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Exploration on Increasing Packet delivery rate in WSN using Cluster Approach

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Abstract

Wireless Sensor Network (WSN) plays a vital role and part of real time communication applications. Location of unknown node is difficult to find in the presence of mobile sensor nodes. Navigator plays an important role in identifying network fault and unknown node location. In existing schemes, either trilateration or geographical position routing were deployed to increase the location accuracy. In this research, Neighbour based Cluster Location Aware Routing (NCLAR) is proposed to achieve more packet delivery rate with high location accuracy. It consists of three phases. In first phase, cluster region is formed with less signal delay value and more signal strength. In second phase, neighbour node routing table is constructed and updated with addition of more fields. These fields are reliability, probability of successful transmission of packets and delay. The back off timer is estimated to update the table within a periodical time. In last phase, location status navigator is calculated to increase location accuracy and to maximize the packet delivery ratio. Based on the simulation results, the proposed scheme NCLAR achieves high location accuracy, more packet delivery ratio, less overhead, less delay and high network lifetime.

Keywords: WSN, Location Accuracy, Neighbor Node Table, Cluster Region, Location Status Navigator and Delay.

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1. Introduction

Wireless Sensor Networks are made up of sensor nodes which are widely used in various real time applications i.e. climate monitoring, military areas, disaster zones etc., in the presence or absence of access point. Each node is equipped with one transceiver and microcontroller. The major job of sensor node is to convert physical energy into electrical energy. In ad hoc fashion, sensor nodes are deployed to cover entire geographical region. The gathered information data and sensor nodes must be positioned to find the location of data packets.

Localization of sensor network is a key part of WSN because it is locates localization systems as a key part of WSNs, because they do not locate events and act as a base for traffic control, protocols and routing. In the presence of threat environment, attackers are mainly targeting localization systems and it may lead to wrong decision making in military plans and other problems.

Finding the exact physical location of sensor node is called localization. Nodes are randomly located in the forest region. The familiar technique called Global Positioning System (GPS) is used to find location of sensor nodes accurately. In the network contains more number of nodes, this method will be more costly and more energy consuming. Hence it is to not easy to deploy sensor nodes with installation. The easiest way to install sensor nodes is that installation of GPS receivers and remaining nodes must find their location using some existing localization methods. The nodes which are known their locations are called as anchor nodes. These nodes are used to find the location of unknown nodes. In

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[1] authors have reported the different varieties of localization algorithms based on various estimations. The comparative analysis was made and concluded each schemes with features. The centralized localization algorithms are expensive and distributed localization techniques are imprecise. This survey paper was suitable for development, alteration and optimization of various localization algorithms

The paper is organized as follows. Chapter 1 introduces the Wireless Sensor Networks and location aware routing. Chapter 2 discusses the recent localization protocols, algorithms and schemes etc. Chapter 3 introduces the proposed scheme. Chapter 4 conveys performance results of proposed and existing schemes. Last chapter concludes the work and future work.

2. Related Works

Wang Wei & Wang Zhaoba [2] have introduced location based encryption modulation algorithm to adopt the new kind of reliationship between unknown sensor nodes and anchor nodes using space transmission model and lognormal distribution technique. To provide different environment for attackers in sensor environment, data will be encrypted and modulating carrier signal using Received Signal Strength Indicator (RSSI) value. The envelope detection and decryption was implemented at receiver side. The node location is identified using maximum likelihood estimation. This algorithm was suitable for ranging requirement not for commercial applications.

Kalpana Sharma et.al [3] explored new localization algorithm with two Geographical Positioning Systems (GPS) with different shapes and sizes. The exact positioning of sensor nodes in remote area can be tracked using GPS. A single round of node mobility was identified to locate neighbor nodes using localization algorithm. Only limited storage space was allocated per hop neighbor node. The energy consumption of sensor nodes was reduced by minimizing cluster heads. To encrypt the data, less processing time and power were utilized.

Nirmala and Manjunatha [4] presented an enhanced voting based localization scheme. The absolute location of sensor nodes was identified and secured using security scheme and the concept of bilateration and trilateration methods. The communication between sensor nodes and anchor nodes and its location were found using this voting based secure localization scheme. The energy consumption of sensor node was reduced by other nodes who are not participated in the localization process.

