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EFFICIENT DATA AGGREGATION TECHNIQUES FOR ENERGY CONSERVATION IN WIRELESS SENSOR NETWORKS

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ABSTRACT
Wireless Sensor Networks (WSNs) are pivotal in various applications, ranging from environmental monitoring to healthcare. However, the limited energy capacity of sensor nodes poses a significant challenge known as the "energy hole" problem, wherein nodes closer to the sink node deplete their energy faster due to frequent data transmissions, leading to network partitioning and reduced network lifetime. Data aggregation, a key technique in WSNs, aims to mitigate this issue by reducing the amount of data transmitted and thus conserving energy. This paper presents an overview of data aggregation techniques in WSNs, including in-network aggregation, data fusion, and compression, highlighting their benefits in terms of energy efficiency, latency reduction, and network lifetime extension. Additionally, the paper discusses open research challenges and future directions in data aggregation, emphasizing the need for novel algorithms and protocols to further enhance the performance of WSNs in mitigating the energy-hole problem.

Keywords: WSNs; Data Gathering; Data aggregation; Clustered based protocols; Single Hop; Multi Hop;

INTRODUCTION:
Wireless Sensor Networks (WSNs) have emerged as a promising technology for monitoring and gathering data in diverse applications, including environmental monitoring, healthcare, and industrial automation [1]. In WSNs, a large number of small, inexpensive sensor nodes are deployed to collaboratively monitor physical or environmental conditions, such as temperature, humidity, and light intensity. These nodes communicate wirelessly with each other to aggregate and transmit data to a sink node or base station [2], which processes the data for further analysis. One of the major challenges in WSNs is the limited energy supply of sensor nodes. The energy consumption for data transmission is significantly higher than that for data processing and sensing. As a result, nodes closer to the sink node tend to deplete their energy faster due to frequent data transmissions, leading to an uneven distribution of energy consumption across the network. This phenomenon, known as the "energy hole" problem, can result in partitioning and reduced network lifetime [3]. Data aggregation is a key technique to address the energy hole problem in WSNs. Data aggregation aims to reduce the amount of data transmitted in the network by merging similar or redundant data [4] packets at intermediate nodes before forwarding them to the sink node. By aggregating data packets, the number of transmissions and the energy consumption can be significantly reduced, thus prolonging the network lifetime. This paper provides an overview of data aggregation techniques in WSNs, including in-network aggregation, data fusion, and compression. It discusses the benefits of data aggregation regarding energy efficiency, latency reduction, and network lifetime extension. Furthermore, the paper highlights the challenges and open research issues in data aggregation, emphasizing the need for novel algorithms and protocols to improve the performance of WSNs in mitigating the energy-hole problem.

Data aggregation techniques in wireless sensor networks (WSNs) are essential for reducing the amount of data transmitted and thereby conserving energy. Here are some common techniques:

In-Network Aggregation: In this technique, intermediate nodes in the network aggregate data from multiple sources before forwarding it to the sink node. This reduces the number of transmissions and saves energy. In-network aggregation can be static or dynamic, depending on whether the aggregation functions are fixed or can be changed based on network conditions.

Data Fusion: Data fusion combines data from multiple sources to create a more accurate and complete representation of the monitored phenomenon. This can reduce the amount of data transmitted by eliminating redundant or correlated information.

Spatial Correlation Exploitation: This technique leverages the spatial correlation of sensor data to reduce redundancy. Nodes can estimate the correlation between their own data and that of their neighbours and only transmit data that provides new information.

Temporal Correlation Exploitation: Similar to spatial correlation, temporal correlation exploits the correlation between data collected at different times. Nodes can use this technique to determine if transmitting new data is necessary or if previously transmitted data is still relevant.

Data Compression: Data compression techniques reduce the size of data packets before transmission. This can be done using algorithms such as Huffman coding, run-length encoding, or differential coding, among others.

Event Detection and Reporting: Instead of reporting raw sensor data, nodes can detect and report specific events or anomalies. This reduces the amount of data transmitted while still providing relevant information.

Cluster-Based Aggregation: Nodes in a WSN can be organized into clusters, with a cluster head responsible for aggregating data from cluster members before forwarding it to the sink node. This reduces the energy consumption of individual nodes and can improve scalability.

