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Authenticated Sensor Node for Efficient Data Collection and Job Scheduling in Wireless Sensor Network

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Abstract
A wireless sensor network is a collection of one or more sensor nodes. Sensor nodes send the collected data to the base stations through intermediate sensor nodes. Data collection is energy-inefficient one for sensor nodes with limited power resources and multi-hop communication protocols. In WSN, the data collection and job scheduling are the demanding task. The existing Connectivity-Based Data Collection (CBDC) algorithm uses connectivity among the sensor nodes to find the route of sink node and minimizes the number of multi-hop communications. CBDC algorithm failed to collect the data and schedule the job in effective manner. In order to address the existing issues, the data collection and job scheduling is carried out through the authenticated sensor node. Initially, k-nearest neighbor classifier for sensor node authentication (kNN-SNA) technique is introduced to classify the nearest neighbor nodes from other nodes. The node cooperative count is calculated based on behavior and activities of node while communicating with other nodes in WSN. When the node cooperative count is higher than the threshold count, the node energy level is calculated. The node energy level is calculated based on the energy consumption during the packet transmission and reception. After calculating the node energy level, it gets compared with threshold energy level. When both the node cooperative count and node energy level are higher than the threshold level, the trust value of the node is calculated. When the trust value is higher than the threshold trust value, the node is said to be authenticated sensor node in WSN. Through that authenticated sensor nodes, the data collection is performed. Finally, the job scheduling is done for authenticated sensor nodes in WSN. This helps to increase the data collection accuracy and reduce the node authentication time.

Keywords
Wireless Sensor Network, Node Energy Level, Node Cooperative Count, Data Collection, K-Nearest Neighbor Classifier, Multi-Hop Communication

I. Introduction

Wireless sensor network (WSN) is a developing technology with many potential applications. Wireless sensor network is a collection of spatially distributed sensors for monitoring the environmental conditions. WSN is formed with many number of sensor nodes. A sensor node is small device with three fundamental units, namely a sensing unit for data realization from physical environment, a processing unit for local data processing as well as storage and wireless communication unit for data transmission to sink node or base station. The sensor nodes are provided with less amount of energy and it is difficult to recharge the batteries as nodes are used in hostile environment. It is disclosed for both powering off the redundant nodes and minimizing the radio power while preserving node connections to efficient power saving.

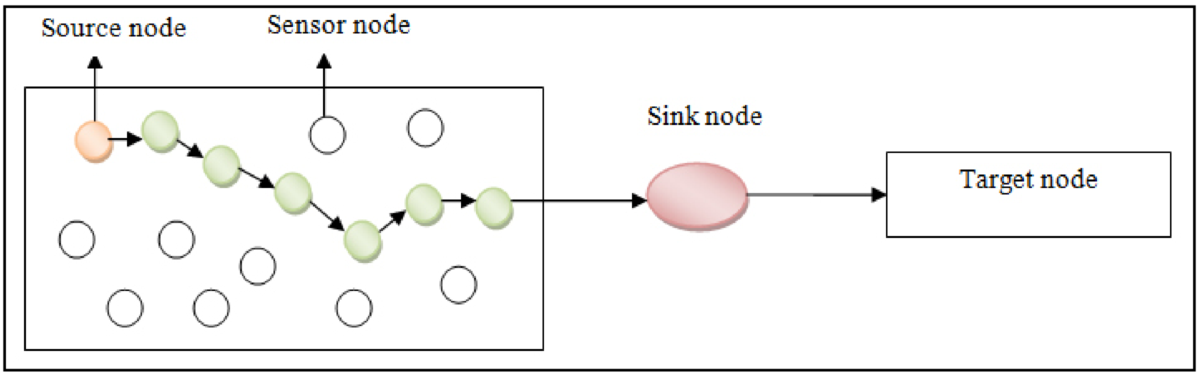

Fig. 1.1 : Wireless Sensor Network Structure

From figure 1.1, the source node sends the packet to the sink node through intermediate sensor nodes. From the sink node, the data are sent to the target node. WSN is an infrastructure less network with many tiny sensor nodes with minimum energy consumption and computational capability. In WSN, sensor nodes are densely used in different environmental terms mainly for monitoring factors. The sensor node comprises the radio transceiver along with antenna, microcontroller, electronic circuit and energy source. Energy preservation is an essential problem in Wireless Sensor Network and data aggregation reduces the energy usage.
A wireless sensor network comprises the low-cost, low-power and battery-powered sensor nodes. When sensor nodes use less and non-rechargeable energy resources, the lifetime of sensor network gets increased. Wireless sensor networks have less computation capacity, less memory space, less power resource and short-range radio communication device. In military applications, sensor nodes are employed in hostile environments like battlefields to examine the actions of enemy force. WSN collects the data through the individual nodes where it is routed to the sink nodes. The monitoring process uses the ideas to forward the packets with essential topological structure.

