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Strategy For Weighted and Clustered Routing In Wireless Mobile Ad Hoc Sensor Networks For Disaster Management

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Abstract

Wireless Mobile Ad hoc Sensor Networks (WMASNs) are deployed in difficult environments where failures of sensor nodes and interruption of connectivity are habitual occurrences. Wireless Mobile Ad hoc Sensor Networks (WMASNs) are infrastructure less, multi-hop, dynamic networks for a collection of mobile sensor nodes. This paper reviewed technological solutions for managing disaster using Wireless Mobile Ad hoc Sensor Networks via cluster management system by providing data sensing and aggregation for search and rescue operations. A clustering architecture provides network scalability and fault tolerance, and results in more efficient use of network resources. Cluster based routing is a scheme in which various clusters of sensor nodes are formed with each cluster having its own cluster head(CH) which is responsible for inter-cluster and intra-cluster communication. A Secondary Cluster Head (SCH) is also elected to avoid the CH from becoming a bottleneck. The SCH stores backup routing and also it acts a monitoring node for cluster head lifetime. For this purpose, An Efficient Weighted and Clustered Routing in Wireless Mobile Ad hoc Sensor Networks for Disaster Management using AODV has been proposed. This approach is based on combined weight metric that takes into account of several system parameters like the degree difference of the node, transmission range, battery power and mobility of the sensor node. For intra cluster communication well known concept TDMA (Time Division Multiple Access) is used. For inter-cluster communication, AODV protocol is used in order to get the routes On Demand and to minimize the memory usage in sensor nodes. The performance of the system is evaluated based on the few metrics like Energy utilization, Packet Delivery Ratio (PDR), network life time and number of overhead messages. As demonstrated, our algorithm reduces frequent head election by having SCH and Gateway node thus improving overall performance and reducing energy utilization.

Keywords: WMASNs, Cluster Head, inter-cluster, intra-cluster, Secondary Cluster Head, TDMA, WIICRP

Introduction

Wireless Mobile Adhoc Sensor Networks (WMASNs) usually contains thousands or hundreds of sensors which are randomly deployed. Sensors are powered by battery, which is an important issue in sensor networks, since routing consumes a lot of energy. Wireless Mobile Ad hoc Sensor Networks (WMASNs) [1-3] are infrastructure less, multi-hop, dynamic networks for a collection of mobile nodes. In figure 1, WMASNs consist of mobile sensor nodes that form the networks without any fixed infrastructure or centralized administration. Each node communicates with the other nodes via intermediate nodes. Such factors might improve the network stability, scalability, bandwidth utilization, and resource sharing and management efficiency. Networking unattended sensor nodes are expected to have significant impact on the efficiency of many military and civil applications [3] such as combat field surveillance, security and disaster management. These systems process data gathered from multiple sensors to monitor events in an area of interest. For example, in a disaster management's setup, a large number of sensors can be dropped by a helicopter. Global climate change is increasing the occurrence of extreme climate phenomenon with increasing severity, both in terms of human casualty as well as economic losses. Authorities need to be better equipped to face these global truths. In the event of disaster, another important issue is a good search and rescue system with high level of precision, timeliness and safety for both the victims and the rescuers.

