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ANN-BASED FUTURE PREDICTION MODEL FOR ENERGY EFFICIENT SLEEP/WAKE SCHEDULING IN WSN

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Abstract:

Wireless Sensor Networks (WSNs) play a significant role in various applications such as environmental monitoring, smart agriculture, and industrial automation. However, the major limitation of WSNs is the restricted energy availability of sensor nodes, which directly affects network lifetime and performance. Continuous operation of nodes leads to rapid energy depletion, making efficient energy management a critical requirement. This paper proposes an AI-based future prediction model for energy-efficient sleep/wake scheduling in Wireless Sensor Networks. The proposed approach employs an Artificial Neural Network (ANN) to perform intelligent node state classification based on multiple parameters, including residual energy, distance to the cluster head, and traffic load. In addition, a predictive mechanism is incorporated to estimate future energy conditions, enabling proactive and adaptive scheduling decisions. The model is implemented in MATLAB and evaluated over multiple simulation rounds. Performance metrics such as energy consumption and network lifetime are analyzed. The results demonstrate that the proposed method significantly reduces energy usage, maintains balanced node activity, and enhances overall network lifetime compared to conventional approaches.

Keywords: Wireless Sensor Networks, ANN, Energy Efficiency, Sleep/Wake Scheduling, Future Prediction

1. INTRODUCTION

Wireless Sensor Networks (WSNs) have gained significant importance in recent years due to their wide range of applications in areas such as environmental monitoring, smart agriculture, healthcare, and industrial automation. A typical WSN consists of a large number of sensor nodes deployed over a geographical region to sense, process, and transmit data to a central node or base station.

Despite their advantages, one of the major challenges in WSNs is the limited energy capacity of sensor nodes. Since these nodes are battery-powered and often deployed in inaccessible locations, replacing or recharging batteries is difficult. Continuous operation of all nodes results in rapid energy depletion, which significantly reduces the overall network lifetime and performance.

To overcome this limitation, efficient energy management techniques are required. One effective approach is sleep/wake scheduling, where nodes are selectively switched between active and sleep states to conserve energy. However, traditional scheduling methods are often static and do not adapt to dynamic network conditions.

In recent years, Artificial Intelligence (AI) techniques, particularly Artificial Neural Networks (ANN), have been widely used to improve decision-making in WSNs. ANN models can learn complex relationships between network parameters and provide adaptive solutions for energy optimization.

In this paper, an AI-based future prediction model is proposed to enhance energy efficiency in WSNs. The model utilizes ANN to make intelligent decisions based on parameters such as energy, distance, and traffic load, while also incorporating predictive analysis to improve scheduling performance.

2. LITERATURE REVIEW

Numerous research efforts have been carried out to enhance energy efficiency in Wireless Sensor Networks (WSNs). Traditional approaches primarily focus on energy-aware routing and clustering techniques, where nodes with higher residual energy are selected for data transmission tasks. Although these methods improve performance to some extent, they often rely on static rules and lack adaptability to dynamic network conditions, Amplification process.

Recent advancements have introduced Artificial Intelligence (AI) and Machine Learning (ML) techniques for optimizing node behaviour. In particular, Artificial Neural Networks (ANN) have been widely applied for decision-making processes such as cluster head selection, routing optimization, and energy management. These models are capable of handling nonlinear relationships between network parameters, resulting in improved system performance.

Several studies have also explored sleep/wake scheduling mechanisms, where nodes are periodically switched between active and idle states to conserve energy. AI-based scheduling techniques provide dynamic control over node activity; however, most existing works consider only limited parameters such as residual energy and distance.

The base paper, *"Model to Optimize Routing and Sleep Wake Schedule for WSN Using ANN (2024)"*, utilizes ANN for optimizing routing and node scheduling. While it demonstrates improved energy efficiency, the approach lacks consideration of traffic load and does not incorporate predictive analysis for future network conditions.

Therefore, there is a need for a more comprehensive model that integrates multiple parameters along with future prediction capability. The proposed work addresses these limitations by incorporating traffic-aware decision making and predictive energy estimation to enhance overall network performance.