A data collection from nodes is used in wireless sensor networks in the sensing field for data transmission. Data collection depends on wireless communications between the sensor nodes and the sink node. In wireless communications, long-range sensor nodes use less amount of energy. For the shorter-range, multi-hop wireless communications are used and data aggregation is carried out with higher network lifetime. Job scheduling in nodes is the process of allocating many tasks to different sensor nodes by target node. The target node manages the prioritized tasks and finds which task to be addressed at first. Job scheduling evaluates the amount of time to be taken by node for completing the tasks.

II. Literature Survey

A significant improvement in wireless environment has resulted in introduction of data collection techniques and job scheduling techniques. In order to reduce the energy utilization rate and to increase data collection accuracy in WSN, their applications have been extensively developed with the help of literature.

1. Connectivity-Based Data Gathering with Path-Constrained Mobile Sink in Wireless Sensor Networks

In this paper [1], the author described the data collection and data gathering using path constrained mobile sink called connectivity-based data collection (CBDC) algorithm. The key objective of the algorithm is to increase the network lifetime which addresses the time and energy limitations of mobile sink. CBDC partitions the sensor nodes into many clusters depending on the connectivity to group all nodes in single cluster. The grouping all nodes into single cluster increases the number of single-hop sensor nodes that helps in increasing the network lifetime. A multi-hop communication protocol is used for nodes that are not positioned in the communication range of mobile sink. An energy load balancing technique is designed for single-hop node called gateway nodes. Gateway nodes prevent the nodes from dying earlier than additional sensor nodes. An additional energy is preserved for increasing the sensor nodes lifetime.

2. Enhancing Energy Efficiency in WSN using Energy Potential and Energy Balancing Concepts

The author proposes an energy balanced data gathering routing algorithm in this paper [2] by potential ideas in classical physics. Energy balanced routing protocol (EBRP) sends the data packets to the sink by the dense energy areas to preserve the nodes with low residual energy. EBRP is mainly used to construct three virtual potential fields, namely depth, energy density and residual energy. The depth field identifies fundamental routing paradigm that helps in moving the packets to the sink. The energy density field guarantees that the packets are forwarded along high energy areas. The residual energy field preserves the low energy nodes. The contribution of the algorithm is given below,

- Energy Balanced Routing Protocol sends the packets to sink to preserve the nodes with low residual energy
- Energy Balanced Routing Protocol is introduced through designing mixed virtual potential field
- It allows the packets to send to the sink node through dense energy area.
- The protocol preserves the sensor nodes with minimum residual energy and delivers the sensed packet to sink node.

3. Efficient Data Collection in Wireless Sensor Networks with Path-constrained Mobile Sinks

The data delivery issues are addressed in large scale wireless sensor networks with mobile sink that transmits the data along fixed path. An efficient data collection scheme termed Maximum Amount Shortest Path (MASP) is designed in the paper [3] for increasing the total amount of data and minimizes the energy consumption at the same time. The members inside MCA are allocated to equivalent sub-sinks in DCA consistent with the length of communication time between mobile sink and sub-sinks, thus improving the network throughput. The MASP optimization issue is taken as 0-1 integer linear programming (ILP) issue and design the genetic algorithm solution with two-dimensional binary chromosomes. A two-phase communication protocol is introduced to execute with low-density and multiple sinks.

4. Energy Efficient Approach based on Evolutionary Algorithm for Coverage Control in Heterogeneous Wireless Sensor Networks

The network coverage and connectivity issues are addressed in this paper [4] uses non-dominated genetic evolutionary algorithm for preserving the coverage and connectivity where a sensor node has many sensing ranges and transmission ranges. The algorithm helps to reduce the energy usage and increase the network lifetime. A multi-objective optimization approach is designed depending on genetic evolutionary algorithm and performed by sink node. The results attained by sink node are sent to the sensor nodes and every sensor nodes varies the transmission range, sensing range and scheduling state. WSN comprises N stationary resource constraint sensor nodes and static resource-rich sink. The sensor nodes used randomly with the same distribution over finite two-dimensional region. Each node varies their transmission range and sensing range.

