IoT Controlling Approach in Hierachical Clustering of Load Balanced Multi Sink Deployment Strategy in Wireless Sensor Network

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The Wireless Sensor Network (WSN) refers to monitoring, recording and communicating of the physical environmental conditions by infrastructure less Sensor devices. The sensors monitoring varies based on user's requirement consisting of Position Sensors, Pressure Sensors, Temperature Sensors, Force Sensors, Vibration Sensors, Piezo Sensors, Fluid Property Sensors, Humidity Sensors. The end objectives of researchers in the field of WSN is to prolong the network life span without degrading its integrity & reliability. Many researchers have proposed their methodology emphasizing on deployment of multi cluster, multi sink approach as the traffic gets split among multiple clusters and multiple sinks. However, it is needed to aggregate and transmit single packet to next Cluster Head (CH) so that traffic load at the higher CH level can be minimized. The redundant data received from multiple sensors leads to buffer overflow that increases miss ratio and decreases packet delivery ratio in the network. The increase in miss ratio of data packets leads to retransmission from source which consumes more energy by sensors. In addition to load balancing by splitting traffic among multi cluster & multi sink approach, user level setting features for sensors should be defined in order to minimize the traffic load. The demand for installation of IoT devices, sensor will remain a challenge to deliver congestion free and reliable data communication. In order to address these issues, I have proposed a model named "Hierarchical Multi Clustered Multi Sink Load Balanced routing protocol (HMCMSLBR)". In this HMCMSLBR protocol, I have proposed to deploy minimum number of Sink nodes based on sensing field area, minimum number of cluster hierarchy, load balancing by setting user level threshold. In addition to that, I have proposed data aggregation methodology at the CH level to send a single packet to the next sensors in the hierarchy at manage the traffic which can help in increasing lifetime of wireless sensor network.

Keywords: Wireless Sensor Network (WSN), Internet of Things (IoT), Hierarchical Load balanced Clustering, Multi Sink WSN, Overlapping Clustered, Data Aggregation.

1. Introduction

The wireless Sensor devices are small embedded devices that can sense the physical phenomena from the environment such as temperature, pressure, humidity, sound, speed, vibrations, heartbeat and pollutant levels etc. [1]. The data received are either transmitted to local server or pushed to Cloud for further processing and viewing. The sensors are equipped with Radio frequency Identification (RFID) tags for identification and tracking. The traditional approach of sensor deployment had many flaws due to lack of technological advancement [4]. In the traditional approach, WSN used a single sink node for gathering data from the entire network. The simple approach used was to transmit their sensed data to the sink node through multi-hop sensor to sensor communication in hierarchical manner. This led to sink node getting overloaded storing its own data along with the data of neighboring sensors. This approach was creating energy-holes near the sink node region and suffering from serious performance issues such as congestion, latency, lack of scalability etc. [6]. In due Course of time with little technological advancement, the sensors formed in a group called clusters and each cluster head was communicating with the sink Node. Both the approach had its limitations, in 1st scenario of deployment the energy level of sensors nearer to sink was getting exhausted quickly due aggregation of data from multiple sensors [8]. In the second approach, the sensors were formed into clusters and cluster head of the sensor were directly communicating with the sink node which resulted huge miss ratio of data. Failure of cluster head was derailing the data communication from sensor to sink [11]. The diagrammatic representation of traditional Sensors deployment is illustrated in the diagram as follows: -

