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Non-Linear Error Identifier Algorithm for Configuring Mobile Sensor Robot

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Abstract – WSN acts as an effective tool for tracking the large scale environments. In such environment, the battery life of the sensor networks is limited due to collection of the data, usage of sensing, computation and communication. To resolve this, a mobile robot is presented to identify the data present in the partitioned sensor networks and passed onto the sink. In novel data collection algorithm, the performance of the data collecting operation is reduced because mobile robot can be used only within the limited range. To enhance the data collection in a changing environment, Non Linear Error Identifier (NLEI) algorithm has been developed and presented in this paper to configure the robot by means of error models which are non-linear. Experimental evaluation has been conducted to estimate the performance of the proposed NLEI and it has been observed that the proposed NLEI algorithm increases the error correction rate upto 42% and efficiency upto 60%.

Keywords: Wireless sensor network, Mobile robot, Data collection, Mobile sink, Mobile robot configuration, Non-linear error model.

1. Introduction

Due to change in most of the environment or inaccessible regions like forest, battlefield etc, the application of wireless sensor network (WSN) plays the vital role to monitor. The WSN consists of sensor nodes and base station (sink). The cost of the sensor nodes are also reduced due to technology developments. This motivates many researchers to investigate many methods in recent past [1-3]. Also the sensor nodes can work autonomously now a day. Autonomous robots contain a broad variety of possible applications, from safety guards and museum regulation to process the data items in the networks. Most independent robots are prepared with direction-finding systems that permit them to plot a course inside working fields. A serious subject for autonomous robots is the accuracy of their direction-finding schemes, in which robot design errors will unavoidably build up owing to factors for instance mechanical vagueness and surface resistance. These errors can be determined utilizing outside location references. The preface of mobile elements [20] has a significant impact to minimize and set scales of energy utilization in wireless sensor networks whereas the data compilation latency might turn higher. The problem of a mobile target to mitigate the level of detection by one or more mobile sensors in a closed network area was presented [10]. Positioning systems might be utilized for outdoor location but not for indoor direction.

One feasible resolution for indoor direction-finding is to organize a network of localization sensors for instance devices to provide the location orientations.

Most of the large body of research on sensor deployment has considered only sensor and environment models. The sensing and communication areas of the sensors have been assumed to have certain shapes (e.g., a circle, a cone, or an irregular convex shape) with the working fields where sensors are deployed also having certain properties (e.g., a square or a stripe with some obstacles). The deployment problem is then formulated as how to cover the working fields with sensors while considering both the sensor and environment models.

These wireless sensor nodes transmit and receive data. But in this case, the Mobile Robot can be considered as mobile sink because it acts as a base station when the actual transceiver nodes fail to receive the packet and transmit to the sink node. These nodes can act as mobile sink nodes which are able to relay data to the base station in a single hop, using for example IEEE 802.11. Hence this Mobile Robot can be named as Mobile sink. The development of a mobile robot organization with the sink node [14] was shaped using three movable robots: two twins that contain appreciation tasks regarding their background and a technique that move towards the area and which also takes the two mobile nodes.

A common collaboration among the robots [4] that mobilized the data packet to the sink node was of greater impact to the robot sensor configuration and management of genuine instance path scheduling was designed for mobile robots.

With the capacities of the robot-sensor network, a crisis set free scheme can be constructed. An adaptive data yielding

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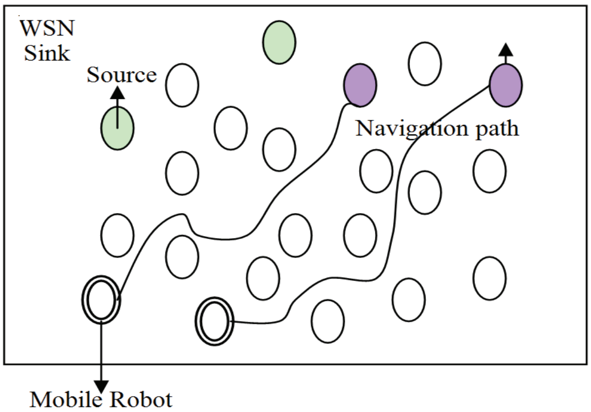

Fig. 1. Navigation of mobile robot to the sink

technique for mobile-agent-assisted [2] data compilation in wireless sensor networks was designed. The replicas of mobile robot routing demonstrate the difficulties during the consumption of sensor system. The robot-sensor network can be utilized to construct the arrangement for serious assignments for instance emergently saving the offended in the battleground as revealed in Fig. 1.