5. Energy-Aware Hierarchical Topology Control for Wireless Sensor Networks with Energy-Harvesting Nodes

In the paper [5], the author designed the topology control scheme for maintaining the connectivity between nodes in long-term WSNs. In long-term WSNs, the nodes are manually restored with energy-harvesting nodes and battery-powered nodes. In this type of WSN, the battery-powered nodes has large amount of residual energy with minimum length. The nodes formed themselves into layers and nodes on upper layer are specified with the job of aggregating data received from nodes on lower layers then finally send it to sink node. This arrangement improves the energy efficiency and connectivity by increasing the lifetime of nodes through locating the energy-harvesting nodes on higher layers.

6. A Progressive Approach to Reducing Data Collection Latency in Wireless Sensor Networks with Mobile Elements

A progressive optimization approach introduced in the paper [6] minimizes the tour length of MEs and travel time reduces the constant travel speed slowly through combining the collection sites for data sources. The data sources are the sensor nodes in networks with flat architecture or cluster heads in hierarchical networks. Depending on the realistic wireless communication features, multirate communication model allocates MEs to gather the data at lower rate in longer distance. CSS scheme gets extended and obtained the multirate CSS (MR-CSS) scheme. In traveling salesman problem with neighborhoods (TSPN), the neighborhoods are meeting at the continuous disks because of its NP-hardness.

7. An energy-efficient data gathering algorithm to prolong lifetime of wireless sensor networks

A routing algorithm called Energy-efficient Routing Algorithm to Prolong Lifetime (ERAPL) is introduced in the paper [7] by reducing the energy utilization. In ERAPL, a data gathering sequence (DGS) eliminates the mutual transmission and loop transmission between nodes and every node send out the traffic to connections confined in DGS. A mathematical programming model is introduced where the lower level residual energy of nodes and total energy consumption are used to optimize network lifetime. Genetic algorithms are employed to identify the optimal solution of the programming issues.

8. A Distributed and Scalable Time Slot Allocation Protocol for Wireless Sensor Networks

A decentralized technique known as Grid-based Latin Squares Scheduling Access (GLASS) is introduced in the paper [8] that preserves the better performance degradation in DISNs when the data load increases. The protocol is introduced with lightweight, overhead-efficient, scalable, and robust in existence of mobility. At one end of spectrum, distributed but scalable CSMA/CA and CPT schemes are designed by addressing the drawbacks because of collisions in case of high data loads. At another end of spectrum, there are no issues addressed during the transmissions in network by scheduling (DRAND and DTA). Scheduling approaches are used for consuming less amount of energy during collisions, but energy waste due to overhead from control messages remained unaddressed. The problem gets further increased as network scale increases in WSNs. Schedules require recomputation when the topology varies because of some mobility. At the middle of spectrum, the overhead issue is addressed, however the performance failed to match the performance of scheduling access.

9. Fast Data Collection in Tree-Based Wireless Sensor Networks

In this paper [10], the author studied two types of data collection, namely Aggregated convergecast and Raw-data convergecast. In Aggregated convergecast, packets are aggregated at every hop and in raw-data convergecast packets are individually relayed to the sink node. Aggregated convergecast is used when strong spatial correlation exists in data. The main objective is to gather the summarized information like maximum sensor reading. Raw-data convergecast is used when every sensor reading is significant or correlation is less. The aggregated convergecast are studied in continuous data collection and raw-data convergecast are studied for one-shot data collection. The two types symbolize two cases of data collection. The latency of data collection is shown with higher the performance results in two extreme cases without any data compression (raw-data converge-cast) and full data compression (aggregated convergecast).

10. Energy-Efficient Data Gathering Scheme Based on Broadcast Transmissions in Wireless Sensor Networks

A framework for data compression uses the broadcasting feature of wireless area by increasing the energy efficiency. A distributed data compression scheme is designed in the paper [11] depending on wireless point to-multipoint communication. Every sensor node compresses its sensing information by data. The data gathering structure is built with help of optimal algorithm. Raw data transmitter (RDT) nodes send out the sensing information devoid of any compression. Nodes not selected as RDT nodes compress information by data received from RDT nodes.