Yang and Zhang [5] introduced the optimized bat algorithm with effective performance to reduce the issues in location errors. An extension of bat algorithm is DV-Hop localization algorithm which works on two dimensional space with average distance between per hop nodes. The new parameter called fitness function was determined to update the metrics i.e. position, intensity, frequency, velocity and so on. By using the concept of multiple location iteration procedure, the optimal average distance per hop was estimated. If the nodes are unknown with more weight, it will be removed for perfect localization.

Soujanya and Suneetha [6] developed the Improved Attack Detection and Localization Scheme (IADLS) to reduce the vulnerability of attacks and localize the sensor nodes. The chaos based encryption was implemented to establish the secure communication. The concept of secure range-independent localization was developed with unique design and implemented at low cost to provide location accuracy. Including this, fast chaotic encryption algorithm was used to provide data confidentiality. The common solution to attacks was given and energy efficient secure communication was given among authenticated sensor nodes.

Nirmala et.al [7] introduced voting based localization scheme with secure and maximum energy efficiency to identify localization area for node with minimum estimation error. The location of sensor nodes was identified with trilateration method with trusted node identities. The false information was filtered using effective authentication technique.

Tamleek ali et.al [8] proposed a secure actor localization approach to prevent malicious nodes from joining the network region and becoming a genuine node of the network. The localization approach was implemented effectively in randomized sensor networks. The possibility of malicious nodes and registration of attacker nodes were reduced. This technique was also deployed to reduce man-in-the-middle attack and increased the data delivery ratio.

Rashmi and Shridhar et.al [9] provided the energy efficient and secure image transmission technique to secure image contents. The data is divided into packets and it is transmitted from source to destination. The coding technique was adopted to secure image contents. In previous cases, many compression techniques were adopted to secure the data. In this work, shortest path between source and destination is identified and compressed the image contents using wavelet fractal image compression technique. Here the encryption algorithm called Advanced Encryption Scheme was adopted and secured the transmission.

Anuja and Raju [10] focused three major themes of sensor networks, i.e. energy efficiency, security and network lifetime. The optimal paths were established from source to destination to increase the packet delivery ration and reduce the packet delay over transmission. Based on residual energy of individual nodes, the weights to the links were assigned to increase the network lifetime. Packet dropping was reduced through the proper selection of optimal paths.

Ganesh and Amutha [11] developed the efficient and secure routing protocol to increase the power efficiency and reduce the packet delivery latency. It was deployed using optimal SNR-based power control mechanism and optimal handoff based self-recovery. The significant decrease in data extraction and more energy usage was resulted because of higher fairness constraints. The analysis was made on more node scenarios and resulted that changes in energy and fairness constraints.

In [12] secure localization was adopted with elliptical curve cryptography technique. Compared to public key cryptographic schemes, the Elliptic Curve Cryptography (ECC) was more effective and implemented to secure node location. The cryptography technique requires minimum key size, minimum bandwidth and hardware. The location of sensor nodes was kept secret and it is known to source sensor node. The new localization method was adopted with cryptography technique to secure node identity.

Julie and Tamilselvi [13] proposed Content based Fuzzy Opportunistic Protocol to reduce the selection process of sensor nodes. It was implemented with dominant based set method. The concept of construction dominating set was done for selecting cluster heads with fault tolerance and high energy efficiency. The fuzzy opportunistic routing decision was provided to increase the network lifetime through optimal path selection. There are three parameters taken for fuzzy input i.e. size of queue, node closeness and residual energy of nodes. This protocol achieved 80% of fault tolerance ratio.

Jian Shen et.al [14] developed RFID based localization algorithm based on the Radio Frequency Identification Technology. This technology plays an important role in real time applications and rapid response. Localization method was achieved and real time monitoring and low cost of sensor nodes was implemented using this RFID technology. The accuracy of sensor nodes was increased and energy consumption was minimized using localization technology.

Pinar and Hakima [15] proposed recursive and ad hoc routing based localization to estimate positions of sensor nodes. The Multi Point Relay (MPR) decision was introduced with two schemes i.e. Distance Vector hop and Distance Vector distance. Three anchors were identified to find the location of node. If the sensor node is found with exact location, position status of anchor node will also be identified. A recursive position estimation (RPE) algorithm was introduced to find density, position error and reference point numbers.

