A Survey on Protocols and Routing Algorithms for Wireless Sensor Networks

Gaurav Kumar Nigam, Chetna Dabas

Abstract: **Wireless Sensor Networks (WSNs) are networks of small and tiny lightweight nodes that are randomly deployed in a large area where it is not possible to monitor continuously. Some physical parameters such as pressure, temperature and relative humidity etc. are used for monitoring the same. Energy consumption is the most important and critical issues for WSNs. The paper classifies the routing protocols based on the basis of two criteria: layers and architecture. Further, a survey of 15 routing protocols are done with their comparison by considering the factors like energy, power consumption, latency, network life etc.**

Keywords: LEACH, PEGASIS, WSN.

I. INTRODUCTION

WSN mainly consists of number of sensor nodes that are randomly deployed in the area that is called as sensor fields or field of observation [1]. Sensor nodes have restricted power supply and may have the problem of charging when battery runs out. Therefore, the mechanism for efficient power utilization consumption is necessary. Wireless sensor nodes perform three operations: event sensing, event processing and communicating with neighbouring nodes. Among these, energy consumption is the major resource for communication. We have to keep in mind that routing protocols must be energy efficient in order to increase the life of sensor node and the sensor network [11]. Routing Protocols [16] are categorised into three categories viz data centric protocols, hierarchical protocols and location based protocols.

The present paper deals with classification of routing protocols and a survey of 15 routing protocols with their comparison as discussed in [1-10]. The balance of the paper is labelled as Section II that contains various perspectives related to architecture and application of WSN. Section III describes the classification of WSN protocols into two categories: (a) Classification based on WSN layers (b) Classification based on architecture and functionality of WSN and discussion of various (networking) routing algorithms in brief. In Section IV, conclusion is given.

II. ARCHITECTURE AND APPLICATION OF WSN

When an event is generated in sensor field, nodes that are near to the event detect it (Figure2) and the neighboring nodes inform the same by different routing algorithms.

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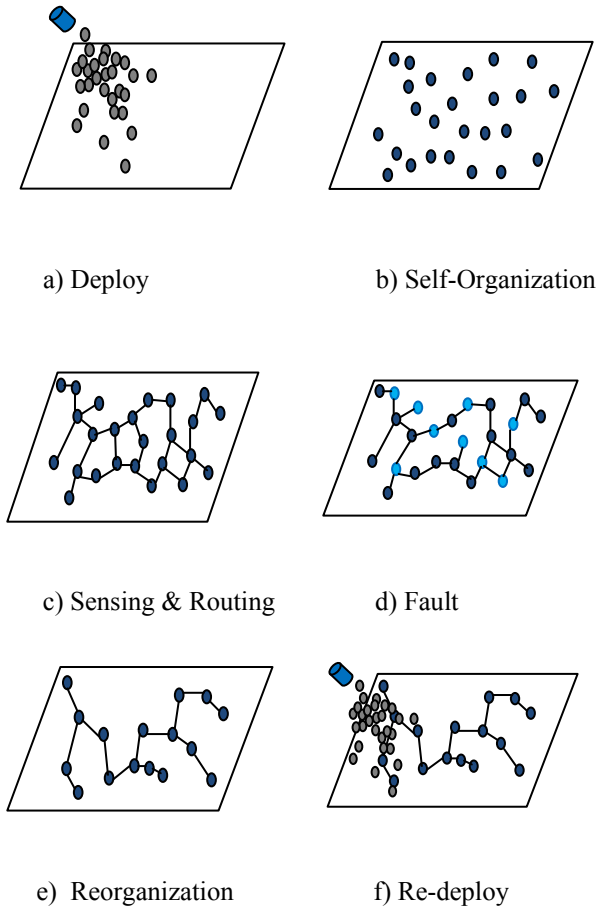

Figure 1. Self organization of sensor nodes

The event is eventually passed to the sink which will transfer it to user/administrator via medium of internet.