Quality-Aware Aggregation: This technique considers the quality of the data being aggregated, such as its accuracy or reliability. Nodes can use this information to make decisions about whether to aggregate or transmit data based on its quality.

These techniques can be used individually or in combination to improve the energy efficiency and performance of WSNs. The choice of technique depends on the specific requirements of the application and the characteristics of the sensor network.

Clustered Based Protocol:

In a wireless sensor network, clustering-based aggregation protocol is a technique for minimising communication and optimising network lifetime. By aggregating data inside the network, clustering lowers direct transmission to the base station and lowers energy usage by shortening the transmitting distance. Hierarchical clustering offers superior node aggregation for big numbers. [5][6][7][8].

Cluster-based Protocols have two types: Homogenous (It again has two sub-parts -single hop and multi-hop) and Heterogenous (It also has two parts -single hop and multi-hop).

Homogenous Single Hop:

Low energy adaptive clustering hierarchy, or LEACH, is a system. It guards against battery depletion and maintains the energy consumption stability of nodes. However, it consumes a significant amount of energy when the Cluster Head (CH) is far from the sink and wastes energy during the CH selection phase. Furthermore, it does not ensure a good distribution of CH.

LEACH-C: The base station starts a centralised method in LEACH_C (Low energy adaptive clustering hierarchy centralised) to elect the CHs based on their location information. It creates more evenly balanced clusters. However, it is not resilient and wastes energy to obtain global information.

LEACH-F-(Fixed): Based on the LEACH protocol, LEACH-F is an efficient clustering algorithm that fixes a cluster after it forms. It also minimises setup overhead by distributing the energy usage among the sensors. Despite having a fixed round period, it wastes information and energy when the CH dies before the round's energy limit is reached.

CLUDDA: Clustered diffusion with dynamic data aggregation, is a type of CLUDD that uses in-network processing to cut out unnecessary transmission and prevent flooding issues. Additionally, dynamic data aggregation points are achieved. However, it increases latency and requires a large amount of RAM.

Sleach (Solar aware LEACH): Solar energy lengthens the lifespan of networks. It is applied to the distributed and centralised CH selection algorithms.

LEACH-ET (Energy Threshold): The Energy Threshold (ET) algorithm determines how many times the LEACH algorithm should rotate. It saves energy by shortening the round rotational period. Nonetheless, the transmission of control signals uses a lot of energy during that process. It is not capable of supporting ongoing observation.

E-LEACH (Energy): The two-phase E-LEACH [9] methodology is similarly divided into rounds in the first phase. Although it preserves the remaining energy of nodes, energy is lost because of timed rounds.

RRCH (Round Robin Cluster Head Protocol): The RRCH reduces energy consumption but adds additional overhead to achieve high energy efficiency. There is only one setup procedure.

MLEACH-L (More energy efficient LEACH): MLEACH for Extensive the WSN protocol interprets two WSN problems: the sharing of channels among neighbours in the same cluster and the collaboration of CHs in data computation. But it also adds to the setup time and additional costs.

TB-LEACH (Time-Based Cluster head selection algorithm for LEACH): The methodology known as TB-LEACH only modifies the CH selection process. Although it prolongs the life of networks, it is ineffective in expansive situations.

HOMOGENOUS MULTI-HOP:

M-LEACH (Multi-hop Leach): Although it is suitable for big networks, its scalability is restricted and it has hotspot issues.

TL-LEACH (Two Level LEACH): By distributing the energy load across the sensors in dense networks, this method lowers energy usage. It is not appropriate for far-dispersed networks, though.

LEACH-L: It lowers energy usage and balances the network load. But has additional overhead.

MS-LEACH (combines multi-hop and single-hop): Through the amalgamation of single-hop and multi-hop transmission nodes, it lowers energy usage. but has additional expenses and restricted scalability.

HETEROGENOUS SINGLE HOP:

EECHE (energy efficient cluster head election protocol): It has limited scalability but outperforms LEACH and SEP in terms of throughput, lifetime network, and low latency.

NEAP (Novel Energy adaptive protocol for heterogeneous wireless sensor networks): Although its scalability is limited and it is not possible to select CH that is located far from the washbasin, its reliability has increased.