Chakchai and Weerat [16] developed MDV Hop BAT localization algorithms to provide routing, reliability and localization in the absence of global positioning services. There are two estimation methods used i.e. range free based localization scheme and soft computing approach. The uncertainty of node location and approximation was addressed using hybrid localization algorithm. Signal normalization with extra weight was derived over location information from the fuzzy logic function located in centroid.

Ahmad et.al [17] introduced a novel low-cost localization algorithm for multi-hop wireless sensor networks with different capacities of nodes. The need for taking different node capacities is that accuracy of node location may be improved. There are two approaches to derive expected hop count to locate sensor nodes with high accuracy. A correction mechanism was developed with low cost to the heterogeneous environment.

Pandey et.al [18] explored smaller level localization method to reduce the path length without degrading the value of clustering co-efficient parameter. The performance of localization was made by new link establishment with link addition probability. According to the requirements of bandwidth, a cognitive approach was developed to compute exact link addition probability value. During localization process, energy consumption and bandwidth allocation were reduced successfully.

Mehdi and Christian [19] presented a range free localization method for wireless sensor networks to provide accurate positioning without the requirement of additional hardware. In this method, all nodes are assumed to have identical transmissions and absence of network partition. Nodes are assumed to have different signal strength and communication ranges. Based on elliptical properties of paths and link estimation method, accuracy of node location was improved.

In [20], an energy and latency aware position based packet forwarding protocol for Wireless Sensor Networks. The proposed protocol has reduced energy consumption and delay and it provides guaranteed packet delivery.

3. Implementation of Proposed Scheme

In this research work, clusters are formed with maximum signal strength. Timers and signal delays are calculated for identifying signal strength of cluster. Energy status is calculated before and after transmission. Location status navigator is estimated based on the transmission between neighbor cluster members and cluster head. Neighbor cluster member table is constructed with many fields which are required to increase the network performance

3.1 Formation of cluster through signal strength

Before the establishment of cluster formation phase, source node broadcasts announcement message to all sensor nodes to form a cluster region. Cluster is a group of node which contains cluster head and remaining nodes are cluster members. Forming cluster region leads to good network connectivity and high signal strength. If any network contains more clusters, the accuracy of node localization can be easily improved in the presence of base station. In this research work, there was no installation of base station to monitor the status of sensor nodes. Instead, cluster head will monitor all activities like routing, packet forwarding, status of node, and path capacity. Cluster Head (CH) is chosen based on signal strength, bandwidth, capacity and communication with neighbor nodes. Selection of cluster head is based on connectivity between cluster members. Initially cluster head can be chosen based on delay value for transmission of data packets towards destination. The cluster member count can be calculated based on signal strength received. In packet forwarding phase, each neighbor node starts signal delay value to estimate the signal strength. Signal delay (τ) can be estimated as,

$$\chi = \frac{d(CH, NCH)}{NCM_{Count}} \quad (1)$$

$$\tau = \frac{1-\delta}{\chi}$$

Where δ is a random approximated value between (0,1), $d(CH, NCH)$ is the distance between cluster head and nearest cluster head of cluster region, and number of neighbor cluster members NCM_{Count}. Parameter χ is used to find cluster member which has more neighbor nodes with least hop distance to the cluster head. All the cluster members join cluster head which clears signal delay value. In starting phase, cluster head broadcasts route discovery message to all neighbor nodes by sending C_{req_form} message. The distance between cluster head to neighbor cluster members is calculated based on received signal strength value. If the neighbor node is not found in the cluster region, it can be found by advertising route id with coverage distance i.e *r*.

