Data Collection Method and their Approaches in Wireless Sensor Network

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Abstract— Data collection is one of the critical issue in the wireless sensor network. WSNs consist of a large number of sensors distributed across a geographical area to monitor and collect data from the environment. In this paper we have highlighted some of the component and there function that how the data is gathered. Some of the techniques are shown with the key metrics with formulas using different evaluation parameters. Even included the analytical model for the energy efficiency. Have discussed the issues and previous solutions related to both data gathering protocol design and data dissemination protocol design in wireless sensor networks (WSNs).Data collection is based on regular and non regular mode from which the data is sensed by defining the characteristics. In this survey paper we have mentioned the protocols of the data gathering with approach and key features which may have impact on the performance.

Key words: Wireless Sensor Network, Protocol, Data Gathering, Data Dissemination, Regular And Non Regular Mode, Sink Node

I. INTRODUCTION

Data collection is indeed one of the fundamental and significant applications of Wireless Sensor Networks (WSNs). The ability to continuously collect data from distributed sensor nodes and transmit it to a central base station or other designated entities for analysis and processing is a key feature of WSNs.

Absolutely, the unique characteristics of wireless sensor networks (WSNs) introduce both opportunities and challenges in their deployment and operation like limited sensor node lifetime, Energy Efficiency, Deployment flexibility, Maintenance and redeployment; even some of the challenges are wireless communication challenges. [1] WSNs find applications in various fields such as environmental monitoring, agriculture, healthcare, smart homes, industrial automation, and more. They provide valuable insights, automate processes, and improve decision-making by utilizing the data gathered from the sensors in the network.

Wireless Sensor Networks (WSNs) are indeed networks composed of small hardware units equipped with sensors capable of sensing, monitoring, or measuring their environment. These sensors are deployed in various locations to gather data about the physical world such as temperature, humidity, light levels, pressure, etc. The collected data is then transmitted either directly or via relays to a central node, often referred to as a sink, base station, or server.[2].It include the key component and function :

Sensor Nodes: Sensor nodes are the fundamental building blocks of a WSN. These nodes consist of a sensor to measure physical parameters and a small-scale processing unit to analyze and process the collected data. Each node is typically equipped with a communication module for transmitting data to other nodes or a central data collection point.

- Sensing and Data Collection: Sensor nodes continuously monitor their surroundings and collect data from the sensors. The sensors can measure a wide range of parameters such as temperature, humidity, light intensity, motion, etc., depending on the application.
- Communication: The collected data is then transmitted using wireless communication protocols. Nodes communicate with each other to share data and relay it to a designated base station or sink node. Communication can be direct to the base station or relayed through intermediate nodes to extend the network's coverage range.
- Base Station or Sink: The base station or sink is a central node that serves as a collection point for the data gathered from the sensor nodes. It usually has more computational power and storage capacity compared to the sensor nodes. The sink aggregates and processes the data received from multiple sensor nodes for further analysis and decision-making.
- Data Processing and Analysis: The sink processes and analyzes the collected data to derive meaningful insights or make informed decisions. Data processing may involve filtering, aggregation, compression, and other operations to reduce the amount of data transmitted and improve efficiency.
- Application Layer: The application layer involves specific applications or services that utilize the data collected by the sensor nodes. These applications can vary widely based on the purpose of the WSN, ranging from environmental monitoring to healthcare and industrial automation.

II. OBJECTIVES AND KEY METRICS FOR EVALUATION

The main objective of the paper is to conduct a comparative analysis of advanced data collection techniques within wireless sensor networks (WSNs). The focus is on evaluating these techniques based on a trade-off between reliability, energy consumption, and considering both compression and networking aspects. Specifically, the evaluation involves examining packet loss, reconstruction error, and network lifetime as key metric[4]s.