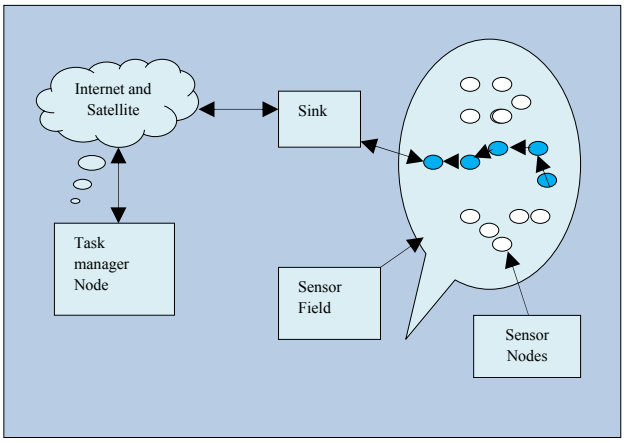

Figure 2. Sensor node in operation

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III. ROUTING ALGORITHMS

Two classifications of WSN protocols have been proposed here as given below.

A. Classification based on Layers:

Physical Layer: It performs Data Encryption techniques, Modulation schemes, synchronization scheme and FEC.

Data Link (MAC) Layer: Small Minimum Energy Consumption Network called as SMECN, Collaborative MAC called as CMAC, Event MAC (EMAC) and Network MAC based Protocols.

Network Layer:

- Data Centric Protocols: Sensor Protocol for information via negotiation like SPIN, COUGAR, Active query forwarding in sensor networks also called ACQUIRE, Sequential assignment routing, Rumor routing, flooding, gossiping and constrained anisotropic diffused routing, directed diffusion, Gradient based routing.
- Hierarchical Protocols: Energy aware scheme, Power efficient gathering for sensor information system called as PEGASIS, Threshold sensitive protocol for energy efficient sensor network i.e. TEEN and APTEEN, LEACH called as Low energy adaptive clustering hierarchy .
- Location Based Protocols: Minimum energy consumption network i.e. MECN, SMECN (Small MECN), Geographical and energy aware routing called as GEAR.

Transport Layer: Reliable Multi Segment Transport i.e. RMST, Pump Slow Fetch Quickly i.e. PSFQ, ESR i.e. event to Sink Reliability.

Application Layer: Sensor query and data dissemination protocol called as SQDDP, Task assignment and data advertisement protocol called as TADAP, and Sensor management protocol i.e. SMP.

B. Classification based on Network Architecture

Architecture:

- Layered: UNPF (Unified Network Protocol Framework)
- Clustered: LEACH

Data Handling

- Data Dissemination: Flooding, Gossiping, Rumor Routing, SAR i.e. Sequential assignment routing, Sensor protocol for information via negotiation i.e. SPIN, Directed Diffusion, SMECN, Cost-field approach, GHT(Geographic Hash Table) .
- Data Gathering: Directed Transmission, PEGASIS, Binary Scheme, Chain based three level scheme .
- Medium Access Control: SMACS, Hybrid time division multiple access or frequency division multiple access, Carrier sense multiple access protocol i.e. CSMA .
- Location Discovery: Indoor localization, Multi-lateration and it may be either automatic or iterative or it may be collaborative.

C. Following is now the brief description on various (networking) routing protocols of WSN.

Flooding:

Algorithms: The maximum hop count is not achieved then each node that receives a packet must broadcast it and node is not the packet destination itself. [1, 12].

Advantages: This is a fastest and highest rate message delivery method. It is also reliable. Flooding convergence first without no or minimum delay [12].

Disadvantages: Broadcast storm, Implosion, inefficient energy, Resource blindness, Gossiping and Overlapping.

SPIN (Sensor Protocols for Information via Negotiation): This protocol is discussed in [6, 12]. SPIN works on the mechanism of negotiation and resource adaptation (Figure 3) to address the deficiency of flooding [1]. Meta-data (data about data) is transmitted instead of raw data. SPIN has three types of messages: ADV (advertisement for metadata), REQ (Request for actual data) & DATA (Actual Data) [12].

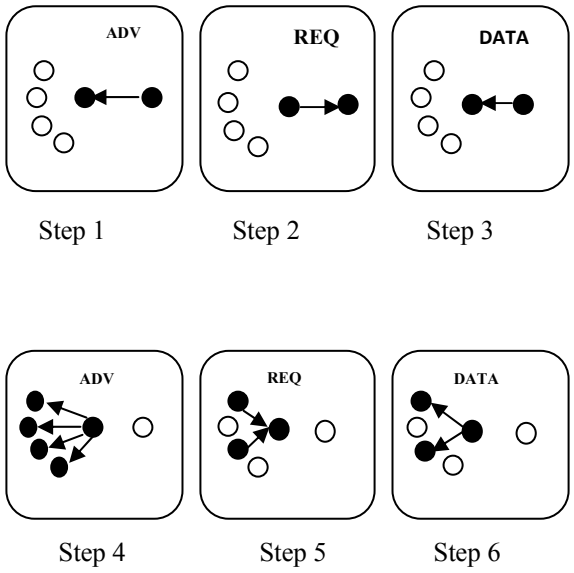

Figure 3. Messaging used in SPIN

Advantages: It solves the problems of previous methods viz. implosion, resource blindness and overlapping.

