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A Survey on Mitigating Hotspot Problems in Wireless Sensor Networks

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Abstract

A Wireless Sensor Network (WSN) is a group of spatially dispersed and dedicated sensors to monitor physical and environmental conditions. The sensor nodes are battery powered and deployed in remote locations, hence energy is a scarce resource in a sensor network. In WSN, the nodes closer to the sink tend to deplete their energy at a faster rate when compared with other nodes. This issue is called as the Hotspot problem. Lot of research is going on to achieve energy efficiency and to mitigate hotspot problems in WSN. In this paper, we make a survey on several energy efficiency protocols to mitigate hotspot problem in WSN. We analyze the merits and limitations of these protocols.

Keywords: WSN, Hotspot, Energy Efficiency, Sink.

Introduction

Due to the advancement in MEMS, lot of research is going on in WSN. The major application areas of WSN are forest fire surveillance, Battle field surveillance, Structural Health monitoring, Home Monitoring, etc..WSN can be classified into several categories namely i) Based on the type of event reporting b) Based on the type of sensor nodes used and c) Based on the type of routing. i) Based on the type of event reporting, WSN can be classified as a) Periodic Reporting and b) Event Driven.

a) Periodic Reporting

WSN with periodic reporting system will monitor certain parameters and reports or updates its detail for every fixed time interval periodically to the base station or sink.

b) Event Driven

WSN with event-driven reporting system will continuously sense the environment and report to the sink when a particular event occurs or when the sensed parameter exceeds the predefined threshold limit.

ii) Based on the type of sensor nodes used, WSN can be classified as a) Homogeneous WSN b) Heterogeneous WSN.

a) Homogeneous WSN

In a homogeneous WSN, the computation, Communication and sensing capability of all the sensor nodes will be similar.

b) Heterogeneous WSN

In a Heterogeneous WSN, the sensing, communication and computational capability of one node will differ from other node.

iii) Based on the type of routing, WSN can be classified as a) Direct Routing b) Multi-hop Routing and c) Clustering.

a) Direct Routing

In the direct routing, sensor nodes directly transmit the sensing data to the sink. It is easy to implement but the nodes away from sink may die early due to more energy dissipation.

b) Multi-hop Routing

The multi-hop routing structure makes each sensor to report the data to the sink in the form of hop-by-hop. Low energy consumption is achieved due to shortening the communication distance. The nodes closer to the sink may die quickly due to more communication.

c) Clustering

In the clustered environment, the data gathered and fused by the sensor is communicated to the sink through a hierarchy of cluster heads.

In the rest of the paper, we study and analyze various energy efficient protocols used in WSN to mitigate the hotspot problem.

LEACH [1] - Low-Energy Adaptive Clustering Hierarchy.

In LEACH, the nodes group themselves into several clusters. One node will act as cluster-head in each cluster. The cluster head in LEACH rotates randomly among various sensors. In addition LEACH performs data fusion to “compress” the quantity of data being sent from the clusters to the sink, further minimizing the consumption of energy and enhancing system life time. Each node decides whether to become cluster head (CH) or not. Node 'n' chooses a random number in the range of 0 to 1. The node will become the cluster head for the current round if the threshold is greater than the chosen number. The threshold is set as

$$T(n) = \begin{cases} \mathbf{P / (-P * (r \bmod 1/P))} & \mathbf{if\ n \in G} \\ \mathbf{0} & \mathbf{Otherwise} \end{cases}$$

P = Desired percentage of CH (0.05)
r = Current Round.
G= set of nodes that are not CH for the past 1/P round.

Merits: Improves the overall life time of the WSN.
Each node has the probability P for becoming CH during round 0. Nodes that are CH in round 0 cannot be CH for next 1/P rounds. After 1/P rounds all nodes are eligible to become CH. A node elected as CH sends advertisement message. Nodes receiving the advertisement message will join the particular CH based on the strength of the received signal. In case of ties a random CH is chosen.

Limitation: Not suitable for larger network, Cannot mitigate the hotspot effect.