Constructing in such a method has to professionally organize and find the way the mobile robots to attain precise objectives for providing support. The system in practice has the subsequent three necessities.

- First, it requests to inform all mobile robots concerning the survival of mobile entities.
- Second, it requests to assign set free tasks amongst mobile robots.
- Third, it desires to direct the mobile robots to arrive at the chosen targets devoid of position information.

The routing path of mobile robot in WSN can be categorized into two groups:

- Mobile robot movement with location information.
- Movement devoid of location information.

Each mobile robot in WSN should go towards the sensor nodes in the network, which possesses the main mobile robot's neighborhood sensitivity range. With the sensitivity range of the sensor nodes in WSN, the process of configuration of robot is accomplished in this paper.

The rest of the paper is organized as follows. Section 2 presents about an extensive literature review related on the wireless sensor mobile robot configuration. The non linear error identifier for configuring the mobile robot in WSN has been proposed in Section 3. Section 4 describes the experimental evaluation and performance analysis against existing approach. The conclusion of the proposed research work has been presented in Section 5. The list of acronyms used in this paper is given in Table 1.

Table 1. Acronyms

DCF	Distribution Coordination Function
DoS	Denial of Service
MAC	Medium Access Control
NLEI	Non Linear Error Identifier
SR	Sensing Range
TR	Transmission Range
WSN	Wireless Sensor Network
MA	Mobile Agent
NP	No. of packets sent at an interval of time t

2. Related Work

The monitoring of mobile robot in wireless sensor network (WSN), possesses sensor nodes and a base station (sink), which is regularly processed with the environments or unreachable regions. In [17], a novel data-collecting algorithm by means of a mobile robot to get intellect data has been obtained from a wireless sensor network (WSN) that possesses separated/islanded WSNs. Mobile robot to collect data in WSN, which make a good balance between WSN energy consumption and data collecting the robots. The mobile robots collect the data which each sensor node sense by the means of directly visiting entire sensor nodes which can effectively reduce the energy consumption of WSN. In [7], different ways in which mobile terminals back off on their uplink, transmit power in order to extend battery lifetimes in WSN was presented to achieve energy savings.

Most self-determining robots are prepared with routing structures that permit them to steer inside working fields. The design is to organize sensors [1] by concentrating the sensors interest with high correctness. Counteractive procedures can be specified once the process of mobile sensor robots has been observed. The arrangement of such sensor networks is processed based on the number of sensors available in WSN, the setting where sensors are prearranged. In wireless sensor networks, adversaries inject false data reports through compromised nodes and propagate the DoS attacks against legitimate reports. Many types of filtering schemes have been presented. In [12], collecting sensed data using this approach will consume more time. Various techniques to approach the process of collecting sensed data using Mobile robot in wireless sensor networks.

A dynamic en-route filtering scheme has been presented to address both false report injection and DoS attacks in wireless sensor networks. In [21] a dynamic en-route filtering scheme was presented to address both false report injection and DoS attacks in wireless sensor networks. The problem of providing with or providing with repair mechanisms in sensor network [3] has been designed to guarantee with a maximum level of multipath connectivity between all the sensor nodes. Such a maximization level provides fault tolerance when failure of nodes occurs in the network. In this hybrid system a behavior based subsystem for operating the mobile sensor robot is discussed with high-level designed actions. This behavior based system will utilize the algorithm to design a routing procedure of delivering the packet concerning these obstructions and wait the robot affecting towards the target. The problem of providing with or providing with repair mechanisms in sensor network [9] was designed to guarantee with a maximum level of multipath connectivity between all the sensor nodes. Such a maximization level provides fault tolerance when failure of nodes occurs in the network.

In [19], a routing plan is designed for independent mobile robots. The routing system is a mixture of behavior-based and model-based routing systems.

In [15], nevertheless, it is necessary to develop the procedure in a varying environment with nodes containing inadequate sensing dispersed control. A routing plan is designed for independent mobile robots. The routing system is a mixture of behavior-based and model-based routing systems.

A specific type of wireless networks with interference constraints on the set of links to be served simultaneously at any given time has been presented in [6] by restricting the traffic to be single-hop, but also allow with the simultaneous transmissions as long as they provide with the underlying interference constraints.