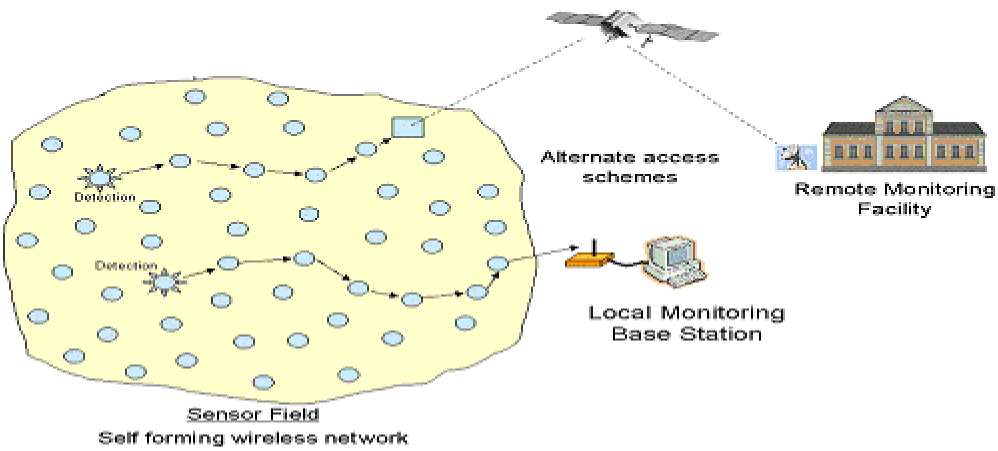


Figure 1: Wireless Sensor Networks

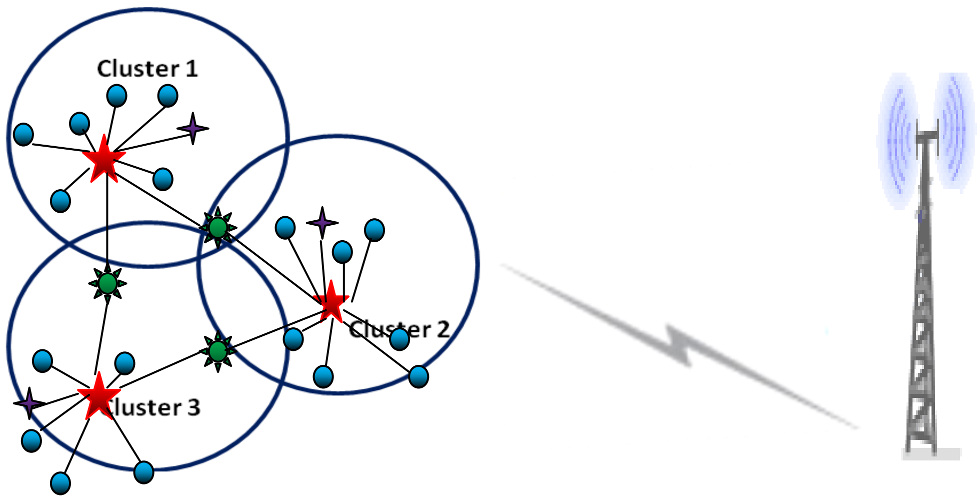
This paper reviewed technological solutions for managing disaster using wireless Mobile Ad hoc Sensor Networks sensor networks (WSN) via disaster detection and cluster management system by providing data sensing and aggregation for search and rescue operations.

Networking these sensors can assist rescue operations by locating survivors, identifying risky areas and making the rescue crew more aware of the overall situation. Such application of sensor networks not only increases the efficiency of rescue operations but also ensure the safety of the rescue crew. On the military side, applications of sensor networks are numerous. For example, the use of networked set of sensors can be limiting the need for personnel involvement in the usually dangerous reconnaissance missions. Security applications of sensor networks include intrusion detection and criminal hunting.

The clustering architecture of Sensor nodes are given in the figure 2 provides three useful features in a WAMSN environment: network scalability, fault tolerance and reduction of communication overheads. Most existing clustering algorithms use either geographical regions as clusters or form new clusters proactively even if their function is not needed [2, 3, and 9].

It can be used for resource management, routing and location management to reduce communication and Computational Overhead .For this purpose, a Novel Weighted Intra and Inter Cluster Routing Protocol for Wireless mobile adhoc sensor networks (WMASNs) (WIICRP) has been proposed for disaster recovery and management. This approach is based on combined weight metric that takes into account several system parameters like the degree difference of the node, transmission range, and battery power and mobility of the sensor node.

The remainder of this paper is organized as follows. Section 2 presents related work done in cluster formation and cluster head election mechanisms. Section 3 presents the proposed data transmission architecture and routing schemes in both intra cluster and inter cluster. Section 4 presents performance evaluation and finally, Section 5 presents conclusions and future work.