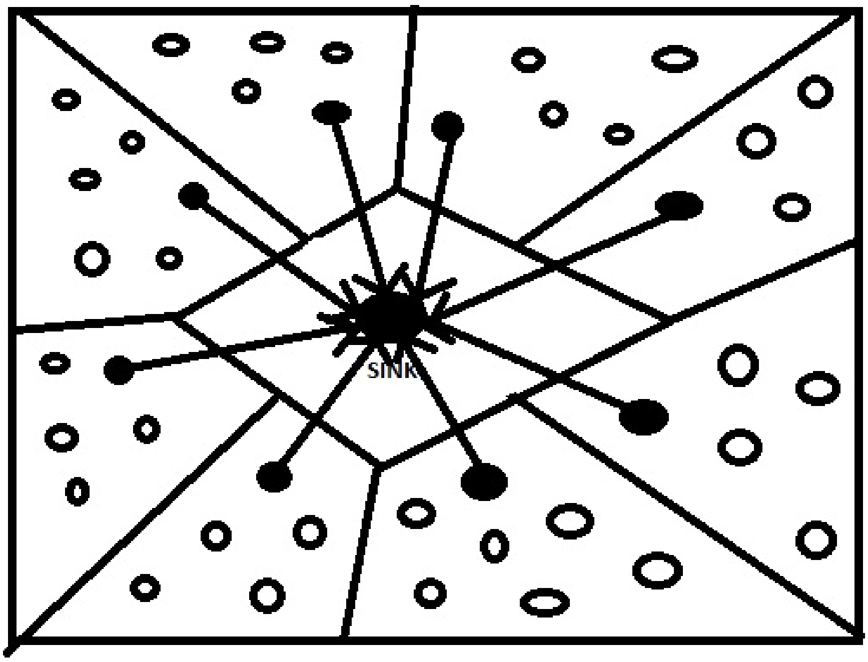

Fig 1 : LEACH

HEED [2] – Hybrid Energy Efficient Distributed Protocol.
The cluster head in HEED is selected based on the residual energy of the node and another parameter, such as proximity of the node to its neighbor or the degree of the node. HEED takes O(1) iteration to terminate, incurs low message overhead achieved fairly uniform cluster head distribution across the network. Residual Energy and Intracluster Communication Cost are considered as primary and secondary parameter respectively, for selecting CH. HEED uses the following terminologies.

T_{CP} – Time taken to cluster the network. (by the clustering protocol)
T_{NO} – Network Operation Time.
Clustering Algorithm is called every $T_{NO} + T_{CP}$ seconds to identify a new CH.
Niter – No. Of iterations required for clustering process.
C_{prob} – Initial percentage of CHs.
The probability for a node to become CH is set as.
$CH_{prob} = C_{prob} * E_{residual}/E_{max}$
$E_{residual}$ – Estimated residual energy of a node.
E_{max} – Reference Maximum Energy.
CH_{prob} should not be less than threshold Pmin to terminate the algorithm in O(1) iterations.
S_{CH} – All tentative CHs after i steps.

The node with the lowest cost in S_{CH} will be selected as CH by a given node. If a node would like to be a Cluster Head, it sends a announcement message cluster_head_msg (Node_id, Selection Status, Cost), where selection status = tentative_CH if CHprob < 1 and selection status = final_CH if CHprob = 1.

A node considers to be covered if it hears from either tentative_CH or final_CH. If a node completes executing HEED without selecting a Cluster Head, it assumes itself as not covered and informs itself to be a CH with final_CH.

Merits: Performs better than LEACH.

Limitations: Cannot Mitigate the hotspot effect.

PEGASIS [3] – Power-Efficient Gathering in Sensor Information System.
PEGASIS is an improvement of the LEACH protocol. Rather than forming multiple clusters, PEGASIS form chain of sensor nodes, so that each node transmits and receives from a neighbor and any one node is selected from that chain to transmit data to the sink. In a greedy way the chain is constructed. Each node receives and transmits data to close neighbors and take turns being the leader. The leader in each round of communication will be at a random position on the chain. If any node dies, the chain will be reconstructed. Nodes take turns to send data to Base Station (BS), In round i, node i mode N will send data to the BS. The total number of nodes in the network is given as N.

