in figure by this aggregation we reduces number of transmission and thus improves network and bandwidth utilization.

The benefits of this aggregation increases if the intermediate nodes perform aggregation process in incremental way, when data is forwarding toward base station. Using continuous data aggregation process we may able to improve bandwidth and energy efficiency but it may possibly affect other performance parameters like delay, accuracy security and fault tolerances.

The synchronization of data transmission among the node is a key aspect of in-network data aggregation [1]. For improvement of aggregation performance nodes usually waits for certain period. There are three timing strategies present in literature for time synchronization [1].

A. Simple Periodic Aggregation

This is the simple timing strategy for data aggregation. In this strategy, each node waits for particular fixed time periods then aggregates all received data packets. Then it forwards that data packets converting in a single packet which in turns results aggregation [1].

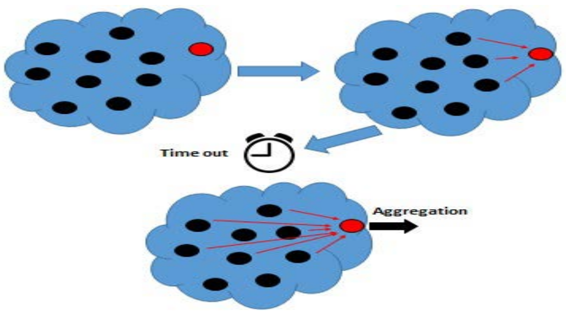

Fig. 3. Simple Perio Aggregation

B. Per-Hop Periodic Aggregation

This is same as previously defined strategy. In this the central or coordinator node waits to get data for all its children. This requires each parent to know its number of children. In case of failure of particular child, timeout can be used to maintain link.

C. Adjusted per-hop periodic aggregation

In this strategy, time period is adjusted according to the node position in the gathering tree. Thus transmission time of node gets changed according to the position in the gathering tree.

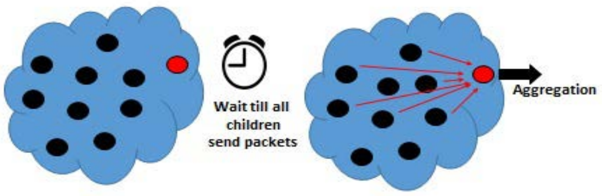

Fig. 4. Per-Hop Periodic Aggregation

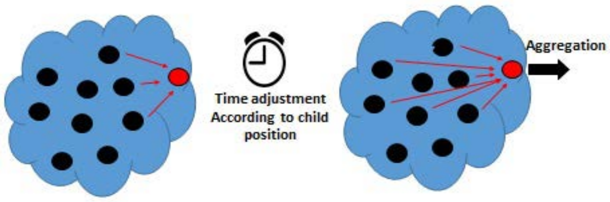

Fig. 5. Adjusted per-hop periodic aggregation

5. VARIOUS APPROACHES FOR DATA AGGREGATION

A. Tree-Based Approach

In this tree structure is constructed first and then it is used later for routing of gathered data or to complete queries which are sent by sink node. During routing aggregation is performed whenever more than one data packets arrived at the same node of the tree.

This approach have drawbacks line whenever packet is lost in particular level in the tree due to various factors like channel impairment, noise affect, the data from complete sub tree will be lost. This approach is suitable for designing of optimal aggregation and to perform efficient energy management [1] [2].

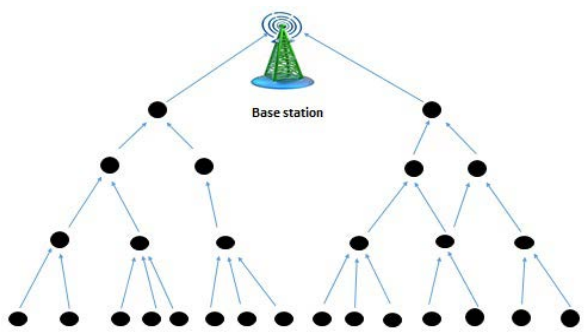

Fig. 6. Tree-Based Approach

B. Cluster-Based Approach

This approach makes use of hierarchical organization of the network. In this nodes are divided into number of clusters. Certain nodes are selected as cluster-heads. In this algorithm cluster head acts as aggregation point and they have direct communication with sink node [1] [2].