11. Hop-by-Hop Message Authentication and Source Privacy in Wireless Sensor Networks

The author proposed an unconditionally secure and efficient source anonymous message authentication (SAMA) scheme in the paper [12] depending on the optimal modified ElGamal signature (MES) scheme on elliptic curves. MES scheme is more secure in case of adaptive chosen-message attacks in random oracle model. The designed scheme allows the intermediate nodes to verify the message where all corrupted message are identified and dropped to reduce the sensor power utilization. When attaining the resiliency cooperation during the flexible-time authentication and source identity protection, the designed scheme failed to undergo threshold issues. The designed scheme is efficient than polynomial-based algorithms in many security levels.

- A source anonymous message authentication code (SAMAC) is introduced on elliptic curves for providing the unconditional source anonymity
- An efficient hop-by-hop message authentication mechanism is carried out for WSNs lacking threshold constraints
- The network implementation criteria are used on source node privacy preservation in WSNs.
- An efficient key management framework guarantees the isolation of compromised nodes

12. Energy efficient structure-free data aggregation and delivery in WSN

An Energy efficient Structure-free Data Aggregation and Delivery (ESDAD) protocol is proposed in the paper [13] to guarantee an efficient data aggregation and delivery lacking explicit preservation of structure. The ESDAD protocol is used in various levels of sensing reliability in sensing field. The data packets are sensibly sent to the next-hop node because of essential reliability for aggregation. The waiting time of packets at every intermediate node is measured sensibly in order that the data are aggregated effectively in path. The designed protocol executes near source data aggregation and calculates the cost function for structure-free next-hop node selection. The buffer of every intermediate node is divided to maintain fair and efficient data delivery with buffer management.

13. Data collection model for energy-efficient wireless sensor networks

A mobile cluster-head data collection model is designed in the paper [14] to minimize the end-to-end packet delay in wireless sensor network. The mobile cluster-head data collection model is designed in two scenarios. The velocity of cluster-head node with is used to minimize the end-to-end packet delay. The mobile cluster-head data collection mobility model are designed with data send rate, network size, sensor node density and cluster-head node density.

15. An energy-efficient path determination strategy for mobile data collectors in wireless sensor network

An algorithm called Mobile Collector Path Planning (MCPP) is designed in the paper [15]. MCPP scheme is validated through computer simulation with both obstacle free and obstacle-resisting network. The algorithm reduces the energy consumption by static sensor nodes and increases the network lifetime.

III. Methodology

In this proposed method, efficient data collection and job scheduling is carried out in WSN through the authenticated sensor nodes. The main goal of the proposed method is to increase the data collection accuracy and reduce the node authentication time. The data collection and job scheduling is carried out after the sensor node authentication based on the trust value of the sensor node.

In the existing techniques, Connectivity-Based Data Collection (CBDC) algorithm uses the connectivity between sensor nodes to establish the route of sink even as suiting its path limit and reducing the number of multi-hop communications. Data collection and data gathering are used by path constrained mobile sink called connectivity-based data collection (CBDC) algorithm. The key objective of the algorithm is to increase the network life time by addressing the time and energy limitations of mobile sink. CBDC partitions the sensor nodes into clusters depending on the connectivity to create all nodes in single cluster. The CBDC algorithm helps to increase the number of single-hop sensor nodes and increases the network lifetime. A multi-hop communication protocol is used for nodes that are not in the communication range of mobile sink. An energy load balancing technique is designed for single-hop node to avoid node from quickly disappearing before other sensor nodes. However, the security remained unaddressed in CBDC algorithm therefore, the data collection as well as job scheduling was not carried out in efficient manner.

Due to the disadvantages in the existing method, we introduce a k-nearsest neighbor classifier for sensor node authentication in this proposed paper. The k-nearsest neighbor classifier for sensor node authentication (kNN –SNA) technique is employed for efficient data collection and job scheduling.

kNN–SNA technique helps to collect the data more efficiently than the existing method. By using the k-nearsest neighbor classifier, the nearesr neighbour nodes are identified based on the distance between two sensor nodes. The cooperaive node count and high energy nodes are found from other nodes after calculating the trust value to collect the data and for successful job scheduling process. The trust value of the each node is calculated based on node cooperation count and node energy level. When the trust value is higher than threshold trust value, the node is said to be authenticated sensor node. Through that node, the data are collected and the job scheduling is carried out.