A. *Reliability Metrics:*

- Packet Loss: This metric measures the percentage of data packets that are lost during transmission. Lower packet loss indicates better reliability in data transmission within the network.
- Reconstruction Error: Reconstruction error assesses the accuracy of reconstructing the original data from compressed or transmitted data. Lower reconstruction error implies a more reliable reconstruction process.

B. *Energy Consumption:*

Network Lifetime: Network lifetime refers to the duration for which the wireless sensor network can operate efficiently without requiring a significant increase in energy, especially for critical components like sensor nodes. Maximizing network lifetime is crucial for sustainable and long-term WSN deployments.

C. *Advanced Data Collection Techniques:*

- Data Compression Algorithms: Different compression algorithms and techniques (e.g., lossless, lossy) to reduce the amount of data transmitted and consequently save energy.
- Networking Protocols and Strategies: Various networking protocols and strategies for efficient data transmission, including direct transmission, clustering, multi-hop communication, etc.

D. *Trade-off Analysis:*

The paper aims to strike a balance between the reliability metrics (packet loss, reconstruction error) and energy consumption (network lifetime). It will analyze how different data collection techniques affect these parameters and how to optimize for a favorable trade-off. Creating a simple analytical model to predict the energy efficiency and reliability of various data collection techniques in wireless sensor networks involves identifying key parameters and relationships that influence these aspects. A high-level approach to develop a basic analytical model:

Define the parameters that significantly affect energy efficiency and reliability, such as:

- Data compression ratio (related to energy efficiency)
- Packet loss rate (related to reliability)
- Network topology and communication range
- Transmission power levels
- Duty cycle and sleep schedule

E. *Formulate Energy Efficiency Model:*

- Consider a basic energy consumption model based on data compression ratio and transmission distance. For example: Energy
- Consumption ∝ Data Size / Data Compression Ratio + Transmission Distance
- Formulate Reliability Model: Reliability can be a function of packet loss rate and network topology. For example:
- Reliability ∝ 1 / (Packet Loss Rate + Network Topology Factor)
- Integrate the energy efficiency and reliability models to create a combined metric that balances both aspects, considering the trade-off. For example:
- Combined Metric = (Energy Efficiency Weight * Energy Consumption) + (Reliability Weight * Reliability)
- Optimization and Sensitivity Analysis: Perform optimization or sensitivity analysis to determine optimal values for parameters that maximize the combined metric while considering different weights for energy efficiency

III. SENSED DATA COLLECTION

In wireless sensor networks (WSNs), the collection of sensed data can occur in either a regular or non-regular mode, each with its own characteristics and implications[11].

1) Regular Mode: In the regular mode of data collection, sensor nodes follow a predefined and systematic schedule for data transmission. This schedule can be based on time intervals, event triggers, or other predetermined criteria. The key features of regular mode data collection include: Fixed Schedule: Sensor nodes transmit data at consistent and regular intervals, which could be set based on the application requirements or a predefined time schedule. Predictability: The data collection times and intervals are predictable, aiding in resource allocation, energy management, and network planning. Controlled Energy Consumption: Since the data transmission schedule is predetermined, energy consumption can be more controlled and managed efficiently, contributing to longer network lifetime. Regular mode often involves synchronized communication among nodes, ensuring that data transmissions align with the predetermined schedule[5].
2) Non-Regular Mode: In the non-regular mode of data collection, sensor nodes do not follow a fixed or predefined schedule for data transmission. Instead, the transmission may be triggered by specific events, thresholds, or dynamically changing conditions. The key features of non-regular mode data collection include: Event-Driven - Data transmission is initiated based on detected events or certain conditions being met, leading to more target and efficient data collection. Variable Intervals - Transmission intervals may vary based on the occurrence and nature of events, providing flexibility in adapting to changing environmental conditions.
3) Energy Efficiency for Bursty Data: This mode can be more energy-efficient for bursty or sporadic data patterns, as nodes transmit data only when necessary, reducing unnecessary communication. The data collection times and intervals are less

predictable compared to the regular mode, making it important to adapt to dynamic network conditions. Choosing between regular and non-regular modes of data collection depends on the specific application, the nature of the sensed data, the energy constraints of the network, and the desired trade-offs between predictability, energy efficiency, and responsiveness to events. Balancing these factors is essential to optimize the performance and efficiency of the wireless sensor network for the intended application