Merits: Performs better than LEACH for different network size and topology.

Limitation: Cannot mitigate the hotspot effect.

C0 -> C1 -> C2 <- C3 <-C4

BS

fig 2 : PEGASIS

PEBECS [4] – The Partition Energy Balanced and efficient clustering scheme.
In PEBECS, the WSN is divided into several partitions of equal size reasonably. Nodes in these partitions are grouped into unequal size clusters. The cluster heads closer to the sink will have smaller cluster size and the cluster heads away from the sink will have larger cluster size. Hence, cluster heads closer to sink can preserve energy for inter cluster communication. A node-weight heuristic algorithm is used to elect the cluster head. This algorithm considers the node's relative location in WSN, the node's degree difference and residual energy, such that more balanced load is achieved.

Merits: Performs better than LEACH.

Limitation: Cannot mitigate the hotspot effect.

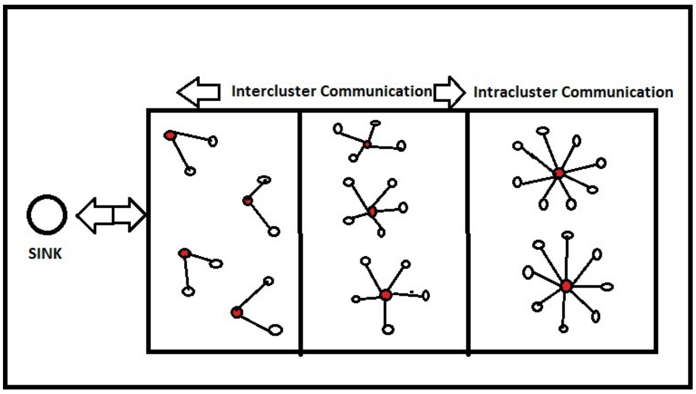

fig3: PEBECS

EC [5] – Energy-efficient Clustering.
EC determines the size of the cluster depending on the hop distance to the sink. EC achieves approximate equalization of node life time and minimized power consumption.

Merits: outperforms HEED and UCR.

Limitation: Cannot mitigate the hotspot effect.

DEAR [6] – Distance – based Energy Aware Routing.
DEAR optimize each individual distance so that all sensor nodes consume their energy at a similar rate. DEAR algorithm has a better performance in energy consumption as well as network life time.

Merits: Better performance in energy consumption and network life time.

Limitation: Cannot mitigate the hotspot effect.

AIMRP [7] – An Address Light Integrated MAC and Routing Protocol for Wireless Sensor Network.

AIMRP is proposed for WSN deployed for detecting rare events which require prompt detection and response. AIMRP organize network into concentric tiers around the sink, and routes event report by forwarding them from one tier to another, in the direction of the sink. AIMRP is address light in that it does not employ unique per-node addressing and integrated since the next hop is identified using the MAC control packets via an anycast query. The key features of AIMRP are

1. No per-node Addressing

A randomly chosen number is used to identify each communication.

2. Integrated MAC and Routing.

Routing is done by MAC control packet itself.

3. Power Saving Mode

AIMRP does not use synchronized power saving mode, each node will go through its own sleep / wake-up pattern.