- Cluster Head - Gateway node - Secondary Cluster Head - Sensor Node

Figure 2: Clustering Architecture of Sensor nodes

Related Work

Various cluster based routing schemes have been proposed in the literature.

Types of Clustering

Clustering protocols are categorized into different approaches based on its distinguished features.

1. **Low-Maintenance Clustering** approach [3, 11-13] provides a stable cluster structure incurring less maintenance cost.
    a) Lowest-ID: Elect the node as a cluster head that has the lowest ID relative to its neighbors
    b) **Maximum Connectivity Clustering (MCC):** The MCC [14] uses the degree of connectivity instead of the node ID in the cluster head election.
2. **Mobility-Based Clustering** approach considers mobility feature of the mobile nodes for cluster formation. It achieves maximum cluster stability by grouping mobile nodes of similar patterns into a single cluster.
    a) **MOBIC:** uses the mobility metric as a basis of cluster formation and cluster head selection.
3. **Weight-Based Clustering** approach takes weight of the mobile nodes into consideration for the choice of the cluster head.
    a) On-Demand Weighted clustering algorithm (On- Demand WCA) The assignment of weight to a mobile node is the combined effect of several system parameters like ideal node degree, degree difference, transmission power, cluster head serving time and mobility. The advantage of this clustering scheme is the flexibility of adjusting the weighting factors for each system parameter to make it suitable for different scenarios.
4. **Flooding-Based Clustering** approach forms the cluster by disseminating information over the whole network
    a) **Max min D-cluster algorithm [6]:** This allows the control and flexibility in the determination of the cluster head density by generalizing the distance of a mobile node from its cluster head to be d hops
5. **Channel Based Clustering** facilitates efficient utilization of channels by scheduling transmissions of the mobile nodes.

Proposed Algorithm

Our proposed work consists of following modules like Initialization phase, Data transmission phase and Maintenance phase. The reason behind using Weight-Based Clustering approach in this paper takes weight of the mobile nodes into consideration for the choice of the cluster head and it considers combined weight metric that takes into account of several system parameters like the degree difference of the node, transmission range, battery power and mobility of the sensor node. But in existing clustering algorithms like MCC, MOBIC and lowest ID, any one of the weight metric is used for electing the CH.

Initialization phase

Initially weight will be computed for every node based on the factors like degree difference of the node, transmission range, and battery power and mobility of the sensor node. This module consists of following sub modules like Cluster Head election and cluster formation.

Weight Computation

Initially each node is assigned a random ID value. It broadcasts its ID value to its neighbors and builds its neighborhood table. Each node calculates its own weight based on the following factors like Node degree difference, Energy remaining, Mobility, distance from all other neighboring nodes. The distance between nodes and mobility is considered to keep the balance between clusters. The WIICRP performs clustering based on parameters described above and selects the Cluster Head for efficient clustering. The weight computation W for all the weights is given as follows in equation (1).

$$W_n = W_1 * \Delta_n + W_2 * E_n - W_3 * M_n + W_4 * D_n \text{ ------------} \quad (1)$$

Where $\Delta_n -$ Degree Difference of node

E_n -Energy in each node represented by Joules

M_n- Mobility of each node. (Less mobility nodes have more probability to become a CH)

D_n - Distance from all other neighboring nodes

The co-efficient used in weight calculations W_1, W_2, W_3, W_4 are assumed as follows. $W_1 = 0.5, W_2 = 0.35, W_3 = 0.05, W_4 = 0.1$. The sum of these co-efficient is 1. The factors degree difference and energy are given more importance and assumed higher co-efficient values 0.5 and 0.35. The combined weight is calculated by using the parameters of Δ_n, E_n, M_n, D_n from the equations 2,3,4,5 respectively. After finding its own weight, each node broadcasts its weight to its neighbors based on neighborhood table. The neighborhood table consists of one hop reachable nodes; its weights. It is maintained by the CH.

