A Study of Backbone Based Approaches Use for Data Dissemination in Wireless Sensor Network: A Survey

Awadhesh Kumar, Neeraj Tyagi, Vinay Kumar, Prabhat Singh

Abstract: - wireless sensor networks consist of sinks, events, and a large number of tiny, multifunctional and battery-powered sensor nodes. Thousands of the sensor nodes are randomly distributed over a vast field to self-organize a large-scale wireless sensor network. The sensor nodes monitor some events in surrounding environments, such as temperature, humidity, sound, vibration, presence of objects, and so on. In Wireless Sensor Networks, data dissemination to multiple mobile sinks consumes a lot of energy. Various grid-based data dissemination schemes have been proposed over the years to reduce the energy consumption in Wireless Sensor Networks. Energy is one of the most important aspects for designing a data dissemination protocol for the applications such as battle-field monitoring, habitat monitoring etc.

Keywords:- Data Centric protocols, Hierarchical protocols.

I. INTRODUCTION

Wireless sensor network (WSN) is growing rapidly and is hot area for researchers. WSNs consist of large number of sensor nodes (SNs) and provide fine observation about phenomenon. SNs are electronic devices which are deployed in the environment. SNs are low cost small devices and have limited memory, limited processing capability, low power and limited communication bandwidth. WSNs consist of large number of such SNs which are able to collect data and disseminate the collected data towards sink. SNs are capable of Performing the tasks of sensing, processing and transmission. Due to small size of SNs, it has limited power. After deployment of SNs in hostile environment, it is difficult to replace their battery. Due to the low cost of SNs, WSNs have become most popular. It is more viable for variety of real life applications. In WSNs each SN has capability to sense the data, perform some computation on that data and communicate to other nodes. Once SNs are deployed in the network, they can keep operating until their energy depletes. In WSNs, large numbers of SNs are deployed to sense an object because single sensor is not capable of sensing the whole environment; therefore all the nodes have collaborate with each other to provide total (full) functioning of these networks. SNs are able to assemble and configure themselves which is more powerful and helpful property in creating the network.

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II. LITERATURE REVIEW

This paper presents literature survey on various types of routing and data dissemination protocols and data aggregation schemes for WSNs. A review of research works that aimed to reduce energy consumption and increase the lifetime, throughput and stability has been provided.

2.1 Energy efficient data dissemination and routing protocols for WSNs

Various routing and data dissemination protocols have been proposed over the years still there is a scope of reducing energy consumption in routing and data dissemination. The functioning of data dissemination and routing protocols depend on the structured of the network which is based on the application. On the basis of applications, network architecture changes and hence a routing protocol, efficient for one application, is not necessary to work for another application. Networks lifetime depends on the consumption of energy of the nodes. According to [2] the energy of a node is depleted by: (i) computational processing (ii) transmission and reception of data. Both of these factors are controlled by network layer.

2.2 Types of data dissemination and routing protocols for WSNs

The data dissemination and routing protocols proposed for WSNs are classified into different categories based on several architectural factors [3]. Classification of data dissemination and routing protocols is helpful in designing the network protocol.

A) Data centric protocols

It is not good to use global identifier for large number of randomly deployed nodes in WSNs. This identifier introduces complexity in WSNs to query data from specific set of nodes. Therefore data is collected from several regions. The collected data from several regions are correlated and most of them are redundant. Hence collected data is aggregated at some node resulting in decrease in the size of actual data to be transmitted and there is less power consumption in transmission of that data. The main consideration of following algorithm is on data and its properties.

a) Flooding

This is an old and classified routing scheme [3]. In this scheme, the gathered data is broadcasted unless packet is reached to the destination or specified number of hops per packet is reached. This protocol has overlap, resource blindness problem and implosion problem.

b) Gossiping:

This is also an old and classical method similar to flooding [4]. In this scheme, sensor node collects data and this collected data is transmitted to

randomly chosen neighbor nodes until it reaches to destination node or to maximum number of hops per packet. The delivery of packets takes long time.

c) SPIN, Sensor protocol for information via negotiation:

The basic idea for SPIN is high level descriptor or metadata [5]. In SPIN three types of messages ADV, REQ and DATA are used. The interested node transmits REQ message for data. After receiving the REQ message source node sends DATA message to interested node. Data can reach to all interested nodes in whole network. Data aggregation is also employed in SPIN. Fig 2.1 illustrates the working of SPIN.