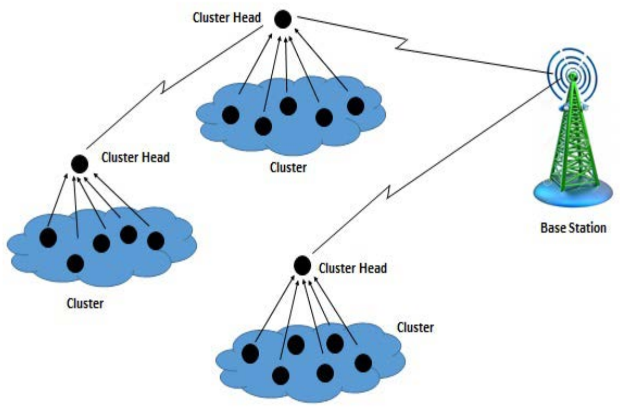

Fig. 7. Cluster-Based Approach

C. Structure-Less Approach

This approach of data aggregation is less prominently used. In this no any particular structure is formed. It makes use of any cast for forwarding of data packets to one hop neighbors which are having packets for aggregation [1] [2].

6. VARIOUS ALGORITHMS AND DATA AGGREGATION TECHNIQUES

A. Shortest path tree algorithm

Shortest path algorithm is a tree based approach for data aggregation technique [1]. It uses a very simple technique to build a routing tree. In a distributed fashion. In this data aggregation algorithm, the each source sends its packets to the sink along the shortest path between the sink and source node. In the tree, when these paths overlap for two different sources, they gets combined to form aggregation tree [3]. The path overlapping makes information fusion.

B. Centre at Nearest Source Algorithm

Centre at Nearest Source algorithm is also the tree based approach. In this algorithm, each node detects an event. Then it sends its gathered information to the aggregator node. This algorithm also uses shortest path [1]. In this source which is nearest to the sink act as aggregation point [3]. Remaining sources directly send their packets to this source which then sends the aggregated information on to the sink. The aggregator is the closest node to the sink node which detects an event [1].

C. Greedy Incremental Tree Algorithm

Greedy Incremental Tree algorithm is also the tree based approach. In this aggregation tree is built sequentially [3]. It establishes an energy efficient paths and greedily attaches other sources in that established paths [1]. In the first step tree consists of shortest path between sink node and nearest source. In next step the next source which is closest to the current tree is gets connected to the tree [3].

D. DAG based In Network Aggregation

DAG stands for Directed Acyclic Graph, which allows the node to have multiple parent nodes. The multiple parents provides tolerance to wireless transmission failure. In this data transmission timing control is extended for tuning correctly on the edge of the DAG according to the actual hop count. [10] This are the major principles of the DAG based in network aggregation methods. This method forms a Directed Acyclic Graph. It uses multiple parents as intermediate nodes which provides tolerance for the failure in wireless transmission. Though there are multiple parents, the method avoids being aggregated by the same parent [10].

E. OPAG

OPAG stands for Opportunistic Data Aggregation in Wire- less Sensor Networks. This [9] claims that no computation error and tolerates moderate message losses in WSNs. OPAG performs in-network data aggregation in two layers data aggregation and data routing. Aggregation results are computed at the data aggregation layer along an overlay spanning tree. Network nodes can opportunistically send intermediate and partial results via multipath routing and underneath the routing tree [9]. OPAG overcomes communication losses by opportunistically using multi-path routing [9]. Using this, it achieves better energy efficiency than using retransmission since retransmission is not energy efficient as it incurs idle listening on more back and more time of waiting for an acknowledgement.