Degree difference

It is defined as the difference between the cluster size N and the actual number of neighbors d_n.From the equation (2), it is known that Δ_n – Degree Difference of node 'n'. In order to find the Degree d_n of the node 'n' by counting its neighbors. Compute the Degree difference for the node 'n', where N is a threshold for the cluster's size.

$$\Delta_n = |d_n - N| \text{ --------------} \quad (2)$$

Energy

Energy in each node represented by Joules. It is represented by E_n - Energy (Battery Power) of node 'n'. Energy E_n is calculated as

$$E_n = E_0 - E_{residual} \text{ --------------} \quad (3)$$

E_0 and $E_{residual}$ are initial and remaining energy of node 'n'

Mobility of Each Node:

Less mobility nodes have more probability to become a CH. It is represented by M_n - Mobility (Speed) of each node. It is calculated as

M_n - Mobility speed of every node by following formula

$$M_n = \frac{1}{T}\sum_{t=1}^{T}\sqrt{(X_t - X_{t-1})^2 + (Y_t - Y_{t-1})^2} \text{ ----------} \quad (4)$$

Where (X_t, Y_t) and (X_{t-1}, Y_{t-1}) are the co-ordinate positions of node 'n' at time t and t-1, T= cumulative time.

Distance

Distance from all other neighboring nodes is represented by D_n .Here; the sum of the distance between member nodes and its neighbors *is* defined by the equation (5). In order to find the neighbor $N(n)$ of each node 'n', the D_n is calculated as

$$D_n = \sum_{n' \in N(n)} distance(n, n') \text{ ------------------------} \quad (5)$$

D_n - The sum of the distances between node 'n' with its entire neighbor.

Cluster Head Election

In the Cluster Head election, every node broadcasts a Hello packet within its transmission range This broadcast contains the node ID and Weight value of that node. When a node receives a predefined number (Np) of Hello packets, it compares all the weights received, the node with highest weight will be announced as a Cluster Head (CH), then the newly elected CH will broadcast welcome-ACK message. A failed CH may cause a cluster to remain isolated until the next re clustering. Meanwhile, important data from sensors cannot be reported and may be lost. To avoid this problem, a Secondary Cluster Head (SCH) is also elected based on next highest weight. The SCH stores backup routing and cluster information.

ALGORITHM FOR CLUSTER HEAD ELECTION

Step 1:
Every node broadcast Hello Message with its
Id in its transmission range.
Step 2:
Node updates its Neighborhood table by receiving
Hello Msg from their Neighbors.
Step 3:
Calculate weight for every node based on the
metrics like Node Degree, Mobility, Connectivity,
and Energy Remaining.
Step 4 :
Broadcast Weight value and its Id to all its neighboring
nodes and the neighborhood table updated with weight value
Step 5:
Cluster Head (CH) and Secondary Cluster Head (SCH)
elected based on the weight value

If (The Node Id with highest weight value)
    Elect that Node as a CH
If (The Node Id with next highest weight value)
    Elect that Node as a SCH
Else Ordinary nodes send Join Request to
CH to form a Cluster

ALGORITHM FOR CLUSTER HEAD LIFETIME

Step 1:
SCH monitor the battery level of CH for every 30s

If (Battery level of CH< Minimum Threshold Level)
    SCH will become New CH,
    Send CH_LIFE DOWN Msg to all member nodes,
    Election procedure iniated to find new SCH
Else
    Re election not needed;

Cluster Formation

In this phase initially all the nodes are considered as stable nodes. Once a wireless node is activated, its id_{CH} field is equal to NULL since it does not belong to any cluster. The node continuously monitors the channel until it figures out that there is some activity in its neighborhood. This is due to the ability to receive the signals from other present nodes in the network. In this case, it broadcasts a Join_Request in order to join the most powerful ClusterHead. Thus, it waits either for a welcome_ACK or for a welcome_NACK. When the entry node receives neither welcome_ACK nor welcome_NACK, it may increase its transmission power in order to broadcast another Join_Request that may reach the outermost ClusterHeads. If this persists for certain number of attempts, the node declares itself as an isolated node, readjusts its transmission power and restarts by broadcasting a new Join_Request after a period of time. CHs might respond by a welcome_ACK or welcome_NACK; the ordinary members have to ignore any Join_Request received even if they are in the transmission range of the new entry node.CH will maintain the member's list with member id and role (Ordinay node, SCH, Gateway node, neighbour CH). Suppose a node receives more than one CH message from different CH, then that will become a Gate Way node and it is responsible for inter-cluster communication. Figure 3 depicts the flow for Cluster formation and Data transmission and Table 1 represents the messages used in cluster head election and formation.