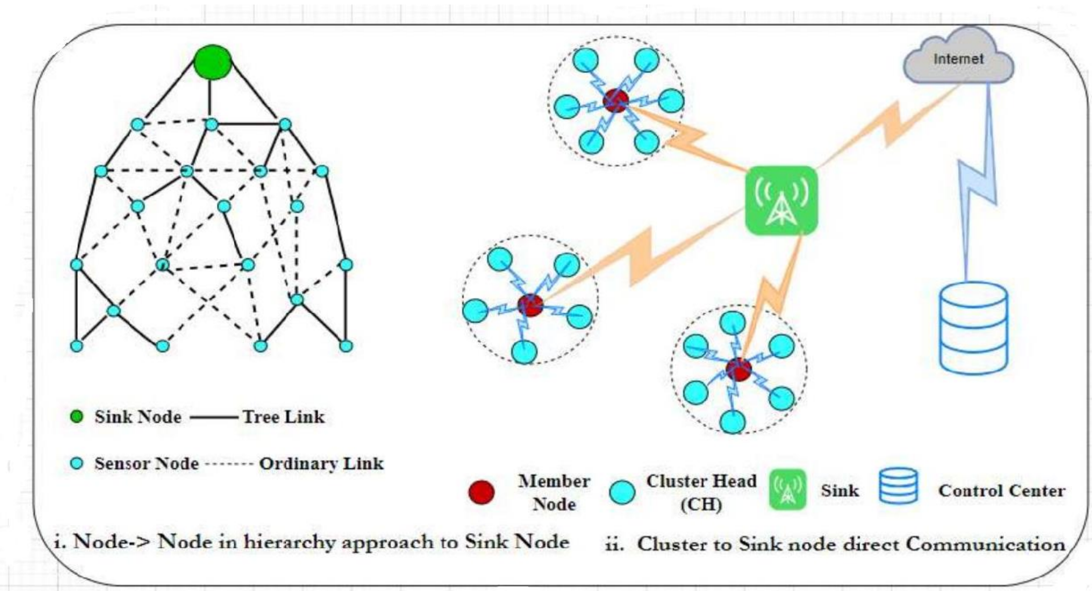
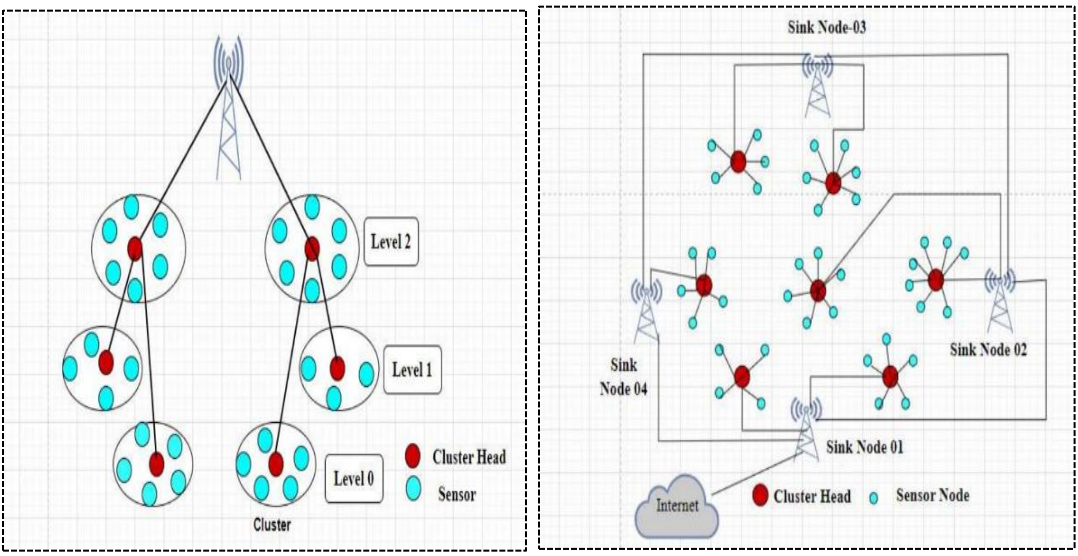


Figure 01: Traditional approach of data communication in Wireless Sensor Network (WSN)

In due course of time and subsequent technological advancement was visible in the field of WSN due to tireless effort put by technocrats and researchers. To improve the WSN network maintainability, the multi sinks with multiple hierarchical cluster approach was implemented. This led to minimization of energy consumption, congestion, and delay etc. [14] However, this deployment strategies have many flaws due to complex sensor deployment set up with protocols compatibility issues.