Disadvantages: It only compares flooding & gossiping. It assumes that all nodes are interested in Data.

SAR (Sequential Assignment Routing) [7]: There is multiple tree creation in SAR such that each tree root is one hop neighbor of the sink. From the sink each tree will grow outwards. At the end of process, most nodes belong to the multiple trees. Delay and available energy sources are the two parameters that each node will record about each path through it, that will help a node to give the choice to select one path among many paths. SAR chooses path with high energy resources and for priority packets QoS metric is used.

Directed Diffusion [2]:

Algorithm: Directed diffusion is based on data-centric (DC), query driven and application-aware technique in the sense that all data generated by sensor nodes is named by two pairs i.e. attribute and value. Data centric routing select from multiple sources a routes to a single destination that allows in-network consolidation of redundant data (flooding) [13].

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Rumor Routing [9]: Agents are circulated in the network to establish a shortest path to an event. Agents visit a node and optimize the path at that nodes. During agent finding, a node updates the routing table when it finds another node whose path is longer than its own to an event [3].

Cost Field Approach [8]: It deals for setting up paths to a sink. Two phase system:

- Setup the cost field: In this the cost field is set up starting from a sink node. ADV packet is broadcasted by the sink with its own cost initialized to be 0. When a node N listens an ADV message from node M then N sets its own path cost to min (LN, LM+CNM). LN = Total Path cost from Node N to Sink. LM = Path cost of M to sink. CNM = Cost from node N to M. When LN is updated the new cost is broadcasted through next ADV [14].
- Data dissemination: In this a message from the source is sent to the sink S upon establishment of the cost field with cost say Cx. The message also contains cost-so-far field, initially set to 0 [14].

ACQUIRE (Active Query forwarding In sensor networks): Earlier Flooding-based query methods such as "Directed Diffusion data-centric routing scheme" are well suited only for continuous-aggregate queries. One-size-fits-all approach but unlikely to provide efficient solutions for other types. So, if the size is not continuous, flooding can dominate the costs associated with querying. Similarly in data aggregation duplicate responses can lead to suboptimal data collection in terms of energy costs [14].

LEACH (Low-Energy Adaptive Clustering Hierarchy):

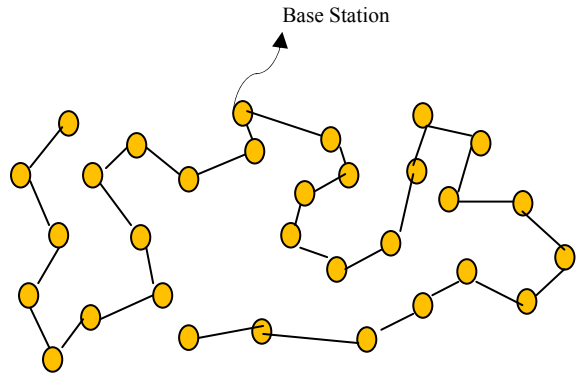

Figure 4. Randomized rotation of local cluster base stations

It minimized the energy dissipation. It randomly selects a node as a cluster head and performs periodic re-election. LEACH has two phases: Setup phase and Steady phase..

- In the setup phase sensor node selects randomly any number in the range (0, 1). If the value of selected number is less than threshold value of the node then, the node is selected as the cluster head [15].

Threshold of node n, is given by:

$T(n) = P / [1 - P (r \times \mod (1/P))]$; if $n \in G$,

$T(n) = 0$; Otherwise.

Here r: current round, G: Set of nodes which has not been head, P: Desired percentage of nodes which are cluster heads.

- Steady: Data transfer takes place based on TDMA schedule [15]. The cluster heads performs data aggregation or fusion. BS receives the aggregated data based on cluster heads only. After certain period of time in steady phase, and again through the setup phase, cluster heads are reselected [15].

PEGASIS (Power-Efficient Gathering for Sensor Information Systems) [5]: It is based on the assumptions that all sensor nodes know the location of every other node and any node has required transmission range to reach to BS in one hop, when it is selected as leader. Goal: we have to minimize the distance over which each node transmits. Broadcasting overhead is also minimized. the number of messages that need to be sent to BS is also minimized.