WSN applications based on their data collection requirements. The table includes the application name, data collection frequency, data transmission mode, and data collection requirements. Some of the application have been mentioned in the table on the bases of the mode and there parameters[10]

Application Name	Data Collection Frequency	Data Transmission Mode	Data Collection Requirements
Environmental Monitoring	Regular or Event-Driven	Wireless Transmission	High accuracy in measuring temperature, humidity, air quality; Regular monitoring for trend analysis
Precision Agriculture	Regular	Wireless Transmission	Accurate and timely data on soil moisture, temperature, crop health; Uniform data sampling across the field
Healthcare Monitoring	Event-Driven	Wireless Transmission	Real-time monitoring of vital signs (heart rate, blood pressure); Immediate response to critical events
Industrial Automation	Regular	Wireless Transmission	Real-time monitoring of machinery status, temperature, pressure; Predictive maintenance scheduling
Traffic Management	Regular	Wireless Transmission	Continuous traffic flow data for congestion detection, route optimization; High-frequency data collection
Structural Health Monitoring	Event-Driven	Wireless Transmission	Immediate detection of structural changes, vibrations, and stress; Triggered data collection based on events
Disaster Response	Event-Driven	Wireless Transmission	Rapid data collection during disasters (e.g., earthquakes, floods); Reliability and robustness in adverse conditions
Wildlife Monitoring	Event-Driven	Wireless Transmission	On-demand data collection triggered by animal movements or specific events; Long battery life for extended deployments
Smart Grids	Regular	Wireless Transmission	Continuous monitoring of energy consumption, grid stability; Real-time data for load balancing and fault detection
Smart Homes	Regular or Event-Driven	Wireless Transmission	Real-time data on energy usage, home security; Event-triggered data collection for energy-saving protocols

IV. APPROACHES OF DATA COLLECTION

Data collection methods in wireless sensor networks (WSNs) are indeed broadly classified into various approaches, including data collection using mobile sensor nodes, data collection using a static sink approach, and data collection using a mobility-based approach. Let see different method of each[1]:

- Data Collection Using Mobile Sensor Nodes: In this approach, sensor nodes are mobile and can move within the network area. They traverse the environment to collect data from different locations. Mobile sensor nodes can follow a predefined path, a random path, or be guided by specific algorithms to gather data. The mobility of nodes allows for dynamic and flexible data collection, making it suitable for scenarios where the environment changes rapidly or where targeted data collection is needed in specific regions.
- Data Collection Using a Static Sink Approach: In this approach, data is collected and aggregated by stationary or static sink nodes strategically placed within the sensor network. Sensor nodes detect and gather data locally and then transmit it to the nearby sink nodes for further aggregation and forwarding to a central server or data storage. The sink nodes act as collection points, aggregating data from the surrounding sensor nodes and minimizing redundant transmissions. This approach is efficient for scenarios where fixed data collection points are practical and provide good coverage of the sensor field.
- Data Collection Using a Mobility-Based Approach: In this approach, a designated mobile entity (e.g., a drone, robot, or vehicle) is used to collect data from the sensor nodes. The mobile entity follows a predefined or adaptive path to traverse the network area and collect data from the deployed sensor nodes.Mobility-based approaches can improve data collection efficiency and coverage, especially in large-scale or remote environments, by reaching areas that may be challenging for static sensor nodes to cover effectively.

These approaches can be further customized based on specific requirements and application scenarios. The choice of the data collection method depends on factors such as the application domain, deployment environment, desired data granularity, energy efficiency considerations, and the need for adaptability and coverage. Each of these methods offers advantages, and their selection is based on the particular needs of the application and the efficiency and effectiveness required for data collection within the wireless sensor network.