HETEROGENOUS MULTI-HOP PROTOCOLS:

SEP (Stable election protocol): Node energy information does not need to be gathered every round, however, multilevel networks cannot use it.

HEED (Hybrid energy efficient distributed clustering): It maintains power stability among nodes and regulates the Above Drawbacks including restricted scalability and a delay.

LEACH-HPR: The strongest node in this CH is chosen as a helper node to help stabilise energy usage, however, it has additional overhead.

LITERATURE REVIEWS:

(Al-Qurabat, 2020) By using data aggregation techniques, the author created a new, energy-efficient routing protocol for wireless sensor networks (WSN) called an efficient reliable routing protocol. The main goal of data aggregation is to gather and aggregate data in an energy-efficient way, thereby extending the lifetime of the network.

(Abdulzahra, 2020) The author suggested a data fusion method for large-scale WSN resource efficiency. Reducing the number of nodes that are active in the network through data fusion lowers the amount of resources that are consumed by the network.

(Qayyum, B., 2015) The author offered network coding-based adaptive data aggregation that is energy-efficient (ADANC). Simple relay nodes and network coder nodes are the two types of sensor nodes in a cluster that make up this energy-oriented cluster-based data aggregation technique. Aggregator nodes are network coder nodes. The degree of data correlation determines how data is aggregated. Network encoding is carried out if the amount of data correlation factor in the received packets is lower. If the data correlation factor is strong, conventional data aggregation is carried out.

(V.Akhila, 2017) A novel data aggregation algorithm called ERDL (Efficient and Real-time algorithm based on a Dynamic message list) was proposed by the author. A dynamic list will be formed in the filtering node to preserve the history messages that this node has ever relayed. ERDL is based on the network layer of WSNs. Whether or not a message is duplicated, it will all be evaluated in WSNs based on the information in the list. Improved filtering efficiency and guaranteed real-time transmit performance are two benefits of ERDL.

(Peiman Ghaffariyan, 2010) The author designated path (DP) scheme, an energy-balanced and effective data aggregation method for WSNs, was proposed by the author. To allow every node to contribute to the effort of collecting data and sending it to the sink, the DP method identified several paths and executed them in a round-robin manner. However, the energy dissipation rose.

(Yaeghoobi, 2014) The author introduced a concept for data aggregation architecture that incorporates a hierarchical structure with several resolutions and computer science to maximise data transmission efficiency.

(Sabri, 2014) The data density correlation degree (DDCD) clustering algorithm and data density correlation degree (DDC) were introduced by the author. In cluster-based data aggregation networks created by the DDCD clustering approach, sensor nodes with strong correlation are separated into the same cluster, enabling more accurate aggregated data to be retrieved. Additionally, less data may be sent to the sink node.

(M. MehdiAfsar, 2014) The author suggested using mobility to collect data and refill energy simultaneously. SenCar, a multipurpose mobile device, was used as an energy transporter that uses wireless energy transmissions to charge static sensors while it migrates, in addition to serving as a mobile data collector that roams the field collecting data via short-range communication.

(Anuradha Rai, 2016) The author presents the mobility in the network to suggest a method for collecting data for WSN. A mobile collector, or M-collector, is a device that functions as a mobile base station that gathers data while travelling throughout an area. It might be a robot or a car that has a transceiver and a large battery. The M-collector periodically collects data from the static sink, polls each sensor when it passes over its communication range, and then sends the data to the static sink.

CONCLUSION

Efficient data aggregation techniques are crucial for optimizing energy consumption and prolonging the network lifetime in Wireless Sensor Networks (WSNs). This paper has reviewed several techniques, including clustering-based protocols and data aggregation approaches. Clustering-based protocols, such as LEACH and its variants, aim to organize sensor nodes into clusters to reduce energy consumption during data transmission. These protocols achieve this by aggregating data at the cluster head before forwarding it to the base station. On the other hand, data aggregation techniques focus on aggregating similar data packets to reduce redundancy and conserve energy. In conclusion, the effectiveness of data aggregation techniques in WSNs depends on various factors, including network topology, traffic patterns, and application requirements. Researchers continue to explore new approaches to further improve the efficiency of data aggregation in WSNs. By selecting the appropriate technique based on the specific network characteristics, it is possible to enhance the overall performance and prolong the network lifetime in WSNs.

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