Table 1: Messages used in the Clustering algorithm

Message	Description
Hello(node-id ,id_{CH}, weight, N, role)	Broadcast the packets and update the neighbourhood table of the node
Join-request(node- id, id_{CH})	To accept as a member
Welcome ACK(node-id), id_{CH})	CH accepts a Join-request
Reject NACK(node-id), id_{CH})	CH rejects a Join-request
CH-request(node-id)	Declares itself as a CH
CH-response(node-id)	CH accepts node-request
Join-acceptance (node id, id_{CH}, Degree d_n, weight, N, role)	The node accepts the Welcome ACK
CH-ACK(node id ,id_{CH},Degree d_n,weight ,N,role)	CH adds the node as a member
Handover information (node id ,id_{CH},Degree d_n,Weight ,N,role)	The current CH sends the information to the newly elected CH(ie SCH)
Handover-ACK(node id ,id_{CH},Degree d_n,weight ,N,role)	The new elected CH accepts the received database
CH-change (id_{CH})	CH notifies a CH Change
CH-info(node id ,id_{CH},Degree d_n,weight ,N,role)	CH accepts the presence of new CH in the network
Leave–request(node id ,id_{CH},Degree d_n,weight ,N,role))	The node leaves the cluster

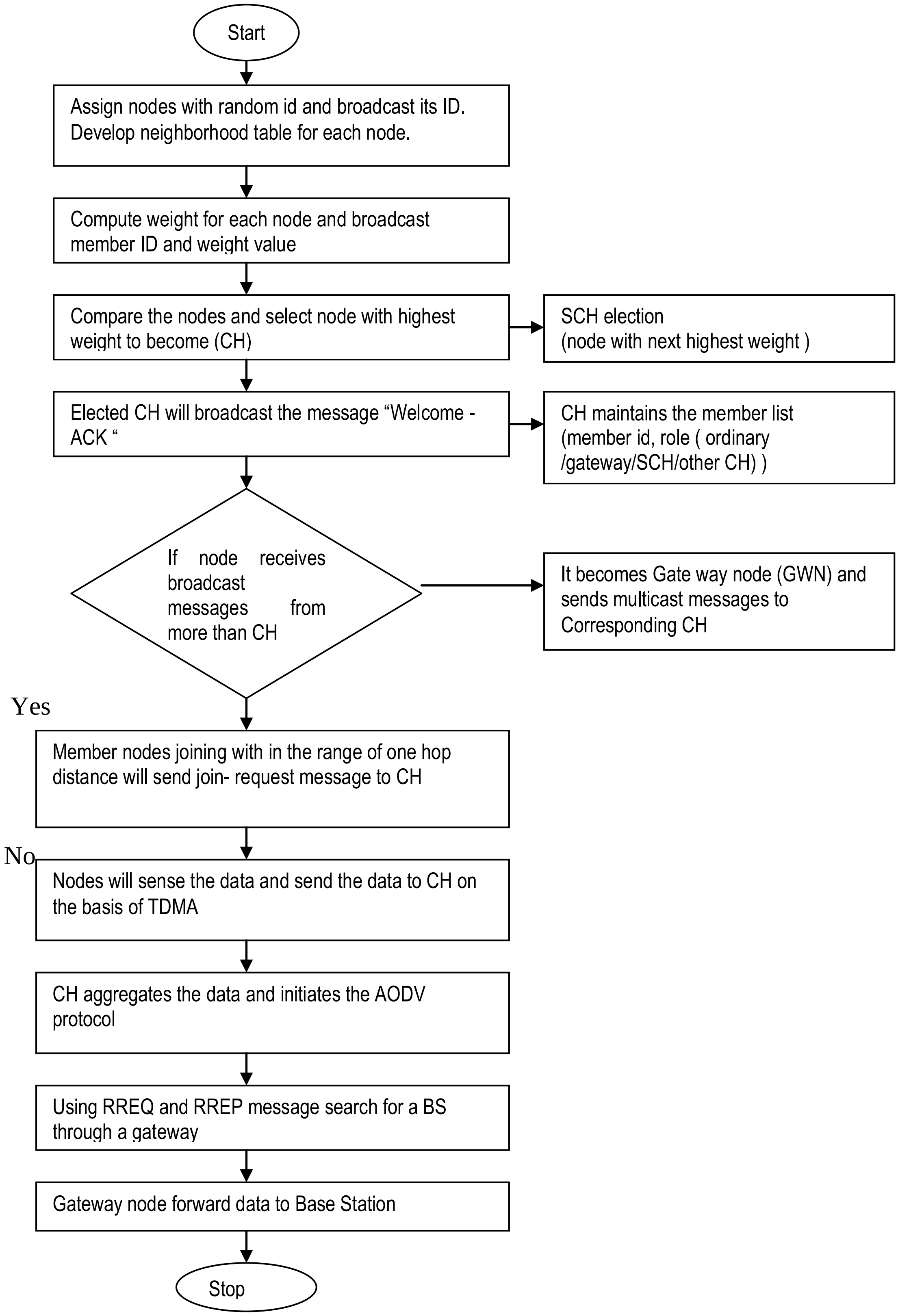


Figure 3: Flow for Cluster formation and Data transmission

A. *Data transmission phase*

This phase consists of sub modules like inter cluster and intra cluster communication . In intra cluster –TDMA is used in order to avoid the congestion in the cluster heads. In the inter cluster communication, AODV protocol is used in order to get the routes On demand and to minimize the memory usage in sensor nodes.

Inter Cluster Routing

CH uses a traditional AODV protocol and send RREQ message to search for a BS through a gateway to its neighbor clusters. To reduce the overhead caused by the RREQ flooding packet, only gateways and CHs are involved in forwarding the RREQ. No ordinary nodes are involved in RREQ packets in the inter-cluster communications will send RREP message to the concerned CH and neighborhood table is maintained. By using the routing information, aggregated data will be forwarded to the BS.