Once the cluster formation completed, each cluster members receive CDMA (Code Division Multiple Access) slot to forward the packets to CH to check the signal strength. All CHs collect packets received from cluster members and forwards it as unique fixed data packet to lower CHs. To check the availability of signal strength, the position of CH should be monitored. The position back off jitter is calculated to locate cluster head. It is calculated as,

$$k = \frac{E_s - E_r}{r-1}$$

$$v = \left(\frac{E_w}{E_r}\right) * \left(1 - \frac{k}{NCM_{count}}\right)$$

$$\tau_b = \frac{1}{1-v}$$

Where k is the energy conservation rate to measure energy of whole cluster region, E_s is starting energy before packet transmission, E_r is residual energy of cluster region, r is radius of transmission region, E_w is energy wasted on packet lost, and v is the parameter to choose cluster members with high visibility and parameter NCM_{Count} to make cluster head election process very effective. If any neighbor cluster member having more coverage transmission, it first clears the signal delay. Hence all CHs will be rotated thoroughly among neighbor cluster members in position based network. In starting stage, distance with cluster head plays a major role and considered as primary metric. In final stage, signal delay plays a major role in identifying CHs in the network. Figure 1 shows illustration of cluster formation based on maximum signal strength.

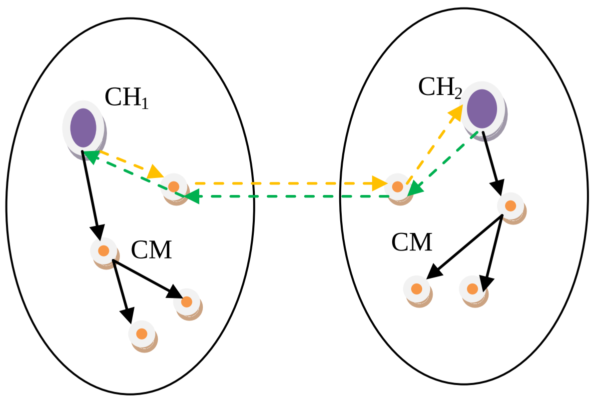

Figure 1. Illustration of Cluster Formation

Cluster is formed from the signal delay value and signal strength. Shortest path lies between CH and CM. Each cluster members initiates and supports route discovery process and estimate link strength. Only those nodes which is having maximum cluster member count and signal strength, it is qualified to join cluster head. Cluster head clears all the delays caused by packet lost and successful transmission.

3.2 Algorithm for Construction of Neighbor Cluster Member Table

Neighbor cluster member receives the packets i.e. request packet, cluster join packet and data packets and update its table periodically. This table is used to estimate the addition fields to find the reliability of nodes, link and path, delay and communication cost. Each cluster member node receives packets after three seconds from cluster head and its neighbors. The following steps show the calculation of fields in the neighbor table.

Step 1: The probability of successfully received packets is calculated as,

$$\overline{B} = \frac{N_{acks} - N_{lost}}{N_{tran}} \tag{2}$$

Where N_{acks} is number of acknowledgement packets, N_{lost} is number of packets lost due to link failure and N_{trans} is number of transmitted packet successfully at the destination.

Step 2: By applying the concept of weighted mobility average of nodes, the Link Reliability (LR) is calculated as,

$$LR_{(CH,m)} = (1-\gamma_r)LR_{(CH,m)} + \gamma_r \times \overline{B} \tag{3}$$

γ_r is the overall weighting factor which lies between 0 and 1. The weighted mobility average is used to estimate the delay based on the MAC (Medium Access Control) and Network layers respectively. From the signal delay value, MAC queue delay and capturing time of window channel is estimated. This is the first packet sent by CH.

Step 3: The reliability of path is estimated as,

$$PR_{(CH,m)} = LR_{(CH,m)} \times PR_{(CH,m)} \tag{4}$$

Initially path reliability lies between 0 and 1. The reliability of path is set as zero at starting phase and it will be added with link reliability after packet transmission begins.

Step 4: The path delay $(DL_{path(CH,m)})$ between CH and CM (Cluster members) is calculated based on node delay $DL_{NCM(m)}$. It is calculated due to processing delay (DL_{pr}), queuing delay (DL_q), packet lost delay (DL_q) and transmission delay ($DL_{trans(m)}$). Let us calculate,

$$DL_{NCM(m)} = DL_{tran(m)} + DL_q + DL_{pr} - DL_{pl} \tag{5}$$

The path delay is estimated as,

$$DL_{path(CH,m)} = DL_{NCM(m)} + DL_{path(CH,m)}$$

Step 5: Estimate communication cost $(C_{CH,m})$ between cluster head and cluster members based on the distance. Consider

$$C_{CH,m} = \frac{(\tau_m * d^2_{(CH,m)})}{E_t} \tag{6}$$

Where E_t be the total energy spent for packet transmission and τ_m is the delay occurred at node m.