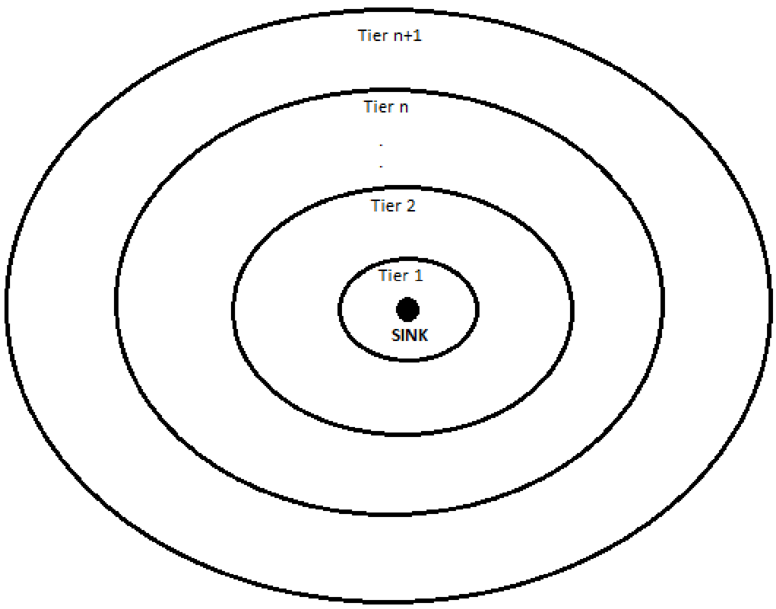

fig 4 : AIMRP

Merits: AIMRP outperforms SMAC for event detection application, in terms of total average power consumption while satisfying identical sensor-to-sink latency constraint.

Limitation: Cannot mitigate hotspot problem.

[8] Proposes a simple and efficient method to mitigate hotspot problem by placing additional sensor nodes around the base station. Also, analytically proved it. By placing additional sensor nodes around the sink the hotspot problem can be solved. Adding a limited number of nodes can drastically increase the life time of certain networks. The number of nodes that already present closer to the base station will make a greater impact on the gain.

The model partitions the set of all sensor nodes V into non-empty subsets S0, S1,......,Sn. Where V= S0 U S1 U S2 U .... U Sn, Si intersection Sj = Ø for all i not equal to j.

Si is the set of nodes reachable from the base station B in i hops, but not less than i hops. Hence, S0 = {B}. The sphere of radius i around S0 is called as Si. 'r' is considered as the amount of energy consumed for receiving one packet and ‘t’ is considered as the amount of energy consumed for transmitting one packet. Energy consumption in a sphere is given as

$$mi = ((N - bi)*r)/Si + ((N-bi+si)*t)/Si.$$

N- bi denotes the total number of nodes outside Bi. The nodes in si must forward N – bi + si packets in each iteration. The denominator Si is used to equally distribute the energy consumption for transmitting and receiving packets among all the nodes in Si.

max {m1, m2....., mn} will be equal to m1 for many sensor networks, i.e. the node that consumes most energy during one iteration is one hop away from the base station. By adding a limited number of nodes around the base station the lifetime of some networks can be increased four times.

Merits: Mitigates hotspot effect to a greater extent.

Limitation: More sensor nodes should be deployed.

[9] Discusses the following strategies for mitigating hotspot problem

a) Transmission Range optimization.

b) Sensor deployment Strategies.

a) Transmission Range Optimization

Transmission Range Optimization is the concept of having different nodes with different transmission ranges depending on the distance of the node form the sink, so that energy consumption can be more evenly distributed and the life time of the network can be extended.

Merits: Mitigates hotspot problem.

Limitation: Energy balancing is achieved at the cost of using the energy resources of certain nodes inefficiently.

b) Sensor Deployment Strategies.

Various sensor deployment strategies are available to extend network life time. These strategies include the i) movement of data sinks and ii) deployment of multiple sink.

i) Movement of Data Sinks

If the sink node is mobile, the sink node moves around the sensing area and collects data from the sensor nodes, thus effectively balancing the energy consumption in the WSN. If the sensor nodes are mobile, the nodes can adjust their position to help balance energy consumption in areas that have high transmission and mitigate network partition.

Merits: Mitigates hotspot problem.

Limitation: Deploying a mobile sink and nodes will increase the WSN's deployment cost.

ii) Deployment of multiple sink

By deploying multiple sink node the entire network traffic can be shared among these sink nodes.

Merits: Mitigates hotspot problem.

Limitation: Increases the WSN's deployment cost.