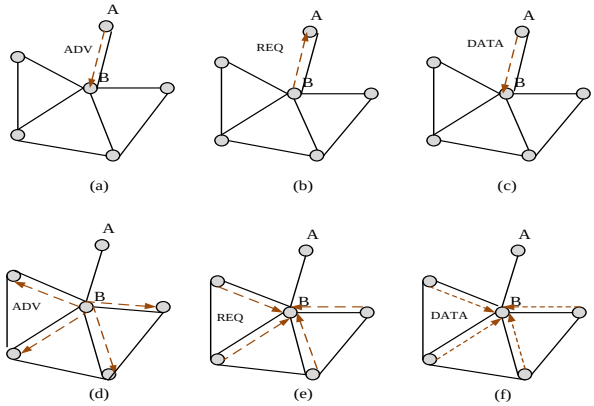

Figure 2.1 SPIN Protocol (a) Node A starts by advertising its data to node B. (b) Node B responds by sending a request to node A. (c) After receiving the requested data node A sends data to node B, (d) node B sends out advertisements to its neighbours, (e) neighbours of nodes B transmit request to node B, (e) node B sends data.

d) Directed Diffusion:

In [6], author proposed a data centric protocol for WSNs. In DD, all SNs are application aware and enable diffusion. DD saves energy, by processing and caching the data, and by selecting optimal paths. To improve the lifetime of network, directed diffusion combines data collected from different nodes and resend them with minimum number of transmissions and remove redundant information. This is a data centric protocol and all communications are for named data. It is the directed-diffusion paradigm for distributed sensing algorithm. DD performs data dissemination using scheme such as omniscient multicast and its main focus is on the MAC layer. DD consists of interests, data messages, gradients, and reinforcement elements. In DD, sink transmit interest message by flooding as shown in fig 2.2(a) and this interest message is periodically flooded by sink. An interest message is a query for what user wants. Each sensor node has interest cache and they forward interest messages to their neighboring nodes. When interest is propagated within the network, all nodes set their gradient. Each sensor node sets its gradient direction towards the neighboring nodes from which it receives interest message as shown in fig 2.2(b). This process continues until gradient is set from source node to the sink node. Loops are not checked at this stage but removed later. This gradient specifies data rate and direction of transmission. Event starts to flow, along multiple paths, towards node initialize interest message. To provide reliability sink periodically sends request to collects data from source node. DD is an energy efficient and stable routing protocol. The problem with directed diffusion is that it can't be applied to applications such as environment monitoring.

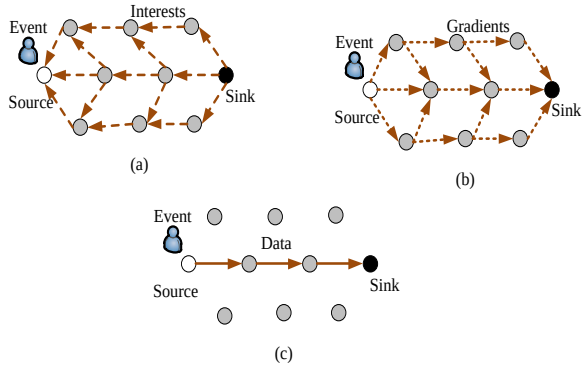

Figure 2.2: Simplified schematic for directed diffusion. (a) Interest propagation. (b) Initial gradients setup. (c) Data delivery along reinforced path.

e) REEP:

In WSNs, nodes are small in size and are powered by irreplaceable batteries. So efficient use of energy is required. This protocol considers two important issues while designing the routing protocol. First, the level of power consumption, at each stage of functionality, should be maintained. Second, tolerance of different types of failures should be achieved. In REEP [7] there are five events: sense events, information events, request event, energy threshold value and request priority queue as shown in fig 2.3. Sink node generates the sense event for collection of basic information. In response, source node generates information event for detected object type and the location information. Sink node generates request event for path setup on receiving this information.