Simulation Results and Discussion

The number of nodes used in the simulation results varies between 20 and 100. The simulations were run for 300 seconds. The cluster size was fixed at 15. We depict some statistics on the formed clusters for different transmission ranges. In the first set of simulations, the scalability of the algorithm is measured in terms of nodes density and transmission range. In this paper, the NS-2 simulator [15] is used for the simulation to show the performance of the proposed method. In the simulation, the parameter values are selected at random and shown in Table 1. The parameters are network size, number of nodes, max speed, pause time, packet size, transmission area, hello packet interval, and simulation time, cluster size and protocol. The proposed method WIICRP is compared with LEACH protocol and AODV protocol for performance evaluation. The total energy consumption of entire network is compared between LEACH and proposed protocol WIICRP and the Packet Delivery Ratio of total network is compared with well known pure AODV protocol and our Weight based Routing protocol WIICRP.

A. Network model and parameter settings

In our proposal the following network mode and its parameter settings are considered: The Simulation Parameters are given in Table 2.

- All the nodes are capable of communicating directly with the BS.
- The BS is located far from the sensor network and fixed.
- All nodes are homogeneous, energy constrained and immobile. Initial energy 0 *E* is 4J in this paper.

Sensor nodes are densely deployed which might generate huge redundant data. Similar data from multiple nodes can be combined or fused together in order to reduce the required number of transmission to the BS [6, 7]. We consider a 100-node network with randomly distributed nodes in a (300X 100) meter area. The BS is located at (x=0, y=0). The length of each signal is 4000 bits and the energy required for data aggregation is 5nJ/bit/signal [8]. The radio spends *E* = 50nJ/bit energy to run receiver and transmitter electronics.