The following table shows the comparison of various techniques discussed so far.

Protocol/Technique	LEACH	HEED	PEGASIS	PEBECS	EC	DEAR	AIMRP	Placing More Nodes around Sink	Transmission Range Optimization	Sensor Deployment Strategies
Routing Type	Proactive	Proactive	Proactive	Proactive	Proactive	Proactive	Reactive	NA	NA	NA
Energy Level	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Homogeneous	Heterogeneous
Hop Count	One	One	Multihop	Multihop	Multihop	Multihop	Multihop	Multihop	Single Hop	Single Hop
Energy Efficency	Good	Better than LEACH	Better than LEACH	Better than LEACH	Outperforms HEED	Better than LEACH	Better than SMAC	Can Reduce the impact of Hot spot to a greater extent	Can reduce the impact of Hotspot effect.	Can reduce the impact of Hotspot to a greater extent.
Limitations	Not Suitable for large networks.	Cannot fully Mitigate Hot spot effect.	Cannot fully Mitigate Hot spot effect.	Cannot fully Mitigate Hot spot effect.	Cannot fully Mitigate Hot spot effect.	Cannot fully Mitigate Hot spot effect.	Cannot fully Mitigate Hot spot effect.	More Sensors should be deployed.	Energy resource of some nodes used inefficiently.	Increases WSN's deployment cost.

Conclusion

From the above discussions we conclude that, routing protocols may add energy efficiency or increase the life time of sensor networks. But, it cannot effectively mitigate the Hotspot problem. Hot spot problem can be mitigated by adding more sensor nodes in the hotspot area, by using intelligent power control technique or by using multiple data sink or using mobile sink. Any one of these techniques can be used with routing algorithm to effectively mitigate the hotspot problem.

References

[1] Wendi Rabiner Heinzelman, Anantha Chandrakasan, and Hari Balakrishnan, Energy-Efficient Communication Protocol for Wireless Microsensor Networks, IEEE Proceedings of the Hawaii International Conference on System Sciences, January 2000.

[2] Ossama Younis, Sonia Fahmy, HEED : A Hybrid, Energy-Efficient, Distributed Clustering Approach for Ad Hoc Sensor Networks, IEEE Transactions on Mobile Computing, Vol 3, No 4, October – December 2004.

[3] Stephanie Lindey, Cauligi S. Raghavendra, PEGASIS : Power-Efficient Gathering in Sensor Information Systems, In Proceedings of IEEE Aerospace Conference, USA, Montana, March 2002, Vol. 1 pp. 368 – 372.

[4] Y. Wang, T.L.X.Yang and D.Zhang, An Energy Efficient and Balance Hierarchical Unequal Clustering Algorithm for Large Scale Sensor Networks, Information Technology Journal, 2009.

[5] Dali Wei, Member, IEEE, Yichao Jin, Serdar Vural, Member, IEEE, Klaus Moessner, Member, IEEE, and Rahim Tafazolli, Member, IEEE, An Energy-efficient Clustering Solution for Wireless Sensor Networks, IEEE Transactions on Wireless Communications, September, 2011

[6] Jin Wang , Jeong-Uk Kim , Lei Shu , Yu Niu and Sungyoung Lee , A Distance-Based Energy Aware Routing Algorithm for Wireless Sensor Networks, Sensors 2010.

[7] Sunil Kulkarni, Aravind Iyer, Catherine Rosenberg, An Address-Light Integrated MAC and Routing Protocol for Wireless Sensor Networks, IEEE/ACM Transactions on Networking, Vol. 14, No.4, August 2006.

[8] Helena Rivas, Theimo Voigt, Adam Dunkels, A Simple and Efficient Method to Mitigate the Hot Spot Problem in Wireless Sensor Networks, In Proc. Of Performance Control in Wireless Sensor Networks, 2006.

[9] Mark Perillo, Zhao Cheng, Wendi Heinzelman, Strategies for Mitigating the Sensor Network Hot Spot Problem, Mobile and Ubiquitous Systems: Networking and Services, 2005.