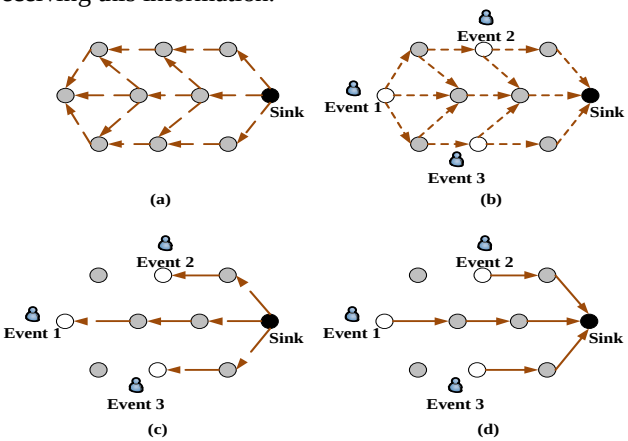

Figure 2.3: A high-level schematic view of REEP (a) Sense event (b) Information event (c) Sink sending request for path (d) Data delivery along dedicated

This protocol has very effective method for use of energy of node. Every node uses energy threshold value, on the basis of which each node decided to participate in the activities. On receiving sequence of information event from different neighboring nodes, each node queue them in request process queue. This is diffusion based data centric protocol. For the energy efficient information flow, it uses aggregated data from network. It uses local topology for path setup. REEP is diffusion based and data centric. It uses data aggregation for energy efficient transmission. REEP is an interactive on-demand protocol, in which

path establishment can be done based on the choice of any user or an application. Each node maintains an energy threshold value and participates in path setup with adequate energy for data transmission.
The request priority queue is used for loop prevention and alternate path setup in case of failed path, without invoking periodic flooding.

f) Energy aware routing:
This proposed a set of sub optimal routes which increases network lifetime. On the basis of energy consumption, routing paths are chosen. Selecting the minimum energy path results in depletion of nodes' energy more frequently hence paths are chosen with equal probability. [8]

g) Rumour Routing:
This is derivation of directed diffusion. Directed diffusion becomes inefficient when large number of requests is made for small number of events. Rumor routing is a solution for short comings of directed diffusion. Unlike directed diffusion, events are flooded at place of queries. In this scheme, queries are routed to the SNs which sense specific events. After detecting the sensed events, nodes make entries of information in their tables and generate an agent which is flooded in the network. With the help of this flooded agent, nodes transmit detected information to distant nodes. [9]

h) Gradient based routing:
It is a different approach from directed diffusion. To request the data, interest packets are diffused in the network. The distance to the sink is recorded in the interest packet in terms of number of hops. Each node searches the shortest path to the sink. The gradient is calculated by differencing the node' gradient and its neighbor' gradient. Node transmits data to the sink node with largest gradient. Several spreading techniques have been proposed such as: Stochastic scheme, Energy based scheme and Stream based scheme. Stochastic scheme is used when two or more nodes have same gradient, node selects one randomly. Energy based scheme is used when node has scarce energy, it increases its gradient. Stream based scheme is used to divert streams away from nodes' relaying traffic. [10]

i) CADR, Constrained Anisotropic Diffusion Routing:
This algorithm maximizes information gain and reduces bandwidth requirements and delay. There are two techniques: CADR and IDSQ (Information-Driven Sensor Querying). In CADR, each node calculates cost, observes information and on the basis of ends user requirements, nodes select the route. While in the IDSQ sink (querying node) selects the node that can provide most useful information with minimum cost.[11]

j) COUGAR:
They considered whole network as large distributed database system. There is a leader node that is selected to aggregate the data and sends this aggregated data to gateway node. This leader node is selected by query plan. The gateway node generates query for the required information about data flow and computation for incoming query. Then gateway node forwards them to the relevant nodes. [12]

k) ACQUIRE, Active Query forwarding in sensor networks:
This scheme is designed for one shot complex query which replicates the data. Flooding based algorithm such as flooding, gossiping, directed diffusion and SPIN are well suited for continuous aggregate queries in which cost of flooding is less and become negligible for continuous data flow between source node(s) and sink node. Theses algorithms are not efficient for one shot complex queries for replicated data. They considered whole network as large distributed database system. Sink node sends the query, each node that receives query respond with its pre-cached information by transiting them to other nodes. Each node updates its pre-cached information continuously. Complex queries are divided into sub queries and forwarded through the path in the network. After resolving the query, node sends information back to the sink node via reverse or shortest path. This scheme is efficient for complex queries.[13]s

B) HIERARCHICAL PROTOCOLS
Many hierarchical protocols have been proposed for WSNs that are scalable and have efficient energy consumption. The main issues in hierarchical protocols are forming sub network (cluster), enabling data fusion and encouraging multi hop transmission.