Table 2: Simulation Parameters

Parameters	Value
Network size	300 m x 300 m
Number of nodes	20 – 100 nodes
Mobility of the node (Speed)	3-30 m/s
Pause time	30s
Packet size	100 bytes
Transmission Range	30-300m
Simulation time	420 s
Hello packet interval	3 s
Frequency band	5.4 Ghz
Cluster size with member nodes	15 nodes
AODV protocol (Inter cluster)	-
TDMA (Intra Cluster)	-

B. *Packet Delivery Ratio (PDR):*

Data Packet Delivery Ratio can be calculated as the ratio between the number of data packets that are sent by the source and the number of data packets that are received by the Base station.

PDR = No. of Packets Sent/ No. of Packets Received

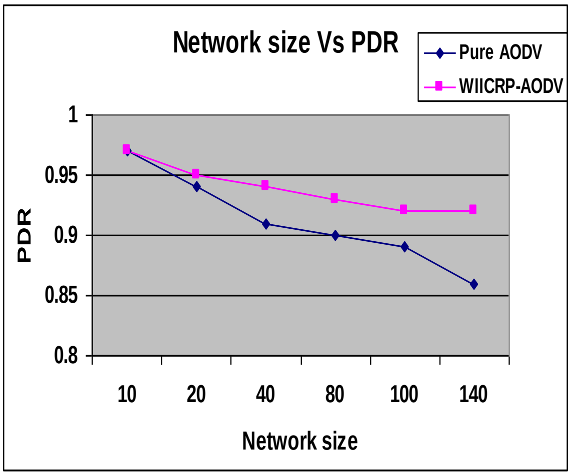


Figure 4: Network size Vs PDR of Pure AODV and WIICRP-AODV

Figure.4 is the total Packet Delivery Ratio (PDR) of entire Network nodes about Pure AODV and our proposed protocol WIICRP. Figure 4 shows that the Packet

Delivery Ratio which is higher for the proposed protocol WIICRP than the pure AODV protocol. The difference in the delivery ratios increases as the network's size increases, which shows the performance gained because of Weight based routing scheme.

C. Total Energy consumption

Figure 5 is the total energy consumption of entire network nodes about LEACH, and our proposed protocol WIICRP. Initially both the protocols consuming energy almost the same but after time of 400, there is a change in energy consumption of two protocols. So, the proposed protocol WIICRP which can save more energy better than LEACH protocol.

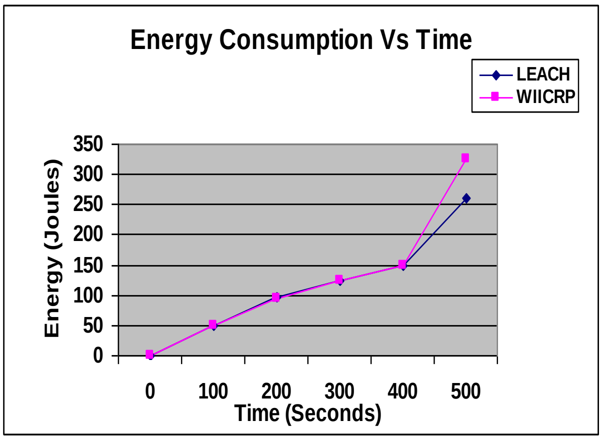


Figure 5: Energy Consumption Vs Time of LEACH and WIICRP

D *Total Number of alive Nodes*

In LEACH every sensor node directly communicate with the BS, so it wastes its maximum energy for transmitting the data, but by applying weight based clustered hierarchy(WIICRP) sensor node directly send their data to its nearest CH and it consume only less transmission power. LEACH was first proposed to reduce total energy consumption in Wireless networks. CHs then aggregate these data's and send them to BS. So this clustered architecture results energy saving for sensor nodes but at the same time, we consume the energy of CHs. To solve this problem, there is a Monitoring node for checking the energy level of CH, when it reaches minimum energy SCH will take part in the communication and it will act as a CH and CH algorithm will be initiated for selecting new SCH. In Figure 6, the proposed protocol (WIICRP) which is having more number of alive nodes than the LEACH protocol.