Jang-Ping Sheu et. al [8] considered sensor networks consisting of both static and mobile nodes which has been suitable for new applications, such as nodes replacement, hole and partition recovery, and autonomous deployment and redeployment. But due to signal interference, the many-to-many service required a longer navigation time to reach each beacon node than the single target service. In addition, total energy consumption of the one-to-many service was less than that of the many-to-many service.

In paper [13], concept of using mobile objects to gather samples from a sensor field has been not long ago proposed. Mobile objects can be used to collect models from a sensor field presented a deterministic technique for preparation for mobile robots to pass the data packet to the sink.

The tradeoff between energy saves and data collection latency in mobile data gathering by exploring a balance between the relay hop count of local data aggregation and the moving tour length of the mobile collector was considered in [11]. A polling-based mobile collection approach named bounded relay hop mobile data collection (BRH-MDC) has been discussed and also it was guaranteed that any packet relay is bounded within a given number of hops.

An active step evolution representation is engaged in the proposed footstep planner which recovers the planning effectiveness in addition to the possibility in the environ-ents. Recent study [16] disclosed the advantage of data gathering in wireless sensor networks by using mobile sensor nodes that meet data by means of short-range transportations. In [18], mobile robot navigation is done through WSN based on compass or GPS unit while communicating with adjacent sensor nodes. The study described about the movement of mobile sensor node is done based on short range transmissions.

In [5], a small group of mobile sensor robots are considered to provide efficient coverage transmission of sensor signals. But this technique provides the complexity for all the sensor nodes in WSN since the hardware design and deployment budget is difficult to process.

In [22], combine-skip-substitute (CSS) scheme is introduced which is a heuristic algorithm, the progressive optimization approach with that multi-rate wireless communication is used to reduce the data collection latency. But this technique is more complex compared to previous schemes. The unreliable nodes are tolerated by redundancy spread through Modified Distributed Storage algorithms [23]. It based on flooding method to send data and this technique performs only for unicasting.

The number of algorithms is described in order to reduce the energy consumption [24]. In data collection process; bottom-up process is used which results in delay, so to avoid these problem, these PEGASIS and LEACH algorithm are used. In [25], multi-track mobile data collecting mechanism (MTMDC) is described and it include three phases such as Estimation Phase, the Energy Estimation Phase and the Multi-track Energy-balance. This technique used in applications like environmental monitoring, weather monitoring and other periodic non real-time monitoring applications Phase.

Based on three characteristic of performance considerations including multihop communication reliability, network longevity and sensing system cost minimization, a new method stair duty-cycle scheduling method for the low-tier sensors is proposed [26].This technique guarantee the reliability but it does not utilize the energy efficiently.

A multi-path scheduling algorithm for snapshot data collection, which has a tighter capacity bound compared to previous work and a novel continuous the data collection algorithm with comprehensive capacity analysis is used to collect the data efficiently[27,28].After the study of aggregation problem in data collection, order-optimal scheduling algorithms is introduced to solve the problems.

The factors which affect the energy and network lifetime will be solved by using beam forming method [29]. A beam forming transmitter scheduling algorithm that considers the size of the sensing area relative to the distance and the base station. It evaluate the method which selects the cluster for beam forming and it improve the lifetime, a complex model is analyzed which reduce the performance.

An energy efficient technique [30], Dynamic search is to improve the energy reduction and network lifetime. While collecting the data, some of the energy is consumed unnecessarily, so they are avoided by this algorithm. It is used in centralized approach which is less efficient than distributed approach.

For collecting the data, it based on some scheduling methods and tools .which are introduced [31]. To reduce the complexity, the heuristic algorithm is used. It concentrates the issues like found best schedule for industrial process automation and control applications. And it undergoes data gathering, schedule determination and deployment evaluation. But potential interference is high during scheduling the data.

Reliable data collection at sink node by using intermediate storage nodes to alleviate congestion problem in wireless sensor network has been discussed [32]. A typical database file attached model is introduced to store the data packets. If the packets are dropped, it is recollected by cluster head using the database file when it receives the negative acknowledgement.

Different topologies, namely flat, cluster-based, chain-based, and tree-based topologies, were discussed in detail [33]. The different performance metrics of WSN topologies also has been discussed and also it has been suggested that chain-oriented topology can be the most promising topology among all topologies.

The taxonomy of data collection is discussed which exploit mobility features [34]. Sink mobility is covered from different perspectives with the main objective of critically discussed about the performance of existing mobile sink-based data collection schemes.