a) LEACH, Low energy adaptive clustering hierarchy:
This scheme is based on clustering. According to received signal ra te, clusters of SNs are formed. Cluster head works as a router to the sink node. Since cluster heads are limited in the network so cluster head should be selected carefully. Cluster heads are selected randomly to balance the energy of network. Each node chooses a number between 0 and 1 randomly. CH is selected by using equation

$$T(n) = \begin{cases} \dfrac{p}{1 - p*(r \bmod \frac{1}{p})} & if \ \ n \in G, \\ 0 & \text{otherwise} \end{cases}$$

Where p is the desired percentage of cluster heads, r is the current round and G is the set of nodes which have not selected for cluster head in the last 1/p round. LEACHis distributed protocol. There is no need of global knowledge.[14]

b) PEGASIS, Power Efficient Gathering in Sensor Information Systems:
It is an improvement over LEACH. In this scheme, chain of SNs is formed in place of cluster formation. One node is responsible to aggregate the data and route them to the sink node. On receiving the data, each node aggregates the data with its own sensed data and sends it to the next ring. Unlike LEACH, it employs multi-hop transmission and only one node transmits data to the BS or sink. The pros of this scheme is overhead of dynamic cluster formation is eliminated. PEGASIS outperforms LEACH since it employs data aggregation and multi-hop transmission. It has cons such as excessive delay for distant node, especially for large networks where single leader can be bottleneck. Fig 2.4 explains PEGASIS algorithm. Node c0 and c4 send their sensed data to node c1 and c3 respectively. Node c1 and c3 aggregate data with their own data and forward to node c2. Node c2 aggregates the data and is responsible for transmission to the BS.

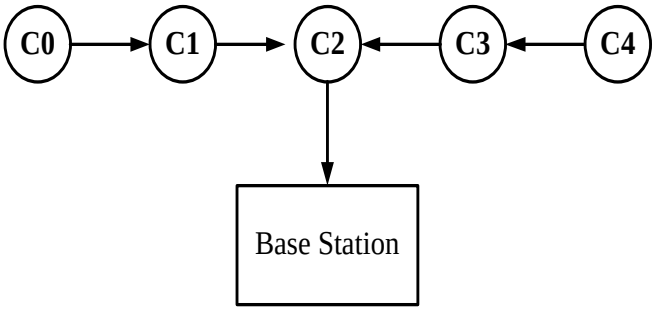

Figure 2.4: Chaining in PEGASIS.

c) Hierarchical-PEGASIS:

This protocol is extended version of PEGASIS which aims to decrease the delay. It employs simultaneous transmission. To avoid collision problem, which arises due to simultaneous transmission, two solutions are proposed. In first solution, signal coding called CDMA is employed and second allowed simultaneous transmission for spatially separated nodes. Fig 2.5 illustrates the algorithm. Nodes c0, c2, c4, and c6 send their obtained data to c1, c3, c5, and c7, respectively. Node c1 and c5 aggregate the data and send them to c3 and c7 respectively. C7 forwards them to c3 and c3 is finally responsible for transmitting them to BS. PEGASIS takes four unit times to send data to c3 that takes 3 unit times to transmit them to BS. As network size increases, difference also increase

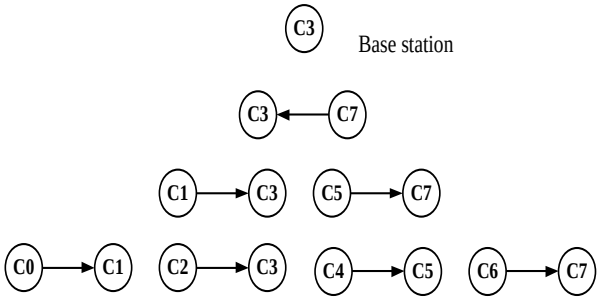

Figure 2.5: Hierarchical PEGASIS for Chain Based

TEEN, Threshold sensitive Energy Efficient sensor Network Protocol [17]: Clusters are formed by closer nodes with a cluster head that transmits collected data to one upper layer. After cluster formation, cluster head broadcasts two threshold values. First one, called hard threshold value, is minimum possible value of attributes to trigger sensor node. Nodes can transmit the events if it is in the range of hard threshold value. Hence significant deduction in transmission delay occurs. A node doesn't send any data packets unless change in minimum threshold value occurs. Redundant data transmission is prevented by soft threshold value. This protocol is suitable for time-critical applications because it is responsive to sudden changes in the sensed attributes. In LEACH, each cluster head directly communicates to sink while in TEEN, there are three types of nodes and BS or sink as shown in the fig 2.6. Simple nodes sense the data from environment and transmits them to the first level cluster head. Each first level cluster head aggregates the data from its cluster nodes and send them to the second level cluster head. Second level cluster head directly sends the data collected from its cluster to the BS. Some simple nodes, that are close to the second level cluster head, belongs to the second level cluster.[17]

d) APTEEN, Adaptive threshold sensitive energy efficient sensor network protocol:

