Optimization Of Energy Consumption For Ensuring Reliable Communication In Wireless Sensor Networks

[1]Dr. Sudeep Saraswat,[2]Dr. Pradeep Pokhriyal
[1]Assisstant Professor,[2]Head of Department
[1]Computer Science and Engineering,
Modern Institute of Technology,Dhalwala, Rishikesh,Uttarakhand.

Abstract:

Wireless Sensor Networks (WSNs) are comprised of resource-constrained nodes with limited battery power. Energy efficiency is paramount for extending network lifetime while maintaining reliable communication. This paper explores various optimization techniques for minimizing energy consumption in WSNs, focusing on routing protocols, data aggregation, duty cycling, and energy harvesting. We analyze the trade-offs between energy efficiency and communication reliability, highlighting the challenges and future directions in this critical area of research.

This paper proposes a Source-Intimated and Energy-Efficient Protocol (SIEEP) to address energy in efficiency in wireless sensor networks. The protocol integrates source-node awareness and adaptive energy management to optimize routing paths and reduce energy consumption. Simulations demonstrate significant improvements in network lifetime and reliability compared to existing protocols.

Keywords:

Wireless Sensor Networks, Energy Efficiency, Source-Intimation, Routing Protocols, Network Lifetime, Adaptive Communication.

1. Introduction

Wireless Sensor Networks (WSNs) have become ubiquitous in various applications, including environmental monitoring, healthcare, industrial automation, and smart cities. These networks consist of numerous tiny sensor nodes, each equipped with sensing, processing, and communication capabilities. However, the limited battery capacity of sensor nodes poses a significant challenge to the longevity and reliability of WSNs. Energy efficiency is therefore a critical concern in designing and deploying WSNs.

2. Energy Consumption in WSNs

The primary sources of energy consumption in WSNs include:

- **Sensing:** Acquiring data from the environment.
- **Communication:** Transmitting and receiving data.
- **Data processing:** Performing computations and aggregations.
- **Idle listening:** Waiting for events or data.

Communication is the most energy-intensive task, particularly for long-distance transmissions. Optimizing communication protocols and minimizing data transmission are crucial for energy conservation.

3. Optimization Techniques

3.1 Energy-Efficient Routing Protocols

Routing protocols determine how data is transmitted from sensor nodes to the base station. Energy-efficient routing protocols aim to minimize the energy consumed by data transmission.

Some of the most popular energy-efficient routing protocols include:

- **LEACH (Low-Energy Adaptive Clustering Hierarchy):** LEACH is a clustering-based protocol that selects cluster heads based on their energy level. Cluster heads (CH)are responsible for collecting data from their cluster members and forwarding it to the base station. During efficient routing ,rotaion of CH is done periodically for balancing the energy consumption.Various variants of LEACH can be used for optimization:

LEACH VARIANTS	OPTIMIZATION FOCUS
Centalized LEACH (LEACH -C)	Base Station can optimize the CH for better energy efficiency.
Fixed Cluster LEACH(LEACH-F)	Formation of CH may be fixed for reduced overhead.
Machinre Learning LEACH(ML- LEACH)	It uses the AI based selection of CH for better transmission and optimization.

- **PEACH (Periodic, Energy-Aware Clustering Hierarchy):** PEACH is a variation of LEACH that improves energy efficiency by using a periodic clustering scheme.

- **PEGASIS (Power-Efficient Gathering in Sensor Information Systems):** PEGASIS is a chain-based protocol that forms a chain of sensor nodes. Data is then transmitted along the chain to the base station.It selects the Leader Nodes to transmit the data.Unlike LEACH, where CH transmit directly to the base station,PEGASIS significantly redices energy consumtion by using Multihop transmission. The Leader Node rotates among different nodes,preventing energy depletion in a single node.Variations of PEGASIS used for energy efficiency may be:

PEGASIS VARIANTS	OPTIMIZATION FOCUS
Heirarchical PEGASIS	Multi level chains for large Scale WSNs.
Mobile PEGASIS	It can be used for Mobile nodes.
Energy Aware PEGASIS	Selection of Leader Node is done on the basis of residual energy of nodes in WSNs.

- **TEEN(Thersold Sensitive Energy Efficient Sensor Network Protocol):** This protocol is designed for time based applications.It introduces hierarchical clustering methods into two thersolds named Hard and Soft Thersolds.Sensor nodes can transmit the data only when sensed events are in the range of internet by conserving energy.

- **GAF(Geographic Adaptive Fidelity):** GAF can preserve the energy by identifying nodes that are equivalent from routing perspective and turning off the unnecessary nodes for conservation of energy.

3.2 Data Aggregation

Data aggregation is a technique that reduces the amount of data that needs to be transmitted by combining data from multiple nodes. This can be done by using a variety of techniques, such as:

- **Data fusion:** This technique combines data from multiple nodes to create a more accurate or complete picture of the environment.

- **Data compression:** This technique reduces the size of data packets by removing redundant or unnecessary information.

3.3 Duty Cycling

Duty cycling is a technique that turns off sensor nodes when they are not needed to conserve energy. This can be done by using a variety of techniques, such as:

- **Scheduled duty cycling:** Sensor nodes are turned on and off according to a predetermined schedule.
- **Event-driven duty cycling:** Sensor nodes are turned on only when an event of interest occurs.