Step 6: Include all the fields in neighbor cluster member table and forward the packets to CH.

3.3 Estimation of Location Status Navigator and Packet delivery

In this phase, cluster members are allowed to identify the local status and location information and send it to CH. The Location Status Navigator (LSN) can effectively detect any link failure, congestion status and instruct node to prevent faults to avoid further network performance degradation. It also makes to create awareness of local condition of nodes to identify the causes of congestion. The LSN is calculated as,

$$LSN_{CH(g)\_m} = K_{CH(m)} - N_{CH(m)} - C_{CH(m)\_n} - LF_{CH(m)\_n} \tag{7}$$

Where K and N are the set values approximated for neighbor cluster members m , n, and C, L are the congestion status and Link failure status. The expiry time is different for all cluster members if it moves from one location to another location. The cluster members divide the sector of cluster region into two subsectors to maximize the throughput. The decisions taken by CH are sent to neighbor cluster members based on geographical route discovery mechanism. This mechanism helps to identify the network partitions inside the network. Fault route recovery mechanism is adopted to recover the failure links in the congestion period. Both packet loss and packet delay deadline must be avoided for successful transmission. Packet delivery ratio is calculated at the end of route maintenance process.

The flow of proposed scheme NCLAR is illustrated in figure 2. From the flow of proposed scheme, the delivery rate is achieved maximum compared to other existing schemes. Once the accuracy and path reliability increased successfully, the probability of packet transmission will be maximum. In neighbor table construction phase, the reliability, network throughput and delay are estimated and fixed as threshold. It will be broadcasted to all neighbor cluster members to follow the threshold value.

3.4 Packet Format of NCLAR

Cluster Head ID	Cluster member ID	LSN	Signal Strength	PR	CRC
2	2	4	2	2	2

Figure 3. Packet format of NCLAR

Figure 2 shows the packet format of proposed scheme NCLAR. In this format, all the fields occupy 2 bytes except third field. Cluster head and Cluster member ID are stored in the header of packet. Status of location navigation will be announced to all neighbor node. Cluster head checks the signal strength and path reliability for efficient reliable packet transmission. CRC is Cyclic Redundancy Check for packet error checking and correction. The packet size is 512 bytes.