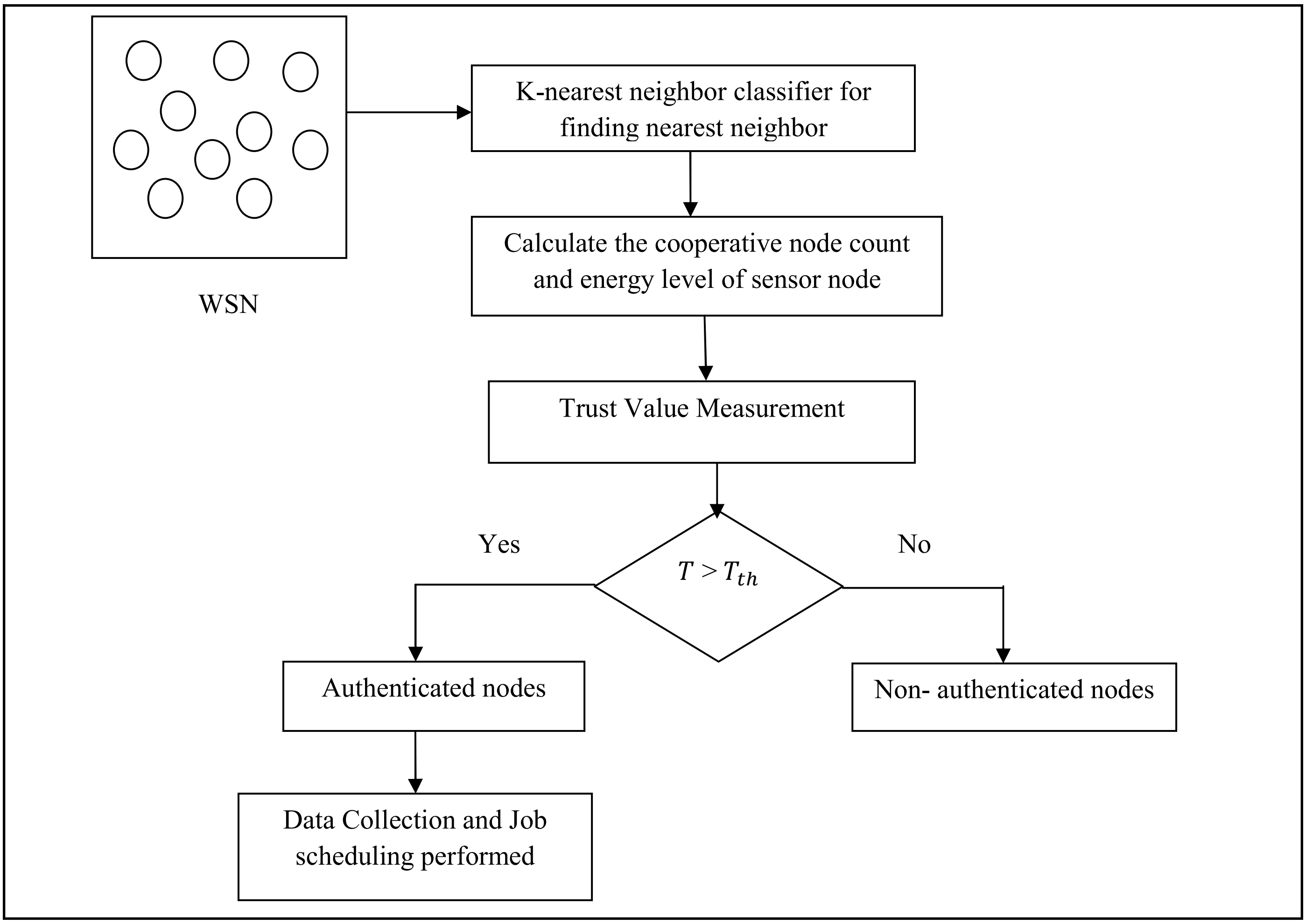

Fig. 3.1 : Architecure of k-Nearsest Neighbor Classifier for Sensor Node Authentication

A. Modules

1. Cooperative node count and energy level of sensor node
2. k-Nearsest Neighbor Classification
3. Trust Value Measurement

B. Module Description

The brief description of modules is given in the following sub-section.