V. DATA DISSEMINATION

Data dissemination in sensor networks involves the transmission of data from sensor nodes to sink nodes, base stations, or other designated data collection points. This process is essential for enabling data analysis, decision-making, and application-specific actions. Let see step-by-step description of how data dissemination typically takes place in a sensor network[1]:

- Data Processing and Aggregation: Sensor nodes may process and aggregate the collected data locally to reduce redundancy and minimize the amount of data that needs to be transmitted[8].
- Data Packaging: The collected and potentially aggregated data is then packaged into messages or packets for transmission.
- Route Determination: In a multi-hop scenario, sensor nodes determine the optimal route to the sink node or base station where the data will be sent. This can be based on routing algorithms, network topology, and energy-aware routing to prolong network lifetime[3].
- Transmission Initiation: Sensor nodes initiate the data transmission process, either based on a predefined schedule, event triggers, or other criteria, depending on the data collection mode (e.g., regular, event-driven).
- Data Transmission: The sensor nodes transmit the data packets through wireless communication to the sink node or designated data collection point.In multi-hop communication, data is relayed through intermediate nodes before reaching the sink node. Data Aggregation (Optional):In some cases, intermediate nodes aggregate data from multiple nodes before forwarding it to further reduce the amount of transmitted data and minimize energy consumption[8].
- Sink Node or Base Station Reception: The sink node or base station receives the transmitted data packets and stores them for further analysis or processing. Data Analysis and Utilization: The collected data is analyzed, processed, and used for various applications, decision-making, or actions based on the objectives of the sensor network deployment. Depending on the specific application and network design, variations of this process may occur. For example, in event-driven scenarios, data dissemination may be triggered by a detected event, and transmission may follow a different set of rules compared to regular data collection[5].

Efficient data dissemination is crucial for optimizing energy consumption, minimizing latency, ensuring data reliability, and maximizing the utility of the sensor network for its intended purpose. The choice of data dissemination strategies depends on the application requirements, network conditions, and the trade-offs between energy efficiency and other performance metrics.

VI. DATA COLLECTION PROTOCOL

Data collection protocols in wireless sensor networks (WSNs) define the rules and procedures for efficiently collecting and transmitting data from sensor nodes to a central data sink or base station. These protocols are crucial for optimizing data communication, ensuring reliability, conserving energy, and meeting the specific requirements of the WSN application. Here are some commonly used data collection protocols in WSNs. These protocols are designed to address different challenges and requirements in data collection within WSNs, ranging from energy efficiency to event-driven data collection and multimedia handling.[3] The choice of protocol depends on the specific application, network characteristics, and objectives of the sensor network

Protocol Name	Approach	Key Features
LEACH	Clustering	Hierarchical structure, probabilistic cluster head selection, energy-efficient data transmission.
PEGASIS	Chain-based	Chain formation, data aggregation within chains, reduced long-distance communication.
SPIN	Data-centric	Query/response model, negotiation for data sharing, reduced data redundancy.
Directed Diffusion	Gradient-based	Data-centric approach, interest propagation via gradients, reinforcement of data flow.
TEEN	Event-driven	Threshold-based data collection, event-triggered transmission, energy efficiency.
BVR (Balanced Virtual Ring)	Clustering	Virtual ring structure, balanced energy consumption, data transmission within clusters.
COUGAR	Underground	Deployment in underground environments, efficient routing and data aggregation.
MMSPEED	Multimedia	Handling of multimedia data types, multi-modal data processing, efficient routing.

VII. CONCLUSION

In this paper we have study about data collection method in wireless sensor network we have represented the different method of data collection. First is the static sink, second is mobile sensor node and third is based on mobility. Represented the key metric and there evaluation parameters with their application and highlighted the techniques. Protocols are stated with their key features. Discussed the design of the data collection and data dissemination.

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