Binary Scheme [10]: This is also chain based scheme like PEGASIS. It classified the node into different levels.

STEP 1: s0 -> s1, s2-> s3, s4->s5, s6->s7.

STEP 2: s1 -> s3, s5->s7.

STEP 3: s3 - > s7.

STEP 4: s7 -> BS.

No of steps = O (log2N), where N: Number of nodes. When nodes are communicating using CDMA technique, so that simultaneous transmission at each level takes place then only this scheme is possible.

Chain-Based Three Level Scheme [10]: Binary scheme is not applicable for non CDMA sensor nodes. In chain based scheme, chain is constructed as in PEGASIS. The chain is divided into number of groups to figure out number of transmission that are simultaneous in order to minimize the interference. Nodes transmit one at a time, in a group. Example: Network size: 100 nodes Group Size: 10 for 1st Level, 5 for 2nd Level. Total Three Levels required.

SMECN (Small Minimum Energy Communication Network) [4]: In this approach it constructs a sub-network from a given network. If G is a complete network, G‟ is constructed by keeping in mind the energy usage of the network that is needed to be minimized. The required power to transmit the data between two nodes u and v is $p(u, v) = t \times d(u, v)^n$, t: constant, n: path loss exponent, d: distance.

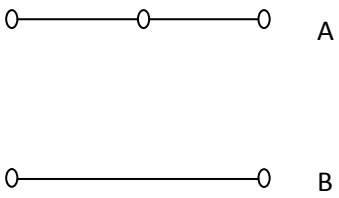

Figure 5. Less energy consumption in Connection A than connection B as the power required to transmit between a pair of nodes increases as n^{th} power of the distance between them (n >==2).

GAF (Geographic Adaptive Fidelity): The available physical space is partitioned virtually into equal size squares. Each node knows its location and nodes with a square are equivalent. On the basis of local information it identifies nodes for routing. In a situation of densely deployed nodes, it turns off all unnecessary nodes. Viz.

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Discovery, Sleeping, active state. There is one active node in each grid. With respect to current state and expected lifetime nodes are ranked [17].

GAF State Transitions: Node Broadcast discovery message and enters active state. After some time Node returns to discovery and release active state for other nodes. Node in sleep state moves to discovery after an application-dependent time. Application dependent ranking decides coordinator among nodes [17, 18].

Disadvantages: Bogus routing information: Broadcast high ranking discovery messages [17, 18].

GEAR (Geographical and Energy-Aware Routing):

Assumptions: Location, Energy, Neighbor aware Nodes, Target Region Specific Queries, Bi-Directional Links, Static sensors. Algorithm: Next hop nodes are chosen for packet forwarding on the basis of geographical closeness or cost. Once packet reaches a target region, recursive geographic Forwarding sends it to destination, or if the density is low, a restricted flooding is used. Forwarding to Sub Region continues until stop condition (Figure 6) : Node is the only one in the Sub Region [18, 19].

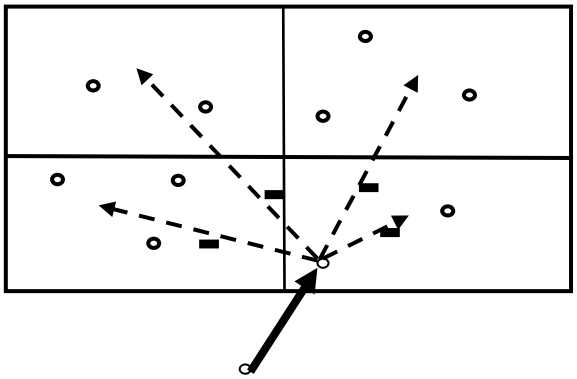

Figure 6**.** Node allocation in GEAR

Grid Heads are called as coordinator, that are responsible of forwarding messages and the other nodes are needed to wake up periodically. Pure geographical forwarding is used if:

- Number of hops threshold is passed.
- Packet reaches nodes with energy depleted.
- Node is near a target region.

Gear is not sensitive in case of Location Error [18,19].

IV. CONCLUSION

High scalability is the factor that we consider geographical routing as an important and essential routing method in consideration to ad hoc networks. Most of the algorithms illustrated here assume that the nodes are static. Some changes may be proposed in case of non-static nodes and some algorithms are designed.

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