3. PROPOSED METHODOLOGY

3.1 Network Initialization

- A Wireless Sensor Network consisting of 100 sensor nodes is deployed randomly
- Nodes are placed within a 100 × 100 m area
- A cluster head (CH) is positioned at the center

3.2 Energy Model

- Each node is assigned an initial energy
- Energy decreases based on node activity
  - Active node → higher energy consumption
  - Sleep node → lower energy consumption

3.3 Parameter Calculation

The following parameters are calculated for each node:

- Residual Energy → Current energy level
- Distance → Distance from cluster head
- Traffic Load → Data transmission requirement

3.4 AI Input Preparation

- The calculated parameters are combined to form the input vector:

Input = [Energy, Distance, Traffic]

- This input is fed into the ANN model

3.5 ANN Model

- A feedforward Artificial Neural Network is used
- The model is trained using supervised learning
- ANN learns the relationship between input parameters and node states

3.6 Node State Prediction

- ANN predicts node condition:
  - Output > 0.5 → Active State
  - Output ≤ 0.5 → Sleep State

3.7 Future Prediction Mechanism

- A simple prediction model estimates future energy levels
- Helps in making proactive scheduling decisions

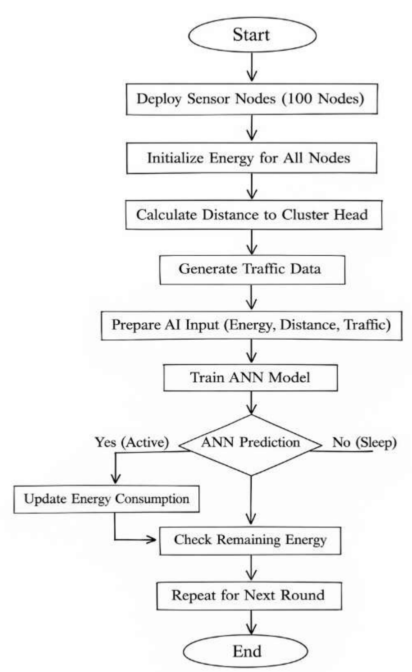
3.8 Energy Update

- Energy is updated after each round:
  - Active nodes consume more energy
  - Sleep nodes conserve energy

3.9 Iterative Simulation

- The process is repeated for multiple rounds
- Performance is evaluated using:
  - Energy consumption
  - Alive nodes
  - Network lifetime

4. FLOW CHART



5. SIMULATION SETUP

Network Configuration: The proposed system is simulated using MATLAB to evaluate its performance in a Wireless Sensor Network environment. A total of 100 sensor nodes randomly deployed within a 100 × 100 m² area. The cluster head is positioned at the centre of the network at coordinates (50, 50), ensuring uniform communication distance across nodes. [5.1]

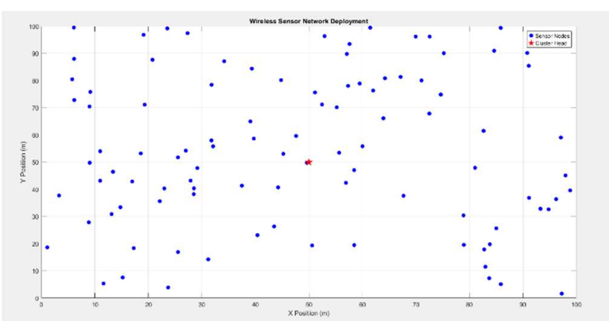
Energy Model: Each sensor node is initialized with an energy of 0.5 Joules. The energy consumption is modelled based on node activity, where nodes in the active state consume 0.05 Joules per round, while nodes in the sleep state consume only 0.005 Joules. This differentiation helps in conserving energy and extending network lifetime. [5.2]

Traffic and Distance Modelling: Traffic load for each node is generated randomly to simulate dynamic data transmission conditions. The distance between each node and the cluster head is calculated using the Euclidean distance formula. These parameters are essential for determining node behaviour and are used as inputs to the ANN model. [5.3]

ANN Configuration: A feedforward Artificial Neural Network (ANN) with 10 hidden neurons is used in the proposed system. The network is trained using supervised learning to understand the relationship between input parameters and node states. The inputs to the ANN include residual energy, distance, and traffic load, while the output represents the node state, classified as active or sleep. [5.4]