Many researchers have proposed dozens of protocols on multi sink approach, multi cluster approach but the approaches used by most of the researchers on cluster formation considering remaining residual energy of sensor node but number of intermediary nodes it has to pass while reaching sink node and distance to its individual neighbors are not considered [14]. Technological advancement at the data aggregation level followed by data fusion and data compression is lagging which needs to be incorporated [16]. In addition to that dynamic bandwidth management at the sink node during traffic overload and new deployment scenarios. The future challenges needs to be tackled with heterogeneous network, protocol compatibility, buffer management and most importantly cost optimization. In order to achieve these, future researchers should work more on data aggregation and fusion approach at each intermediary level of data communication. The modern sensor deployment strategy is represented in the diagram as follows: -



i. Single Sink Multi hierarchical Cluster ii. Multi Sink Multi hierarchical Cluster

Figure 02: Transformation from Single Sink Multi hierarchical Cluster to Multi Sink

The key contribution of this research paper has been described as follows: -

- Proposed Hierarchical Multi Clustered Multi Sink Load Balanced routing protocol (HMCMSLBR) by considering multi sink multi hierarchy data aggregation approach.
- Developed a model to minimise the deployment of sink nodes and formation of Cluster Head and number intermediary hierarchy in cluster to cluster communication.
- Provision to execute aggregation followed by data fusion at each individual node to minimise data redundancy at each intermediary node before reaching cluster Heads.
- Load Balancing approach to aggregate and fusion of data at each individual cluster before transmitting to other cluster Heads till it reaches Sink Nodes.

- Compared performance of the proposed protocol with the existing counterparts with respect to energy consumption, delay, miss Ratio and Packet Deliver Ratio.

- The proposed HMCMSLBR protocol has consumed less energy consumption, delay ratio and more packet delivery as compared to CABRLB, CRSH, HCRATD, MSLBM & TEEN protocol.

RELATED WORK

In order to fulfill this research objectives, I have analyzed some of the multi sink, multi cluster framework for data gathering at Cluster Head & Sink Level of Wireless Sensor Network. The logics and methodologies used by some of the researchers in their protocols have been analyzed and its limitations have been put in this section.

Congestion Avoidance Based Reliable Load Balance Technique (CABRLB): -This protocol has emphasized on sharing of traffic among multiple routes which will avoid congestion in the network [4]. The protocol is talking about multiple routes, multi cluster approach based on the remaining residual energy of sensor node for Cluster Head (CH) Selection.

Limitations: -The number of hierarchies it has to pass through and distance of the sensor node from the requested node along with its distance from neighbors are not considered.

Cluster-based routing scheme for heterogeneous network (CRSH): - This protocol is talking about clustering of nodes as well as data aggregation approach in the network [8]. In this proposed model, most energy-efficient node is considered as Cluster head and carryout data aggregation to eliminate the redundant data packets.

imitations: -The load balancing approach and basis of path selection and data aggregation approach is not defined. The only criteria of residual energy of the requesting node for selection of cluster head is not effective.

Hybrid clustering and routing algorithm with threshold-based data collection (HCRATD): - This protocol has emphasized for hybrid deployment of both homogeneous & heterogeneous wireless sensor networks [9]. In this model multi hub approach is proposed to cover larger network areas. User level threshold is set to prevent unnecessary transmission to minor changes in the device and load balancing approach is used to share traffic among multiple clusters. The load balancing approach has decreased end to end delay as it uses threshold-based data transmission model.

Limitations: -Time critical applications will fail and setting of thresholds is not clearly defined.

The Multi-Sink Load-Balancing Mechanism (MSLBM):- To distribute the traffic load among the multi sink by calculating current state of the resources of each sink. On processing of a task the load is computed before data transmission, leads to increase in computational overhead.

Limitations: - On increase of number of sink node leads to network complexity thereby increasing the network cost.

TEEN (Threshold-Sensitive Energy-Efficient Sensor Network):- To control the data transmission and conserve the energy to increase lifespan of the sensor network by adding the hard threshold (HT) and soft threshold (ST) to control the number of data transmission. It is suitable for time critical data sensing applications. The nodes sense data continuously but data transmission occurs less frequently that conserve more energy than proactive network.