F. Ant Colony Algorithm

This algorithm was inspired by observing behavior of real ants [5]. This behavior helps them to find the shortest path between food sources and their home. First ant finds their source of food and during return path they deposits pheromone train on the ground. The quantity of the deposited pheromone is depends on quality and quantity of the food. This indirect communication allows them to find shortest path from their home and food. This functionality is used in ant colony algorithm [5]. In WSNs, this algorithm assigns ants (aggregator node) to source nodes [5]. The node finds routes and communicate with other using pheromones. Every ant makes iteration. These iterations are used in construction of aggregation tree where the internal nodes are aggregate points. The ant either tries to find the shortest route towards destination and terminate or finds nearest aggregation point of the route which was searched by previous ands and terminates.

In ant colony algorithm for data aggregation in wireless sensor networks, every ant explores all possible routes from source to sink node. Accumulation of pheromone forms the aggregation tree. After some short period, the amount of pheromone on the aggregation node increases sufficiently large to guide the packets originating from different sources to meet together at these nodes for aggregation [5].

G. DRINA

DRINA stands for data routing in network aggregation. It is a cluster based approach [1]. The main proposed goal of DRINA algorithm is building a routing tree with shortest path which will be connecting all source nodes to sink with

Increasing data aggregation. DRINA algorithm is based on three phases as,

1) Hop Tree formation

In this distance from sink to each node is calculated in Hops and accordingly hop tree formation takes place. Phase stated by sink node flooding HCM (Hop Configuration Message). HCM message consists of two fields ID and Hop To Tree. ID is the node identifier and Hop To Tree is the distance in hops calculated for path identification whose value is initially selected as 1 and later on it updates according to position of nodes.

2) Formation of Clusters

This phase describes the cluster formation in the network and the selection of group coordinator. The group coordinator is selected such that the node which is closet to sink node. When event gets detected by one or many nodes, leader election algorithm gets initiated. For this selection each nodes are eligible but from these coordinator is selected such that the node which is closest for sink node. After coordinator node is selected, all the reaming nodes are act as collaborator which gathers information and sends to the co-ordination. Late coordinator aggregates them and forwards to the sink. [1] Claims that this aggregation technique is more efficient than opportunistic aggregation.

3) Routing Formation and Hop tree Updating

After the group coordinator selection, the formation of new route and event dissemination is descried in this phase. In this coordinator sends route establishment message to its next node. After receiving message next node retransmits the message to its next node and by this tree updating process takes place. These steps are repeated until either it reaches to the sink node or already established route is found.

7. PERFORMANCE EVALUATION

In most of the algorithms performance of algorithm is evaluated using following parameters

1) Packet Delivery Rate-

It is the number of packets reached to the destination i.e. sink node. Lower the packet delivery rate greater the aggregation rate of built tree.

2) Control overhead-

It is the number of control messages used for building of the routing tree.

3) Efficiency (Packets per processed data)-

It is the measure of Packets per processed data (Total Packet Transmitted (data and control packet)) / (Number of data received by sink node)

4) Routing tree cost-

Total number of edges in routing tree structure which are built by the algorithm.

5) Loss of aggregated data-

It is the number of data packets lost during the routing

8. CONCLUSION

In this paper we survey various aspects of WSNs, rout- ing, various routing challenges and design issues of wireless Sensor network. Also we overviewed data aggregation, its timing strategies and various algorithms of data aggregation like shortest path tree algorithm, Centre at Nearest Source algorithm, Greedy Incremental Tree Algorithm, DAG based In Network Aggregation, OPAG, Ant Colony Algorithm and DRINA. Finally introduction to some performance evaluation parameters for these algorithm.

The need of deployment of wireless sensor network is in- creasing day by day. Aggregation helps in energy management and increasing efficiency of the network. Thus aggregation aware routing algorithms plays major role for WSNs. Each algorithm has its own set of advantages. Improvement of one parameter may results in lowering of other. For e.g. increasing aggregation will improve network lifetime but it may also increases delay in the network. Thus selection of routing algorithm and methodology is completely application specific. The main advantage of aggregation is improvement of network lifetime and efficiency. Depending on application a suitable aggregation technique should be selected which fulfils the requirement of the purpose of implementation of WSN.

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