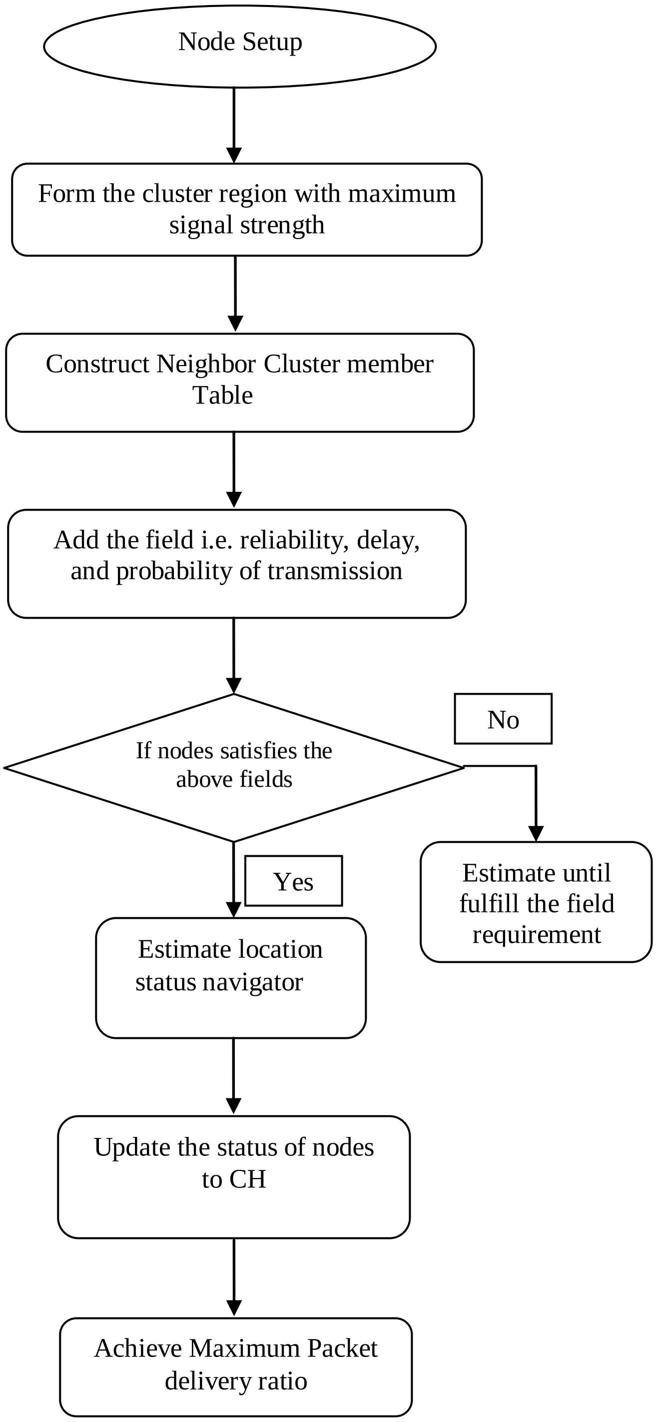

Figure 2. Flowchart of NCLAR

4. Performance Evaluation

The proposed scheme is examined and tested through the network simulation tool (NS 2.34). This tool is an open source tool and updation is more. Compared to other tools like JIST, Glomosim and Qualnet, it contains more packages and scripts. For simulation of proposed scheme, number of nodes is 150 nodes. Area size is 1100 x 1100 m^2. Transmission range of this simulation setup is 150m. The settings of simulation for NCLAR are tabulated in Table 1.

a. Performance Metrics

The performance metrics of proposed scheme are given below.
Network lifetime: It is defined as the number of epochs consumed per nodes. Energy spent on transmission and reception.
Packet Delivery ratio: It is defined as the number of packets received to the number of packets sent.
Location accuracy: It estimates the exact geographical location of nodes centralized with respect to axis. It should be high.
Node detection ratio: It defines the number of unknown nodes identified successfully inside the cluster region.
Control overhead: Node consumes excessive number of packets in the cluster routing.
End to end delay: Delay caused by sensor nodes to forward the packets from one cluster head to another cluster head.

Table 1. Simulation and Settings parameters of NCLAR

No. of Nodes	150
Area Size	1100 x 1100 m^2
Mac	802.15.4
Radio Range	150 m
Simulation Time	100 sec
Traffic Source	Poisson
Packet Size	512 bytes
Mobility Model	Random Walk
Initial energy	986 Joules
Transmitted power	0.789 watts
Received Power	0.0694 watts
Protocol	LEACH

b. Results

In Figure 4, number of nodes is varied as 20, 30,.100. Packet delivery ratio is measured for all schemes for all kind of nodes. When the number of nodes increases, packet delivery ratio may get decreased due to the presence of link failures and congestion routing. The proposed scheme NCLAR achieves high packet delivery ratio (38-94)% of the maximum rate. It is because of neighbor table updation. If the nodes are not frequently updating the route history, packet loss may be occurred.

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In the absence of base station, cluster head improves the fault tolerant route to increase the packet delivery ratio.