Limitations: - The nodes start communicating only if the thresholds of the nodes are reached.

3. Proposed Protocol: - The Hierarchical Multi Clustered Multi Sink Load Balanced routing protocol (HMCMSLBR) creates hierarchical clusters to cluster communication for sensing as well as transmitting data to the sink nodes. This protocol proposes multi sink, multi cluster, multi hierarchy sink deployment strategy along with load balancing to avoid miss ratio and increase the number of reliable round communication. In this approach, data communication cycle starts from cluster to cluster head and then cluster head to cluster head node and then to sink node and finally from last sink node to individual sink nearer to it by splitting traffic among multiple Sink nodes. In this approach, there are no provision of all clusters to communicate directly to the Sink node. The last Cluster head that is nearer to the sink will communicate and intermediary clusters will just transmit data to the clusters nearer to the sink nodes. This approach has emphasized on minimal deployment of number of sink nodes in this competitive technological market place due to high deployment cost of sink nodes.

The objectives of HMCMSLBR protocol have been achieved in five stages: -

Stage-1: -The deployment of minimum numbers of Sink nodes to optimise the cost.

Stage-2: -Formation of minimum number of hierarchical clusters to minimise the end–to-end delay and energy consumption during data transmission.

Stage-3: -Formation of Last Cluster Head (LCH).

Stage-4: -Adoption of Load balancing Mechanism to transfer data.

Stage-5: - Data Redundancy reduction at each intermediary node.

Stage -6: -Data Aggregation & fusion by last cluster member nearer to CH & CH level.

Stage-1: -The number of sink node deployment depends upon the area of sensing field. The proposed protocol has different approach for deployment of sink nodes based on the size of sensing field and accordingly topology is framed. Post finalisation of topology, number of sinks are decided based on the basis proposed.

The basis for sink node requirement is based on topological deployment of sensor nodes.

If the sensors are deployed in bus topological structure then

$$\text{Maximum Nos. of sink nodes to be deployed} = \frac{\text{Horizontal distance of the Sensing Field}}{\text{Transmission range of Sink Nodes}}$$

Where

Transmission range of Sink Nodes=

Maximum range of number of sensor hierarchy <=Transceiver capacity of Sink Node.

If the sensing field comes closer to rectangle shape then rectangle is formed which has two diagonals with two end points. There will be four co-ordinate points exist in the two diagonals. One diagonal and its co-ordinate point will be marked for selecting the sink positions.

A_1, $A_1^{/}$ are distance between diagonal end point & diagonal intersection point in the sensing field.

(A_2, $A_2^{/}$), (A_3, $A_3^{/}$) and (A_4, $A_4^{/}$) will be computed accordingly.

The distance between (A_1, $A_1^{/}$), (A_2, $A_2^{/}$), (A_3, $A_3^{/}$) and (A_4, $A_4^{/}$) will be computed using Equation: $\text{Coordinate Distance (CD)} = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$

$\text{Selected}_{\text{diagonal}}$ for placement of sink node will be $= \min\{(CD1 + CD2), (CD3 + CD4)\}$

2 Numbers of Sink Nodes to be placed at two intersection point of the Selected diagonal.

If the sensor field is closer to circle then square size formed touching the sensing field will have two diagonals and two intersection point of sensing fields for each diagonal. Four numbers of sink will be deployed at the intersection points.

The number of sink nodes to be deployed will be decided based on the size of the sensing field and transceiver capacity of the sensors and Sink Nodes.

Stage-2: - Calculation of minimum number of hierarchical clusters as follows: -

The Minimum Hierarchical Cluster (M_{hc}) will be calculated by the Sink node using equation.

$$M_{hc} = \frac{1}{2}\left(\frac{SS_{maxd}}{ST_d} - 1\right)$$

Where

SS_{maxd} is the maximum distance from one sink node to the other sink node.

ST_d is the communication range of a sensor node.