An iterative model of identification algorithm is proposed [35], which uses the on-board processors for estimation of system parameters through iteration cycles. The iterative algorithm residential such that each individual sensor, having an initial estimate of the system parameters, its local measurement, and the excitation signal will be updated the estimated model and passes it through the network until convergence.

An efficient data collection scheme (MASP) for wireless sensor networks with path-constrained mobile sink was developed by Shuai Gao et. al [36]. Simulation has been carried over with fixed range and path mobile sink.

The main bottleneck of the above reported algorithms and methods are, it fails to collect the data for varying environment i.e under nonlinear conditions. This has motivated the author(s) to develop a novel algorithm called NLEI algorithm that not only considers the nonlinear conditions with moving robot which is suitable for varying environment but also constructs sink and mobile sink node to address the problems related to both inside and outside communication ranges. This study further improves the proposed algorithm to eliminate the bottleneck of the reported methods in need for minimizing the energy consumption and increasing the delivery rate by means of sensitivity range.

3. Proposed Methodology

Wireless sensor networks consist of set of sensor nodes which are small, less expensive and spatially distributed with communication links has been considered. With the sensor nodes, the usage of mobile robot intelligently moves and interacts with the hostile environment for data collection. When the mobile robot is in non-linear state i.e., localization changed error occurs and then it is very difficult to route the data packet from source to destination. In order to rectify this error, nonlinear error identifier has been proposed to detect and resolve the error to change the mobile robot from non-linear state into linear state and to route the packet to mobile sink without any interruption.

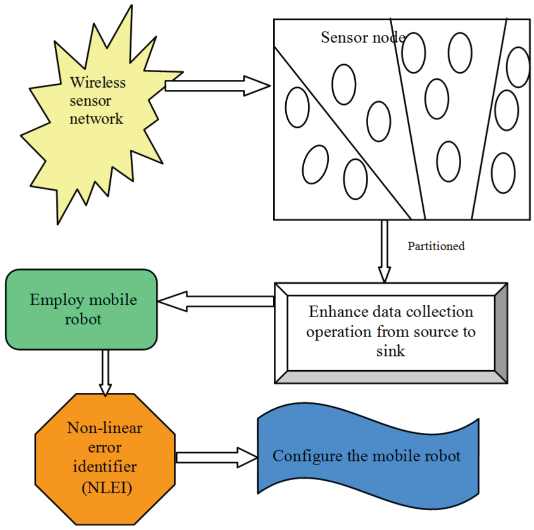

Fig. 2. Architecture diagram of the proposed non-linear error identifier in WSN

The architecture diagram of the proposed mobile sensor robot configuration in WSN is shown in Fig. 2. From Fig. 2, it is being observed that the non-linear error identifier identifies and rectifies the error occurred when mobile robot is in non-linear state. Then the mobile robot routes the data packet from source to mobile sink in WSN.

3.1. System model

It is necessary to organize a set of sensor nodes in WSN which are denoted as $S = \{s_1, s_2, \cdots, s_n\}$ to shape a sensor network. The sensor network monitors all the sensor nodes in the network within the communication range. Each sensor node in a network s_i is outfitted with a sensor device which can scrutinize sensor region with the target points.

Assume that a sensor node in network can supervise numerous destination points inside its communication region.

- Each sensor node si can effectively communicate with all other sensor nodes or the mobile robot inside a communication region.
- Henceforth, assume SR and TR as the sensing range and the transmission range of the sensor nodes in the network correspondingly.
- But all the nodes will have fixed values for SR and TR.
- The mobile robot has high broadcast range than the sensor node, so that it can communicate with all sensor nodes if it lies within the communication range.

For the data collection problem in WSN, a set of sensors

S are specified in the network, the identification of the destination points are specified as D = $\{d_1, d_2, \cdots, d_k\}$ where the robot are ready to collect the data from sensors, such that

- The robot can communicate with every sensor while performing the communication and keep less pauses for packet transmission.
- The path in which the mobile robot will travel to gather data on every stop points maintains shortest path.