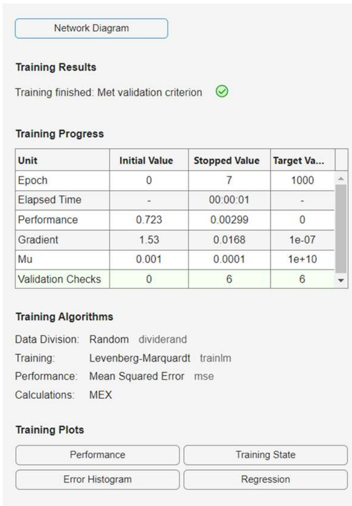
Performance Metrics: The performance of the system is evaluated based on key metrics such as total energy consumption, number of alive nodes, node activity distribution, and overall network lifetime. These metrics help in analyzing the effectiveness of the proposed model in optimizing energy usage. [5.5]

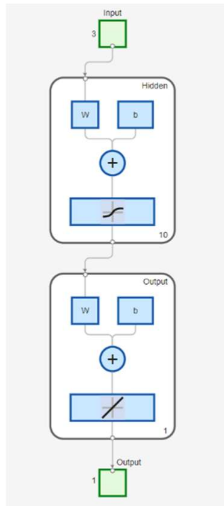
6. OUTPUT



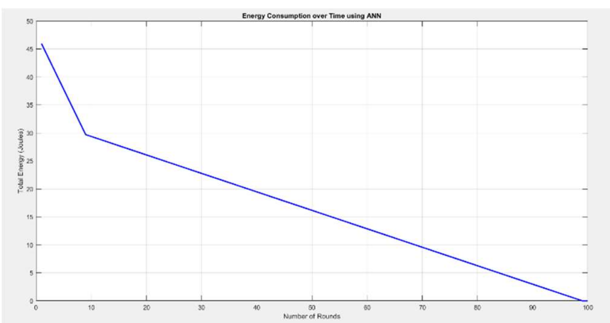
Node deployment (fig1)

The deployment of a Wireless Sensor Network in a 100×100 m area. Blue dots represent randomly distributed sensor nodes, while the red star indicates the centrally located cluster head. The layout illustrates node distribution, spatial coverage, and distance variations, which are essential for communication, energy analysis, and network performance evaluation.



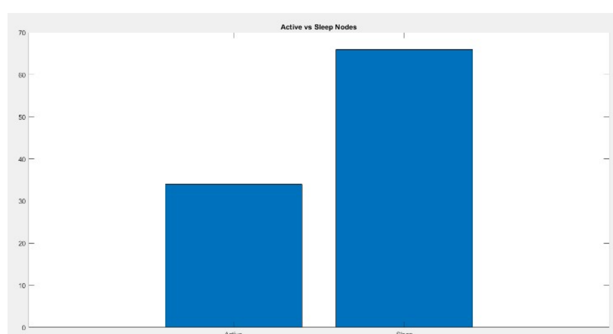


ANN Training (fig2.1) **Network Diagram of ANN (fig2.2)**



Energy Consumption (fig3)

The total energy decreasing over simulation rounds using an ANN-based model. Energy drops rapidly at first, then declines gradually, indicating controlled consumption. The trend demonstrates efficient energy management, where sleep/wake scheduling helps extend network lifetime by reducing unnecessary energy usage.



Active vs Sleep Node (fig 4)

It compares the number of active and sleep nodes in the wireless sensor network. Sleep nodes are significantly higher than active nodes, showing that the ANN-based scheduling effectively places more nodes in low-power mode, thereby reducing energy consumption and improving overall network lifetime and efficiency.

7.CONCLUSION

The proposed ANN-based model for Wireless Sensor Networks successfully improves energy efficiency through intelligent sleep and wake scheduling. By utilizing key parameters such as residual energy, distance, and traffic load, the system effectively predicts node states and minimizes unnecessary energy consumption. The results demonstrate that the network maintains a higher number of sleep nodes while ensuring sufficient active nodes for communication, thereby extending the overall network lifetime. The integration of a simple future prediction mechanism further enhances decision-making capability and system stability. Overall, the proposed approach provides a reliable and scalable solution for energy optimization in WSNs.

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