Stage-3: - (Formation of Last Cluster Head (LCH))

Final cluster Head that communicate with the Sink Node is the LCH.There are four parameters have been kept in the request message. These are ID of sensor nodes (SN_{ID}), remaining battery power ($Rem_{battpow}$), distance of node from sink node (D_{SN}) and ID of sink node (SN_{ID}).

Ratio between energy (battery power) and the distance of every requesting node is calculated by sink node($r=Res_{battpow}/D_{SN}$)

The node will be chosen as LCH whose having supreme r value.

Stage 04: - In this load balancing approach, user sets data level where traffic load touches a particular threshold value then data is transmitted to the next level in hierarchy else remain in the sleep mode.

i. User sets a user defined threshold for the counter till the counter reaches at the threshold value.

ii. Attaining threshold, the communication starts from the beginning by adjusting counter to zero.

iii. The threshold for the counter has been used to avoid misinterpret a long period of silent.

iv. This may happen when the node may be dead but sensor treat it as silent phase.

Stage 05: - The data received from multiple sources are integrated and redundant data is filtered. The aggregated filtered data is transmitted to next Cluster head till it reaches Sink Node. While filtered data is transmitted is sent in one packet so that traffic load gets minimised.

Integrated data: -a1, a2, a3, a1, a3, a5, a4(7 Packets)

Transmission after aggregation & fusion: -a1, a2, a3, a4, a5(Merged to 1 Packet)

4. Illustration of proposed protocol: -In this diagram we have taken three numbers of sensors inside cluster number 03 as i.e. S1, S2, S3 where the distance of S1 to S2 is 10 meters, S2 to S3 15 meters, S2 to S3 is 10 meters. In this way each individual cluster have sensors where its distance in between the sensors are within 20 meters. Cluster head to Sink node 1 distance is 60 meters and each CH to CH distances are not more than 70 meters. The other parameters are as follows: -

i. The distance between Sink 1 to Sink 2 is 2.5km & Sink Node 1 to Main Controller is 4km

ii. The distance from Sink Node 2 to Main Controller is 3.5km

iii. The distance from Cluster 1 to Cluster 2 is 2.5km & Cluster 1 to Cluster 3 is 2km

iv. The distance from Cluster 3 to Cluster 5 is 1km & Cluster 3 to Cluster 4 is 1.5km