3.2. Data collection based on mobile robot

The mobile robot in the organized network, all sensors can initiate to gather information regarding the nearest route path. The collected information about the sensor nodes routing is analyzed and processed to the centralized control centre. On the other hand, the transmission range of each sensor in the network is restricted. The sensor network might be divided to several mobile elements secluded from each other nodes in the network. Accumulating more number of sensor nodes in the network enhances the connectivity nevertheless; it is not possible in numerous applications, for instance space examination with exclusive sensor devices. In such situation, the mobile robot can assist the path of data packet from source to destination. Assume that the mobile robot is also prepared with transmission devices and can gather data from the organized sensors. The robot holds a sensor node which is utilized to converse with the sensor nodes in the WSN. The sensor nodes produce the response recurrently to the destination in WSN. The robot provides the distance among each sensor node and the robot based on the route path specified.

Assume set of sensor nodes be S = $\{s_1, s_2,\ldots,s_n\}$ and p be the packet data which is to be collected from source node and passed onto the sink in WSN. There is a chance of sensor node in WSN reached unstable stage. The unstable status of the sensor node is measured based on the energy utilization of sensor node in the network. If the particular sensor node's energy depletion occurs, the node fails to transmit the packet. So this case the sensor node agent will search the nearby mobile robot which lies within the communication range. After detecting the mobile robot the sensor agent sends a command regarding the node failure. Then the mobile robot identified the data packet p, carried by the failed sensor node and identified the location of sink in the WSN. After identification, it passes onto the desired location and bring back the data packet to the sink.

3.3. Proposed NLEI algorithm

In a wireless sensor network, sensor nodes are fixed at position and packets are passed from source to destination by choosing the route path. In real world, the sensor will move through an environment. In such cases, the sensor node does not lie within the communication range then it has lost its survival status then the packet transmitted via that sensor node will get dropped. Hence, the mobile robot is presented along with the network to enhance the data collection operation in WSN. But the mobile sensor robot does not rely on fixed place; it keeps on moving along the network in a random manner. When the mobile sensor robot moves out of communication, then it is complex to transmit the packet to the sink and error can occurs. To resolve this issue, non-linear error identifier is presented to identify and rectify the issues raised by analyzing the movement of mobile robot in the network. Also mobile sink node (i.e., used when mobile sensor robot lies outside the communication range) and sink node (i.e., used when mobile sensor robot lies inside the communication range) is used in this paper, where sink node acts as the base station and also with the rapid movement observed in Wireless Sensor Network, we have introduced mobile sink which is a dynamic node.

The non linear error identifier works based on three set of phases. They are

- Initial phase
- Location identification phase
- Final phase

During the initial phase, the geographical information about the location of mobile robot in wireless sensor networks has been investigated. The information includes the position of robot and the status of identifying the robot sensing range.

In location identification phase, the location of the mobile robot in WSN has been identified using the proposed algorithm. Since the mobile robot is moving in nature, the position determination is difficult to achieve. It is necessary for mobile robot to reside within the communication range of sensor network. If it moves out of communication range, the position determination of mobile robot is accomplished to resolve the occurrence of error.

The process of transmitting the packet from identified source node to the sink without any interruption by means of mobile robot location information has been done in final phase.

Assume a set of sensor nodes in WSN be S = $\{s_1, s_2, \ldots, s_n\}$ and the mobile robot MR be moving around the network. Before assumption, the wireless sensor network is partitioned into sub sensor networks to transmit the packet effectively. Hence, the mobile sensor robot will travel around each set of sub sensor network. In order to monitor the mobile robot location around the network, the mobile agent MA is chosen for each partitioned WSN. The mobile agent in each partitioned sensor network will keep on monitoring the mobile robot movements and positions. The mobile robot is travelling around the sensor network with the sensing range SR. Through the value of sensing range the mobile robot will check with the mobile robot whether it lies within the communication range.

//Proposed Algorithm

Input: Sensor nodes S = {s_1, s_2,…,s_n}, mobile agent MA, mobile robot MR, data packet P, route R, sensitivity range SR, energy utilization E, communication range CR

```
Begin
    Partition the network into different small sub networks
    Assume a set of sensor nodes are ready to send a packet
     data to mobile sink in each partitioned WSN
    Set a route path R from source sensor node to sink node
        Set SR = α
        Set threshold value (T) for E
        For each S
            Identify the neighbor sensor node NS
            Do
                For each NS
                    Identify the E (NS)
                    E(NS) = NP / t
                    If E (NS) < T
                        Select the node and pass the packet
                    Else
                        Mobile robot ();
                    End If
                End For
                    While (S reaches mobile sink)
         End For
End
```