This protocol covers both time critical events as well as periodical data collections and is an extension of TEEN protocol. The architecture of APTEEN is similar to TEEN. After cluster formation cluster head broadcasts attributes, transmission schedule and threshold values to all nodes in cluster. Cluster head node performs data aggregation to reduce the size of transmission data which reduces energy consumption. In terms of network lifetime and energy dissipation, TEEN gives better results than LEACH and APTEEN because of decrease in number of transmissions. The main cons of TEEN and APTEEN are complexity and overhead of forming cluster at multiple levels, dealing with attributes based named queries and implementing threshold based function.

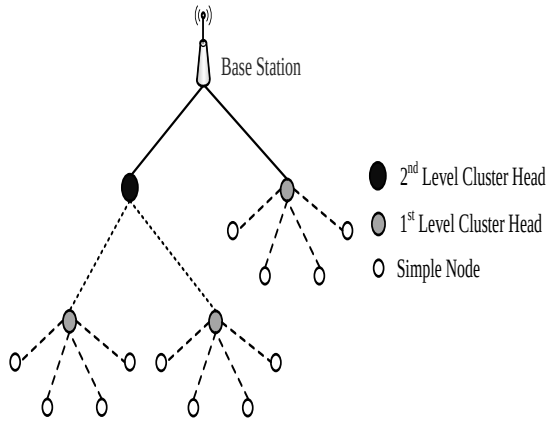

Figure 2.6 – Hierarchical Clustering in TEEN and APTEEN

e) Energy-aware routing for cluster-based sensor networks:

SNs are grouped by cluster formation. Cluster head and gateway nodes are less energy constrained nodes. Gateway nodes maintain multi hop routes and maintain state of the nodes. Sink only communicates with the gateway nodes. Gateway nodes inform to other nodes in the slots they can transmit their data and in the slots they can listen other nodes transmission. Each SN can work in four modes: sensing, relaying only, sensing-relaying and inactive mode. Cost function between two nodes is defined in terms of delay optimization, energy consumption and other performance metrics. A minimum cost path between SNs and gateway nodes is found using such function.

C) Heterogeneous data dissemination and routing protocols for WSNs

WSN attracted lots of researchers because of its special challenges and its potentially wide applications. In Past few years, WSNs main focus is on the homogeneous WSNs where each sensor node has same capability and has same system resources. But now scenario is changed and heterogeneous WSNs have become more and more powerful. The heterogeneous WSNs improve reliability and lifetime of network without any significant cost increment. A heterogeneous network is more expensive and is capable to provide data fusion, transport and data filtering. It can possess different types of nodes such as enhanced computation capability nodes and enhanced energy capacity nodes. Their batteries can be replaced easily or they can be powered with line. Compared

with normal nodes, they can be configured with more powerful microprocessor and can have large size memory. They can also communicate to the BS directly with high bandwidth or long network. The presence of heterogeneous nodes in a WSNs increase network reliability and lifetime. The main problem in heterogeneous networks is to where and how much heterogeneous nodes should be deployed in the network.

a) Types of heterogeneous resources

The heterogeneous resources can be broadly divided into three categories such as: link heterogeneity, energy heterogeneity and computational heterogeneity [22].

i. Link heterogeneity: Link heterogeneity shows that nodes have long-haul transceiver and high bandwidth network. Link heterogeneity increases reliability in data transmission.

ii. Energy heterogeneity: Energy heterogeneity shows that heterogeneous nodes battery is replaceable or it is line powered. Among these three heterogeneities, energy heterogeneity is most important because both computational heterogeneity and link heterogeneity consumes more battery power. Without energy heterogeneity computational heterogeneity and link heterogeneity shows negative results to the WSNs.

iii. Computational heterogeneity: Computational heterogeneity shows that nodes have more memory and more powerful microprocessor and microcontroller than the normal nodes. The SNs that have more powerful microprocessor and more sized memory can solve complex computation.

III. CONCLUSION

This paper presents literature survey on various types of routing and data dissemination protocols and data aggregation schemes for WSNs. A review of research works that aimed to reduce energy consumption and increase the lifetime, throughput and stability has been provided.

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