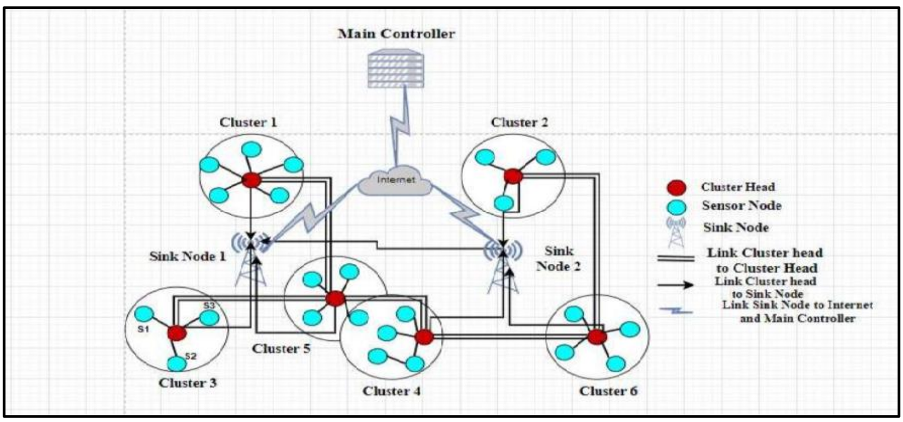


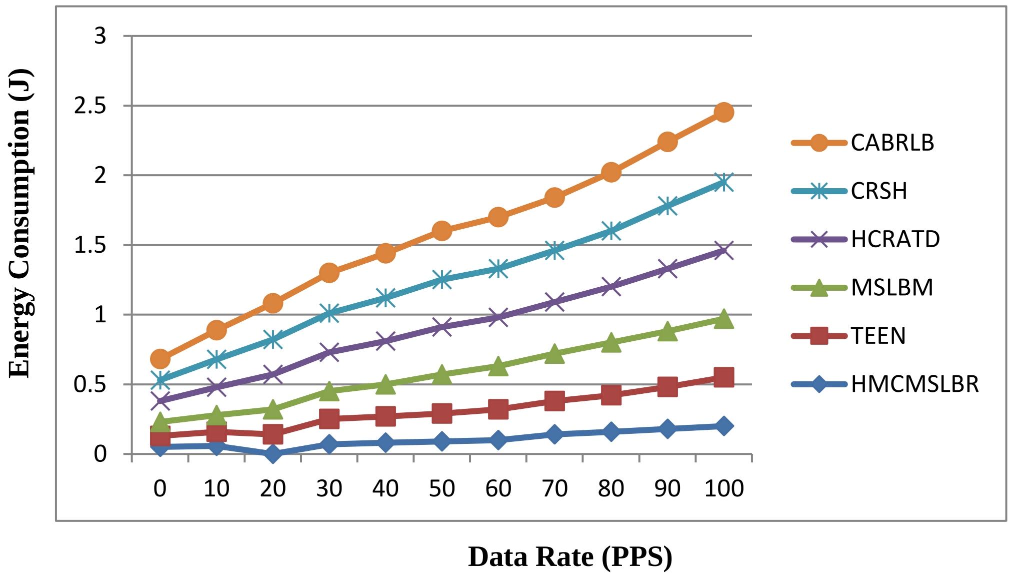
Figure 03: Diagrammatical illustration of proposed network in HMCMSLBR.

In this diagram, I have demonstrated how the data gets communicated in hierarchical cluster approach and redundant data to be filtered in each cluster heads due to overlapping region within cluster 4 & 5. Hence my proposed model has emphasized to use load balancing as well as data aggregation and data fusion approach to increase the lifespan of WSN.

PERFORMANCE EVALUATION

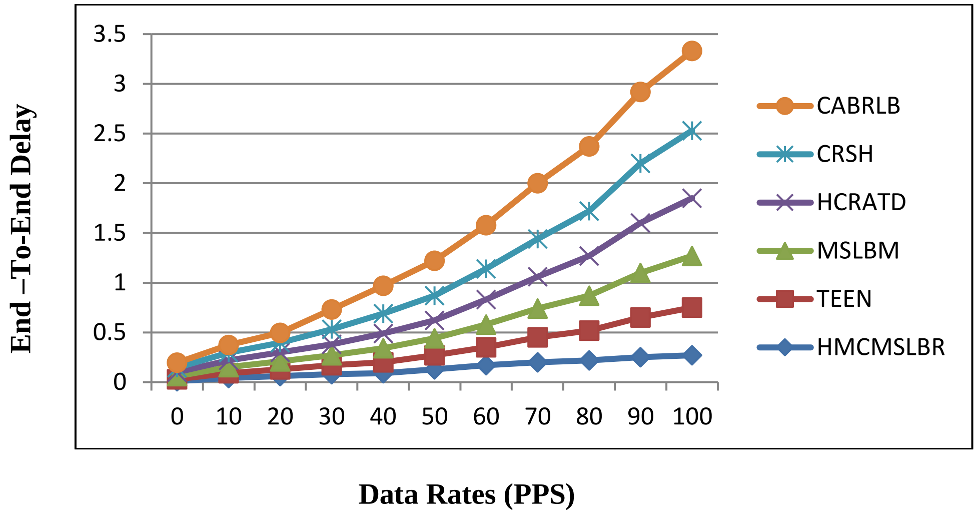
The performance evaluation of the proposed Hierarchical Multi Clustered Multi Sink Load Balanced routing protocol (HMCMSLBR) has been simulated through NS-2.29 simulator. The proposed protocol has been compared with parameter values consisting of range of sensor, no. of sensor nodes, length of Packet, length of buffer, Initial energy of node, bandwidth, range of Radio through various metrics such as consumption of energy, average data delivery and miss ratio and its performance has performed better than its counter parts. Simulated result has given edge to my proposed protocol as compared to its counterparts i.e. CABRLB, CRSH, HCRATD, MSLBM, TEEN.