// configuring mobile robot using non linear error identifier
mobile robot ()

```
Begin
For each partitioned WSN, Set mobile agent MA
    MA monitors the MR whether it lies in the CR or not
    If lies
        Pass the data packet to the respective MR
    Else
        Identify the SR of MR
      If MR ≠ α
        Non-linearity error occurs
        Rectify the error by searching the location of
        MR through sensing Range
        If MR far-flung
            Search nearby MR
            Pass the packet to the sink node
        End If
      End if
    End if
End For
End
```

The mobile agent will set a maximum and minimum value for mobile robot's non-linearity state i.e sensitive range. The sensitivity value of the mobile robot with the constant value based on its movement over the path of the network has been set. If the sensitivity value of the mobile robot varies, then assume the mobile robot is in non-linear state i.e., it moves beyond the communication range. This non-linearity state error is identified based on the changes in the values of sensitivity over the full range of sensor nodes in the sensor network. Hence, a suitable algorithm has been developed and presented to identify and rectify the non-linear error occurred in sensor network. The proposed algorithm is shown above.

The Entire network has been first partitioned in to a small sub networks. Then the sensor nodes are ready to send a packet data to mobile sink. The route path R and sensing range for each Sensor node also has been assigned as α. The threshold value for each node has been set as T and if E (NS) < T the packet has been sent to the particular sink node. Otherwise it has been found the node is lying outside the communication range i.e., MR≠α. Hence the non-linearity error occurs. This error has been rectified by searching the location of MR through the sensing range. Then the packet has been passed to the sink node. Similarly it has been repeated for all set of sensor nodes for efficient data collection.

With the above algorithm, the non-linearity error is determined based on the sensitivity range of mobile robot identified and resolved the error. Based on the sensitivity range of sensor node, the mobile robot location is determined and resolved.

3.4. Metrics for mobile robot configuration

The performance of the mobile robot configuration for wireless sensor network is determined in terms of delivery rate, error correction and efficiency. The rate at which the set of data packets from all sensor nodes successfully reaches the mobile sink node in WSN is termed as delivery rate.

$$Deliveryrate = \frac{MR_p + Sink_p}{TOT(p)} \tag{1}$$

where, MR_p – Data packet sent by the mobile robot, $Sink_p$ – Data reached at sink node, TOT (p) – Total no. of packets sent.

The delivery rate is measured as the data composed from all of sensor nodes reached the sink node. In the NLEI approach, the delivery rate is considerably high even if the sensor node has been failed in the middle. Because, the mobile agent will monitor the mobile robot all the time by means of sensitivity range. If the mobile robot goes beyond the communication range, the mobile agent senses the location and makes an alternative arrangement using nearby mobile robot to pass the packet to the sink node.

The error correction is measured when the percentage of the correction of error occurred by means of mobile robot movement beyond the communication range in WSN. In proposed algorithm, the error correction is done effectively based on the mobile agent sensing capacity. The occurrence of non-linearity error is identified based on the mobile robot sensitivity value across the network. Once the error is detected, the mobile robot is configured based on the sensor nodes in the network. Efficiency is measured based on, packet transmission from source sensor node to sink without any interruption. In proposed algorithm, the efficiency is high since the mobile robot is configured at the instant for packet transmission even when the sensor node fails while communication in WSN.

4. Experimental Evaluation and Result Discussions

In this section, the simulation has been carried out to analyze and evaluate the performance of the proposed NLEI algorithm using NS2 simulator. Also, the effectiveness of the proposed algorithm has been verified with the existing novel data collection technique.

The simulation environment of the area of the geographical region used for NS2 has been assumed as 900 m × 900 m. The energy model for the sensor nodes in NS2 has been assigned as 0.16 W, 0.32 W and 0.00000145 W for receiving power, transmitting power and idling power respectively and the initial battery energy is assumed as 12 J. The sensing range SR of each sensor node, sink and the *MR* is assumed to be a circular area of 50 m in diameter and adopted in NS2. The entire geographical area has been partitioned in to 16 sub network for better results. The MAC layer used in this simulation is IEEE802.11 standard with distribution coordination function (DCF). In this simulation, the two-ray ground radio propagation and an Omni-directional antenna with unity gain has been adopted.

Simulation of 20 runs has been carried over with chain-oriented topology and average has been considered for performance analysis of the proposed NLEI algorithm. The chain-oriented topology has been selected because it has been found that it can be the most promising topology among all topologies [33].