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1. k-Nearsest Neighbor Classification

k-Nearsest Neighbor Classification is carried out in the wireless sensor networks for sensor node authentication. The classifiers failed to classify the nodes only based on memory. The KNN employs neighborhood classification as predication value of new instance. The classifier is used to find the k training samples for determining the k nearest neighbors depending on the distance measure. The majority of the k nearest neighbor identifies the category of next neighboring node. The k-nearest-neighbor (kNN) measures the distance between two sensor nodes in wireless sensor network. The two sensor node be SN_1 and SN_2. Let the coordinate of be SN_1 be (a_1, b_1) and SN_2 be (a_2, b_2).

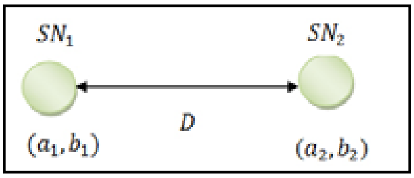

Fig. 3.2 : Distance between two sensor nodes

The distance between the mobile node and is measured for finding the nearest neighbor. The distance between two sensor nodes are measured as follows,

$$D = \sqrt{(a_2 - a_1)^2 + (b_2 - b_1)^2} \quad (1)$$

From (1), D is the distance between the two sensor nodes in WSN. By calculating the distance, the nearest neighbor is identified. After finding the neighboring node, the cooperation of that node with other nodes is identified.

2. Cooperative node count and energy level of sensor node

The cooperativeness of node is identified based on the behavior and activities of node while communicating with other nodes in WSN. The monitoring of the behavior of nodes is carried out based on the cooperativeness of the nodes assumed.

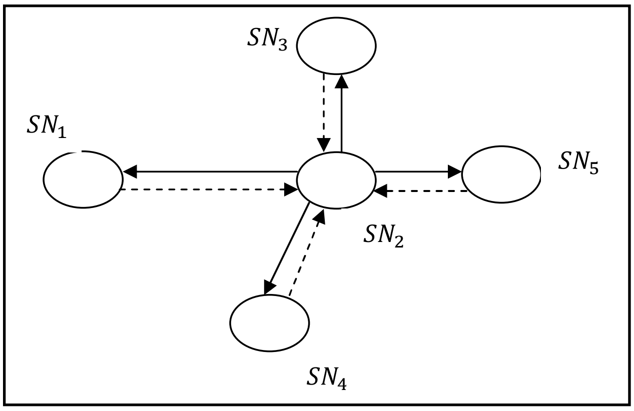

Fig. 3.3 : Node Cooperation Process

After calculating the node cooperation count, the node cooperation count is compared with the threshold node count ‘’. When the calculated node cooperation count is higher than the ‘’, the node is taken for data collection and job scheduling in WSN. After evaluating the node cooperation count, node energy level is to be calculated. Initially, all sensor nodes contain initial energy for data transmission in WSN. But during the data transmission, node energy level gets reduced. Therefore, the nodes with higher energy level are selected for data collection. The energy used by sensor node for sending the l-bit of data to the neighboring node at distance 'd'meters is expressed as,

$$E_S = (EU + E_A * D^i) * l \quad (2)$$

From (2), *Es* is the energy used for sending the data, *'EU'* is the energy utilization for data collection, *'D'* represents distance between two i^th sensor node and its neighboring node. Then, the energy utilized by the node for receiving the l-bit of data is measured by,

$$E_R = EU * l \quad (3)$$

From (3), E_R represents the energy of the node after receiving the l-bit of packet is multiplied with total energy utilized *'EU'*. The node energy level of sensor node is expressed as,

$$Node\ energy\ level = E_I - E_S - E_R \quad (4)$$

From (4), the node energy level is calculated E_1. represents the initial node energy level. Then, the node energy level is compared with the threshold energy level *‘E_{th}’*. When is higher than *‘E_{th}’*, the sensor node is chosen for measuring the trust value in order to find the authenticated sensor nodes.

3. Trust Value Measurement

The trust value of the node is calculated based on the node cooperation count and node energy level. Then, the calculated trust value is compared with threshold trust value ‘’. When the trust value is higher than the ‘’, the node is said to be authenticated sensor nodes. Through the authenticated sensor nodes, the data collection is carried out and job scheduling is performed.