i. Average energy consumption variation in data rates: -The average energy consumption with increase of data rates is less compared to counterparts because of following reasons:



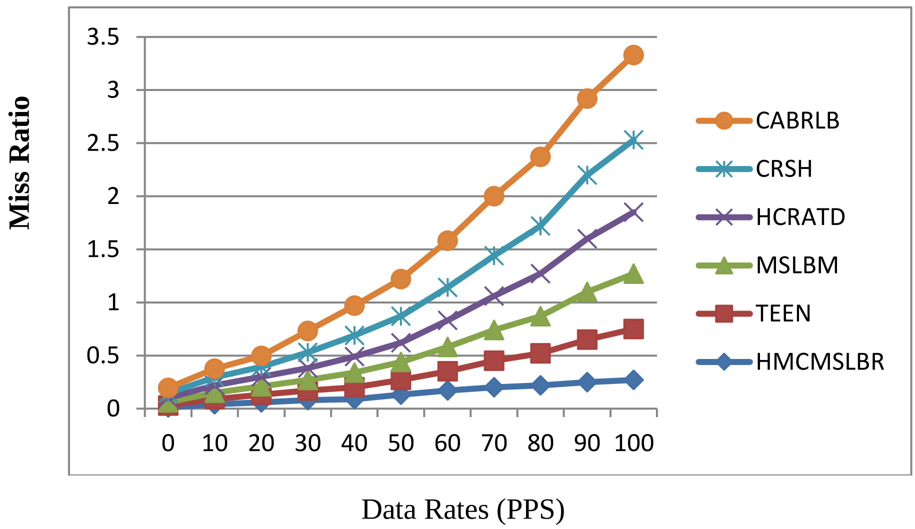
- Traffic load is shared among multiple Cluster Heads then to Multiple Sink Node.
- Scans & filter duplicate data and aggregates before transmitting it.
- Protocol computes the redundant data before transmitting from source node
- Minimum retransmission of lost packet during communication.

ii. End to end delay is less in different data rate: - The entire sensing field is split evenly as these nodes are minimum distance apart from destination. The communication distance between source and destination is minimum.



- End-to-end delay varies due to transmission of non-redundant data.
- The waiting policy dynamically adjusts the waiting time limit in the aggregator node.
- The CHs as aggregator nodes adjusts the wait-time limit dynamically.

iii. Miss Ratio is less with different data rate due to: -



- Selectively forwards data and supresses the duplicate data without transmitting it to next level.
- The CH performs aggregation to convert single data packet for receiving duplicate data from multiple source.
- This reduces traffic load and energy consumption during transmission.

- Our proposed protocol adjusts the buffer space dynamically during traffic load

2. Conclusion And Future Work

Proposed Hierarchical Multi Clustered Multi Sink Load Balanced routing protocol (HMCMSLBR) forms hierarchical Cluster for data delivery in multi sink WSN architecture. Multiple sinks are deployed in the sensing field far from each other to split the traffic for efficient data gathering. Data packets gets aggregated at the CH so that traffic load to the upper-level CH gets minimized. Provision has been kept to allocate waiting time dynamically for CH node based on frequency of traffic load during period of aggregation. Energy consumption is less with the increment in data rate as the traffic is shared among multiple Cluster Heads to Multiple Sink Node. Protocol has the provision for hierarchical cluster data transmission to reduce the traffic load thereby increasing the life span of WSN. However, the elimination of data redundancy and minimization of overlapping region and protocol compatibility is and will remain a big challenge in the future days to come.

The minimisation of data redudany at cluter head due to deployment of sensors under the coverage of multiple cluster region is going to my further research. In order to minimise redudant data flow from CH, I will try to create a suitable structure based data transmission approach that can handle the redundant data transmission to maximize the network life time of WSN. Considering all the limitations, a protocol will be proposed that can maintain reliability and compression of data in the aggregator node and ascertain compatibity with the multiprotocol is taken careoff in the network.

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