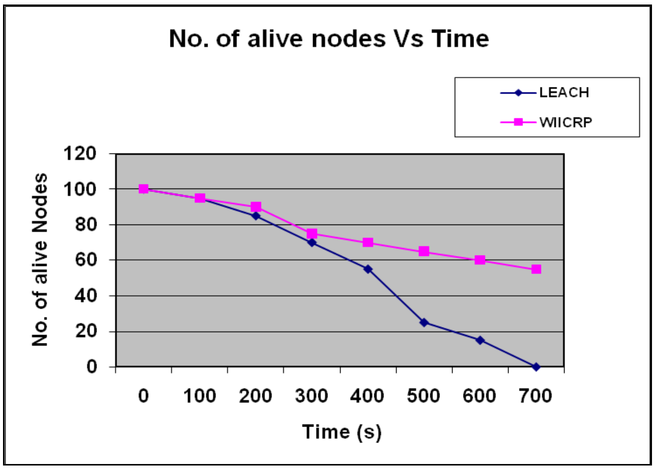


Figure 6: No. of alive nodes Vs Time of Pure AODV and WIICRP-AODV

E *Packet Delivery Ratio Vs Pause Time*
Pause time is the time duration for which all nodes hold the same positions at waypoints. The mobility model used is the random way point model which generates waypoints at random. A node moves at the given speed to a random waypoint and when it hits that, it chooses another waypoint at random and begins moving toward it. If the pause time is 100, there is no node mobility since the simulation time is also 100 seconds. If it is 10, then a node holds its position for 10 seconds whenever it hits each waypoint.

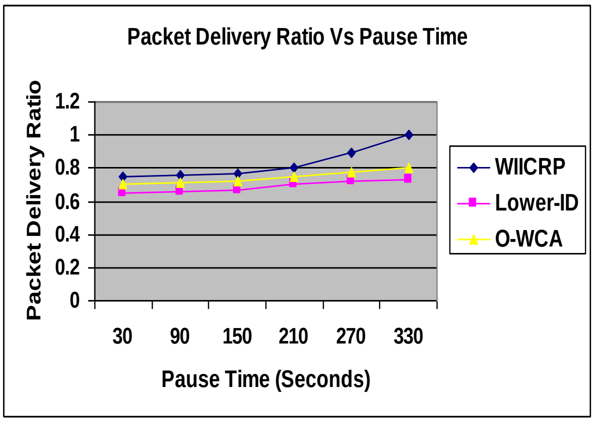


Figure 7: Packet Delivery Ratio Vs Pause Time

Conclusion

In this paper, an Efficient Weighted and Clustered Routing in Wireless Mobile Ad hoc Sensor Networks for Disaster Management using AODV. This approach is based on combined weight metric that takes into account of several system parameters like the degree difference of the node, transmission range, battery power and mobility of the sensor node. As demonstrated, our algorithm reduces control messages overhead by having SCH and Gateway node thus improving overall performance and reducing energy utilization. Since energy utilization is the most important criteria in cluster based routing schemes, our protocol provides better results than existing Lowest-id, WCA algorithm and LEACH algorithm. A clustering architecture improves the network's scalability and results in a more efficient use of network resources. Performance metrics like network size with Packet delivery Ratio, Energy Consumption, No. of alive nodes with its network life time have been evaluated with different protocols. In the near future, some other performance metrics like fault tolerance can be taken for performance evaluation and this protocol can be extended to include group key management among clusters to provide secure transmission of collected data. We also intend to extend the clustering architecture to support multi-hop clustering in Wireless mobile adhoc sensor networks (WMASNs). Effective utilization of power, Bandwidth wastage, Stable Clusters helps in improving the quality of service in WMASNs by applying the Weighted Clustering Algorithm. The scheme is used for integrated routing and message delivery in clustered networks for disaster management .This paper applies cluster management system by providing data sensing and aggregation for search and rescue operations for disaster mangement. In the future solar energy system will be exercised for improving the battery life time and network life time.

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