The performance analysis has been verified and validated based on the data delivery rate, the error correction rate and efficiency (distance travelled by the MR). Meanwhile, the mobility and speed of the MR are of importance when the MR is introduced in a WSN to assist in collecting sensed data. Thus, the various speeds of the MR has been conducted and analyzed. In addition, the thresholds of the sensor nodes also have been studied.

Table 2. Experimental Parameters

Simulation time	3000s
Number of nodes	600
Near-death energy	2 J
Dead energy	3 J
Speed of MR	5 m/s
MAC layer	IEEE 802.11
Sensing Range	50 m diameter
No. of sub network	16

Finally, the simulation results of the impact of the density of the sensor node have been presented. For the comparison of the impact of different navigation strategies, the general configuration of the setting is described in Table 2.

4.1. The delivery rate

With the specified simulations, the wireless sensor network has been modeled and estimated the performance of the proposed algorithm for NLEI. The Fig. 3 describes the performance analysis of the proposed NLEI and existing novel data collection technique [17] applied in wireless sensor networks. The delivery rate of the packet data has been measured based on the number of sensor nodes in the network. The delivery rate is determined for the proposed NLEI approach and is compared with the existing novel data collection technique and is illustrated in Table 3.

From Fig. 3 it has been observed that the proposed NLEI approach provides high delivery rate as compared with the existing novel data collection technique even for higher number of nodes. But the delivery rate decreases when the

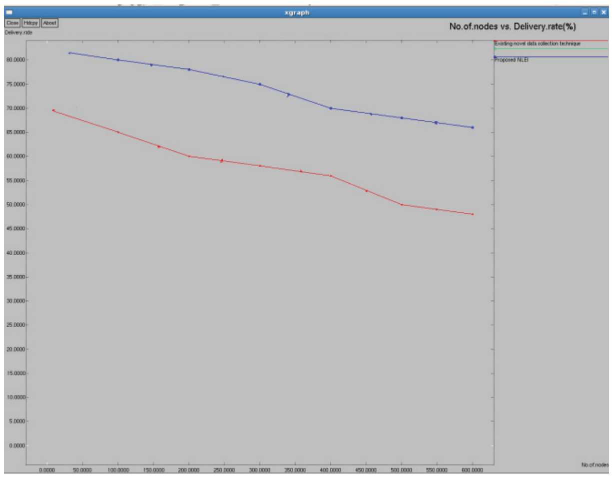

Fig. 3. No. of nodes vs. Delivery Rate

Table 3. No. of nodes vs. Delivery Rate

No. of nodes	Delivery rate (%)	
	Proposed NLEI	Existing novel data collection technique
50	85	69
100	80	65
150	79	62
200	78	60
250	77	59
300	76	58.5
350	75	57
400	74	56.5
450	72.5	55
500	72	54
550	71.5	53.5
600	71	52

number of sensor nodes increases in the WSN. This is because of the collision of data met while implementing the mobile robot. The proposed algorithm provides better data packet delivery of 15-17.5% higher when compared with existing data collection technique.

4.2. The error correction rate

The error correction rate has been measured when the percentage of the correction of error occurred by means of mobile robot movement beyond the communication range in WSN. The error correction rate has been determined for the proposed NLEI approach and it has been compared with the existing novel data collection technique which is illustrated in Table 4.

Fig. 4 illustrates the error correction rate which is measured based on the number of sensor nodes in the network. The non-linearity error has occurred when the mobile robot leaves the communication range in WSN. It has been found that the proposed NLEI algorithm rectifies the presence of error at high value as compared with the existing novel data collection technique. Also it has been observed that the error correction rate increases even for higher number of sensor nodes. The error correction rate of the proposed NLEI algorithm has been achieved 14-22% higher than the existing technique.

Table 4. No. of nodes vs. error correction rate

No. of nodes	Error correction rate (%)	
	Proposed NLEI	Existing novel data collection technique
50	8	3
100	10	5
150	12	7
200	15	8
250	18	10
300	22	12
350	24	14
400	30	16
450	32	18
500	33	20
550	36	22
600	42	24