Duty Cycling can be measured with following formula:

Duty Cycle = $T_{active} / (T_{active} + T_{sleep}) * 100$

Where T_{active} = Active time for sensor node while conservation of energy.

T_{sleep} = Sleep time of sensor node for conservation of energy.

3.4. Energy Harvesting

Energy harvesting is a technique that allows sensor nodes to replenish their energy from the environment. This can be done by using a variety of techniques, such as:

- **Solar energy harvesting:** Sensor nodes can use solar panels to convert sunlight into electricity.
- **Vibration energy harvesting:** Sensor nodes can use piezoelectric devices to convert mechanical vibrations into electricity.

3.5 Trade-offs and Challenges

Optimizing energy consumption often involves trade-offs with other performance metrics, such as:

- **Communication latency:** Energy-efficient routing protocols may introduce delays in data delivery.
- **Network reliability:** Aggressive duty cycling may lead to missed events or data loss.
- **Deployment cost:** Energy harvesting solutions may require additional hardware and infrastructure.

4. Source-Intimation

InWSN source intimation can be a mechanism of notifying the specific node about an event sensed or detected by sensor node.It can play significant role in data transmission,energy consumption and to reduce network overload.

4.1 Routing Protocols for Source Intimation

The routing protocols for source intimation can use LEACH,PDORP for direct data transmission in WSN to ensure occurance of specific event. Since WSN have energy constraints, source intimation must reduce redundanr transmission to reduce overhead on network.

LEACH can support formation of clusters, which are self organized nodes in the network.Among various nodes any node can be choosen as Cluster Head(CH). This Cluster Head node can directly receive the sensed event from the sensor node.After receiving the event, CH can regenerate the energy of received signal and propogates towards Base Station. In WSN various CH nodes can be used to enhance the efficiency. These nodes also supports Adaptive Transmission .

PDORP is designed for enhancing the source intimation process by selecting the optimal paths in dynamic nature.It selects the best forwarding nodes on the basis of sufficient energy levels and distance from the base station.During this ,it may set the priority of selecting the nodes by reducing the un-wanted hopes and delays.PDORP also manage the load balancing by distributing the transmission load to prevent the energy depletion ona specific region of the network.

5. Challenges and Future Directions

There are a number of challenges in energy optimization for WSNs, such as:

- **Scalability:** WSNs can be deployed in large numbers, which makes it difficult to manage energy consumption.
- **Reliability:** WSNs need to be reliable in order to provide accurate data.

- **Security:** WSNs need to be secure from unauthorized access.

Future research in energy optimization for WSNs will focus on addressing these challenges.

7. Conclusion

Energy efficiency is a critical issue in WSNs. There are a number of techniques that have been proposed to reduce energy consumption, such as energy-efficient routing protocols, data aggregation, duty cycling, and energy harvesting. Future research will focus on developing new and innovative techniques to further improve energy efficiency in WSNs.

REFERENCES

[1] Heinzelman, W., Chandrakasn, A., and Balakrishnan, H.," Energy-Efficient Commnication Protocol for Wireless Microsensor Networks",Proceeding of 33rd Hawaiian International Conference on System Science (HICSS),January 2000.

[2] Lindsey,S., and Raghvendra,C.S.,"PEGASIS: Power Efficient Gathering in Snesor Information System"Proceeding of the IEEE Aerospace Conference,2002.

[3] Manjeshwar,A., and Agarwal, D.P.,"TEEN: A Routong Protocol for Enhanced Efficiency in Wireless Sensor Network", Proceeding of the 15th international Parallel and Distributed Processing Sysmposium,2001.

[4] M. Merck."The icecube detector: A large sensor network at the south pole". IEEE Pervasive Computing, 2010, vol. (4), pp 43-47.

[5] Arnau Rovira Sugranes a, Abolfazl Razi b, Fatemeh Afghah c and Jacob Chakareski, "A review of AIenabled routing protocols for UAV networks: Trends, challenges, and future outlook", Ad Hoc Networks, Vol.130, doi.org/10.1016/j.adhoc.2022.102790, 2022.

[6] Qianqian Sang, Honghai Wu, Ling Xing and Ping Xie, "Review and comparison of emerging routing protocols in flying Ad Hoc networks", Symmetry, 12 (2020), p. 971, 10.3390/sym12060971, 2020.

[7] Shivashankar and Varaprasad G, "Performance analysis of EEDR routing protocol for WSN", IET Journal of Wireless Sensor Systems, Vol. No.7, ISSN: 2043-6386, doi: 10.1049/ietwss.2016.0029.ISSN: 2043-6394, 2017.

[8] Rajendra Prasad P and Shivashankar, "Efficient Performance Analysis of Energy aware on demand Routing Protocol in Mobile Ad-Hoc Network", Wiley PublicationEngineering Report, Vol.2, Issue-3, ISSN: 2577-8196, DOI: 10.1002/eng2.12116, 2021.

[9] Shivashankar and Rajendra Prasad, "Enhanced Energy Efficient Secure Routing Protocol for Mobile Ad-Hoc Network", Global Transitions Proceedings, KeAi Publishing, Vol. 3, doi.org/10.1016/j.gltp.2021.10.001, 2022

[10] Hitesh Mohapatra1 and Amiya Kumar Rath, "Fault-tolerant mechanism for wireless sensor network", IET Wireless Sensor Systems, Vol. 10, pp. 23-30, doi: 10.1049/iet-wss.2019.0106, 2020.