Input: Number of sensor nodes *‘SN_1, SN_2, SN_3, SN_4, ... SNn’*
Output: Authenticated sensor node
Step 1 : **begin** **Step 2 :** Classify the nearest neighbor node from other nodes by k-Nearest Neighbor classifier after evaluating distance by (1) **Step 3 :** **for** all nearest sensor node **Step 4 :** Find the cooperative node count **Step 5 :** **if** (*node cooperation count > $count_{th}$*) **Step 6 :** Find the node energy level using (4) **Step 7 :** **if** (*node energy level > E_{th}*) **Step 8 :** Calculate trust value **Step 9 :** **if** *(Trust value > Tth)* **Step 10:** Node is said to be authenticated nodes **Step 11:** Data collection and job scheduling is carried out with help of authenticated nodes **Step 12:** **end if** **Step 13:** **end if** **Step 14:** **end if** **Step 15:** **end for** **Step 16:** **end**

Algorithm for data collection and job scheduling based on trust measurement using k-Nearest Neighbor classifier

IV. Experimental Evaluation

In this paper worked on performance evaluation in terms of node authentication time, node energy utilization and data collection accuracy. The performance metrics are simulated on NS2. The performance measures of the proposed work are analyzed with following metrics:

- Node energy utilization
- Node authentication time and

- Data collection accuracy

A. Node Energy Utilization Rate

Node energy utilization rate is defined as the amount of energy consumed by the node for efficient data collection and job scheduling in WSN. It is measured in terms of joules (J).

Table 4.1: Tabulation for Node Energy Utilization Rate

Number of Sensor Nodes (Number)	Node Energy Utilization Rate (Joules)	
	Connectivity-Based Data Collection (CBDC) algorithm	k-Nearsest Neighbor Classifier for Sensor Node Authentication (kNN-SNA)
50	55	32
100	59	36
150	63	40
200	65	42
250	70	48

Table 4.1 explains the node energy utilization rate comparison for different number of sensor node in the range of 50 to 250. The node energy utilization rate comparison takes place on existing Connectivity-Based Data Collection (CBDC) algorithm and proposed k-Nearsest Neighbor Classifier for Sensor Node Authentication (kNN-SNA).

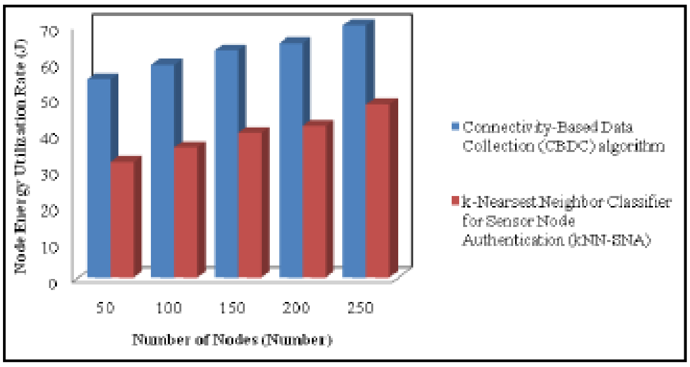

Fig. 4.1: Measure of Node Energy Utilization Rate

Figure 4.1 demonstrates the node energy utilization rate. The number of sensor nodes taken for the experimental consideration is varied from 50 to 250. From the figure X axis represents the number of sensor nodes whereas Y axis denotes Node Energy Utilization Rate using kNN-SNA technique. From the figure it is clearly evident that the proposed kNN-SNA technique minimizes the node energy utilization rate than the existing CBDC algorithm. Hence, the node energy utilization rate is reduced by 36% in proposed kNN-SNA technique than the existing CBDC algorithm.

B. Data Collection Accuracy

Data collection accuracy is defined the rate at which the data collected exactly. Data collection accuracy is defined as the number of data collected accurately from the authenticated sensor nodes. It is measured in terms of percentage (%).

Table 4.2: Tabulation for Data Collection Accuracy

Number of Sensor Nodes (Number)	Data Collection Accuracy (%)	
	Connectivity-Based Data Collection (CBDC) algorithm	k-Nearsest Neighbor Classifier for Sensor Node Authentication (kNN-SNA)
50	75	81
100	79	84
150	81	86
200	84	90
250	86	94

Table 4.2 explains data collection accuracy the comparison for different number of sensor node in the range of 50 to 250 The data collection accuracy comparison takes place on existing Connectivity-Based Data Collection (CBDC) algorithm and proposed k-Nearsest Neighbor Classifier for Sensor Node Authentication (kNN-SNA).