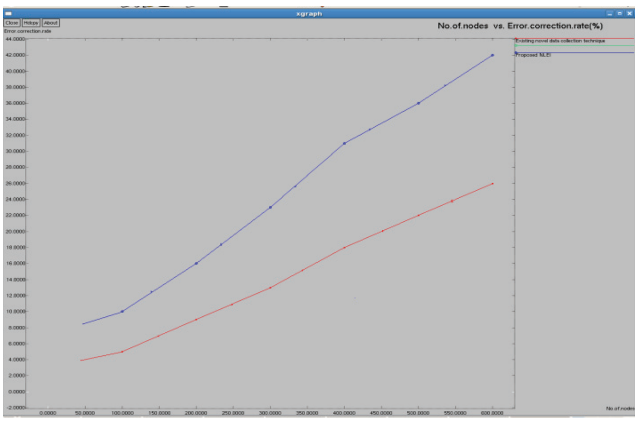

Fig. 4. No. of nodes vs. error correction rate

4.3. The efficiency

The efficiency of the proposed algorithm has been defined based on the number of sensor nodes in the network without nonlinear error. In the proposed NLEI algorithm, the mobile robot is configured at the instant for packet transmission even when the sensor node fails while communication. Hence the packet has been transmitted from source sensor node to sink without any interruption. The same has been simulated for the proposed NLEI algorithm with the existing novel data collection technique and is illustrated in Fig. 5 and for easy understanding the same has been given in Table 5.

Fig. 5 shows that the proposed NLEI algorithm provides high efficiency than existing data collection technique since it corrects the error and packet delivery. It has been observed that the efficiency of the proposed algorithm is 13-32% higher than that of the existing one.

From the above performance analysis it has been found that the proposed NLEI algorithm configures the mobile robot effectively by setting up the sensitivity range in WSN.

Table 5. No. of nodes vs. Efficiency

No. of nodes	Efficiency (%)	
	Proposed NLEI	Existing novel data collection technique
20	22	8.5
40	24	9
60	25	10
80	26	11.5
100	28	12
120	30	13
140	32	14
160	34	16
180	36	16.5
200	38.5	18
220	40	20
240	44	22
260	46	24
280	50	26
300	60	28

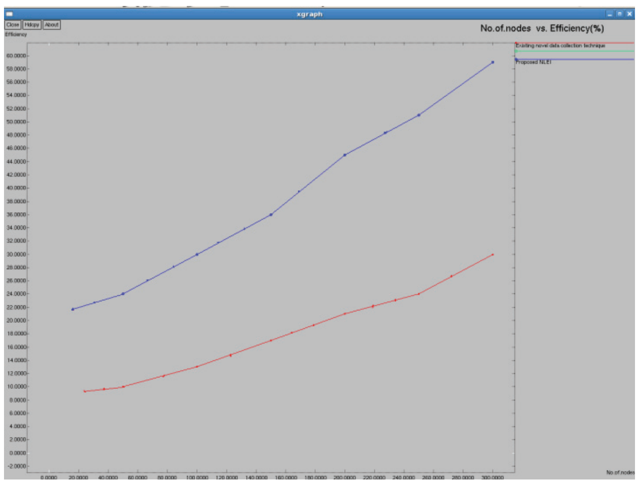

Fig. 5. No. of nodes vs. efficiency

From Fig. 3, with the increasing number of nodes, it can be observed that the delivery rate gets decreased because of the possibility of occurrence of collision during data accumulation while deploying mobile robot. However in Fig. 4, with an increase in the number of nodes, the error correction rate gets improved because of the application of NLEI algorithm that efficiently rectifies the presence of non-linearity error whenever the mobile robot leaves the communication range in WSN. The mobile robot is configured based on the mobile agent in the partitioned WSN. The transmission of packet reached the mobile sink from source node in WSN.

5. Conclusion

In this paper, the nonlinear error identifier (NLEI) approach has been adapted for configuring the mobile robot in wireless sensor network. The source node checks with the neighboring node status to pass the packet. If node failure occurs, the respective mobile agent monitored the mobile robot moving across the network. The non-linearity error occurred when the mobile robot goes beyond the communication link. This error has been rectified by the sensitivity value of each mobile robot passing across the communication range and transfers the packet data safely to the sink. Simulation has been done to estimate the performance of the proposed NLEI algorithm against the existing data collecting algorithm in terms of delivery rate, error correction and efficiency. From the simulated results it has been observed that the proposed NLEI algorithm increases the error correction rate upto 42% and efficiency upto 60% for 600 nodes when compared with existing data collection technique.

The NLEI algorithm has been simulated with the traces obtained from WSN. At this stage, the simulation has been carried out NS2 simulator. As future work, the number of nodes also has been increased and real test sensor bed environments also have been considered for better performance.

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