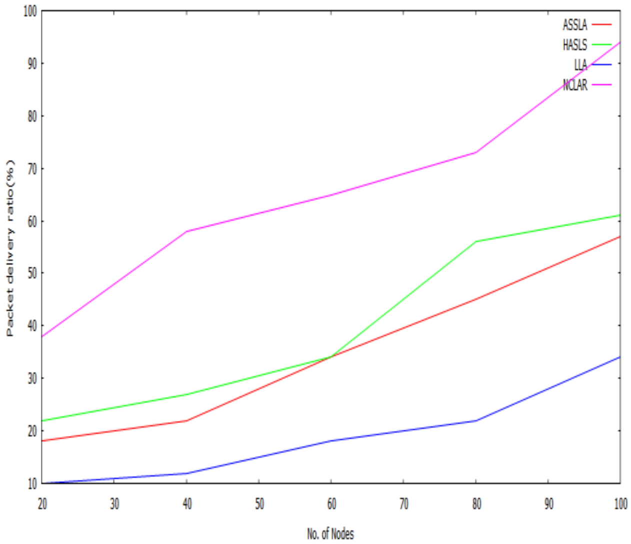

Figure 4. Packet Delivery Ratio Vs Number of Nodes

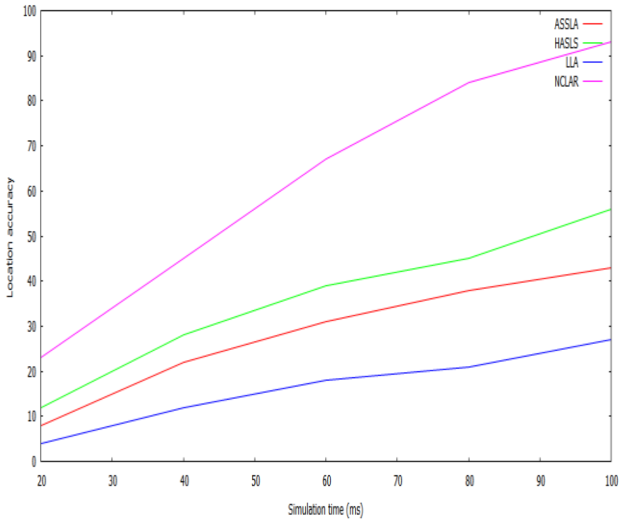

Figure 5. Location accuracy Vs Simulation time

Figure 5 shows the result of Location accuracy Vs Simulation time. Location accuracy plays a major role in network to increase the network lifetime. Identification of unknown nodes is very difficult in existing schemes. In our proposed scheme NCLAR, it achieves (23-93) % of location accuracy rate. In existing schemes, only trilateration and TOA method were adopted. In our localization scheme, partition based geographical position is adopted to increase accuracy of node location.

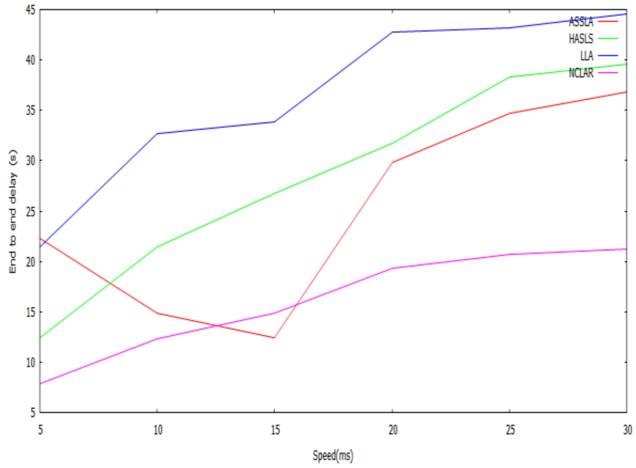

Figure 6. End to end delay Vs Speed

Figure 6 illustrates the performance of end to end delay for NCLAR, ASSLA, HASLS and LLA schemes. In existing scheme and our previously proposed schemes, delay consumed by nodes is more. In our proposed scheme NCLAR, delay consumed by neighbor cluster members is (7.9-21.2) s. It is because of implementation of location status navigator. From this navigator, CH can easily find unknown nodes with minimum span of time.

Figure 7 shows the results of detection efficiency for the nodes 10, 20….100 nodes scenarios. The proposed approach achieves more detection efficiency than previous schemes. Around 69% of detection of unknown nodes location is achieved in NCLAR. It is because of integration of cluster formation with maximum signal strength. Neighbor table updation is more compared to existing schemes.