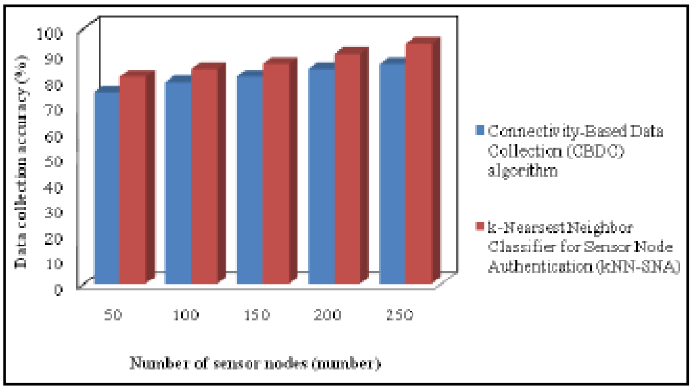

Fig. 4.2: Measure of Data Collection Accuracy

Figure 4.2 demonstrates the data collection accuracy. The number of sensor nodes taken for the experimental consideration is varied from 50 to 250. From the figure X axis represents the number of sensor nodes whereas Y axis denotes Data Collection Accuracy using kNN-SNA technique. From the figure it is clearly evident that the proposed kNN-SNA technique increases the data collection accuracy than the existing CBDC algorithm. Hence, the data collection accuracy is increased by 7% in proposed kNN-SNA technique than the existing CBDC algorithm.

C. Node Authentication Time

Node authentication time is defined as the difference of starting time and ending time for sensor node authentication. It is measured in terms of milliseconds (ms).

Node Authentication Time
= Ending time - Starting time of sensor node authentication

Table 4.3: Tabulation for Node Authentication Time

Number of Sensor Nodes (Number)	Node Authentication Time (ms)	
	Connectivity-Based Data Collection (CBDC) algorithm	k-Nearsest Neighbor Classifier for Sensor Node Authentication (kNN-SNA)
50	23	15
100	27	19
150	31	23
200	35	25
250	41	26

Table 4.3 explains node authentication time the comparison for different number of sensor node in the range of 50 to 250. The node authentication time comparison takes place on existing Connectivity-Based Data Collection (CBDC) algorithm and proposed k-Nearsest Neighbor Classifier for Sensor Node Authentication (kNN-SNA).

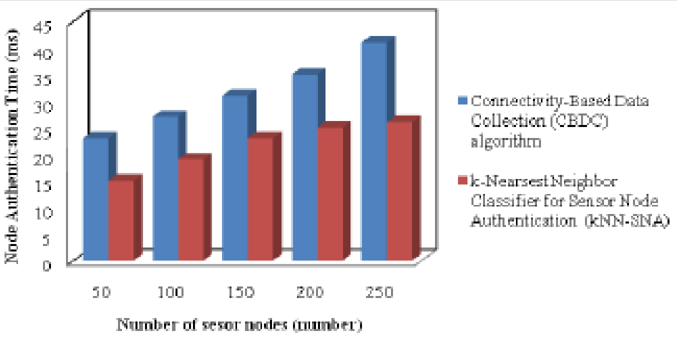

Fig. 4.3: Measure of Node Authentication Time

Figure 4.3 demonstrates the node authentication time. The number of sensor nodes taken for the experimental consideration is varied from 50 to 250. From the figure X axis represents the number of sensor nodes whereas Y axis denotes Node Authentication Time using kNN-SNA technique. From the figure it is clearly evident that the proposed kNN-SNA technique reduces the node authentication time than the existing CBDC algorithm. Hence, the node authentication time is reduced by 31% in proposed kNN-SNA technique than the existing CBDC algorithm.

V. Conclusion

In this paper, we have described the detail architecture diagram for data collection and job scheduling in WSN. In this architecture, k-nearest neighbor classifier for sensor node authentication (kNN-SNA) classifies the nearest neighbor nodes from other nodes. Then, the trust value is calculated based on the node cooperative count and node energy level. Based on the trust values, the authenticated sensor nodes are identified. Then, the data collection is performed and job scheduling is carried out. Finally, we applied our analysis results to the design of k-nearest neighbor classifier for sensor node authentication and the proposed technique is simulated on NS2. We simulated the proposed technique, and conducted comprehensive performance analysis and evaluation, which showed its accuracy and advantages over existing schemes.

The future work enhances the performance of data collection and job scheduling by using advanced level of classifier such as neural network classifier.

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