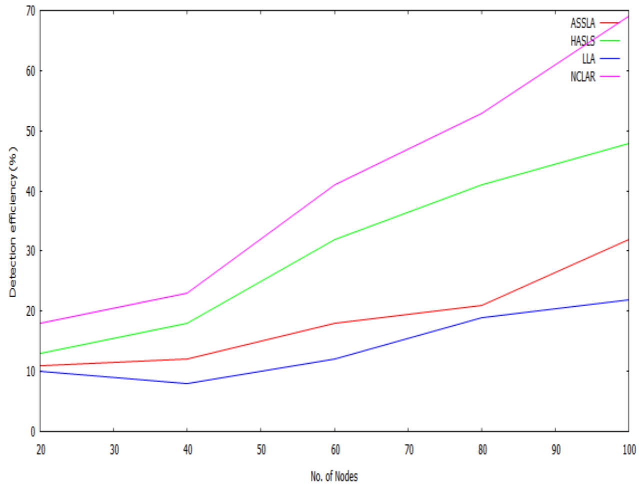

Figure 7. Detection efficiency Vs Number of Nodes

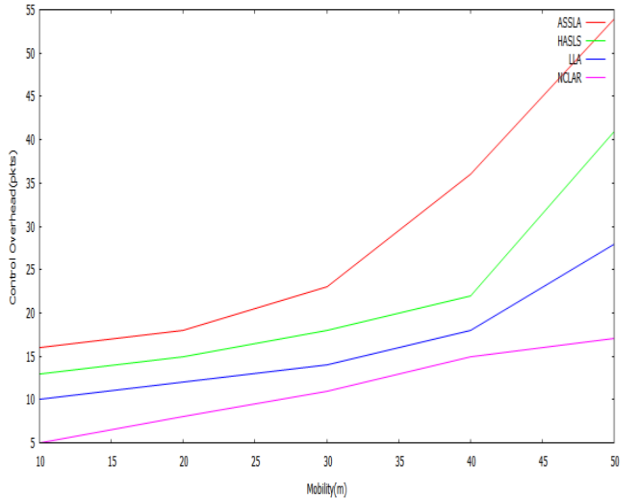

Figure 8. Control Overhead Vs Mobility

Figure 8 shows the result of Control Overhead Vs Mobility. From the results, our proposed scheme NCLAR achieves less control overhead than the existing schemes because of fault tolerable routes established from source to destination. Control overhead consumed by number of nodes is very less in proposed schemes. It happened because of linear topology integrated with random walk model.

In Figure 9, number of nodes is varied as 10, 20,….100. Network lifetime of proposed scheme NCLAR is high compared to existing schemes. It is because of fault tolerant based routing with maximum reliability of nodes, links and paths. Path reliability is extended upto maximum level.

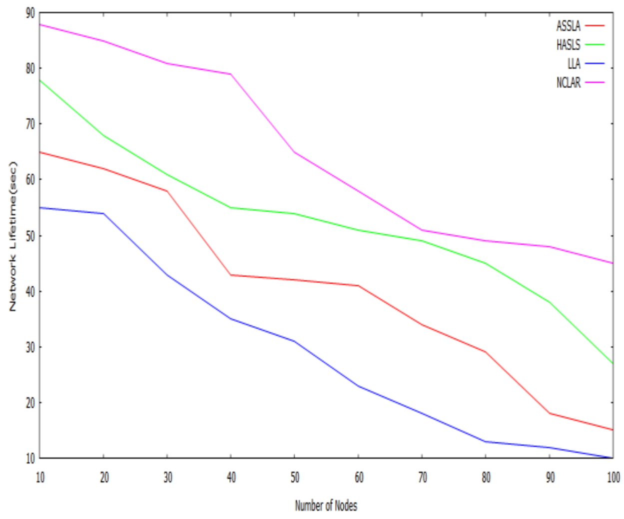

Figure 9. End to end delay Vs Speed

5. Conclusion

In this research work, Neighbor based Cluster Location Aware Routing (NCLAR) is introduced to achieve maximum location accuracy. Cluster is formed with maximum signal strength. Path reliability metric is added in each neighbor node table. From the construction of neighbor cluster member and formation of cluster region, it is easy to improve the packet delivery ratio with maximum accuracy. Nodes are deployed in random walk manner to achieve ad hoc nature. Cluster head plays a major role in identifying the location of neighbor nodes and construction of routing table. If any node falls below threshold value of link reliability, path reliability and location accuracy, it will be identified and removed from participating in the network. In future, it is planned to propose secure cross layer based multicast localization scheme to attain location integrity and authentication.

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