Abstract

Energy Efficient and QoS based data gathering is a quite challenging for Wireless Sensor Network (WSN) applications such as target tracking and monitoring because of limited battery resources. This study focuses on survey of various MAC protocols that consumes lesser energy by using dynamic clustering techniques and Routing protocols that are used to achieve Energy Efficient and QoS Data Gathering by assigning priority to the generating packets and data fusion techniques in WSN for various applications.

Keywords: Data Funnelling, Data Gathering, MAC-Medium Access Control, Quality of Service (QoS), Routing Protocol, Wireless Sensor Network

1. Introduction

Wireless Sensor Network (WSN) attains its unique funnelling problem, where the sensor data are travelled through hop-by-hop after the event is generated or the data is transferred continuously. When the data is reached closer to the sink node, it creates the choke point where increasing the traffic intensity, increase in congestion and increase in packet loss and energy occur. To avoid huge loss, there is a need for an efficient data gathering technique simply called as data funnelling, some of the data funnelling techniques to avoid funnelling effect is the usage of data aggregation technique but still it does not give the desired solution so as to improve a data gathering at sink node. A lot of research is going on in WSN related to energy efficient clustering and data gathering, for example the application of Ocean Status Communication System, clustering is formed based on LEACH protocol, communication takes place by using Smart Inner Routing Algorithm, this method avoids the redundant data and consumes very less energy. Data aggregation is quite efficient in same type of sensor network, when compared to heterogeneous because it deals with different types of sensor and a different network application.

To achieve logical separation of nodes, based on the attribute that grouping the same category, after that executing the Minimum Spanning Tree (MST) for every logical attributed group. And then data aggregation takes place in MST. The communication is initiated by the Base Station (BS). First, it sends the message to all cluster heads which locate equal distance to base station to absorb the situations of clusters heads. The cluster head reply to the base station, BS sets the message inter to cluster heads according to the message received. Energy efficient is the most important parameter in wireless network, here in target tracking application, sensors are deployed in random number if all the sensors are activated for tracking then the life time of the network is gradually decreased to avoid that the node close to the target after is detected to be in active mode rest and will not be participated in the communication process. The noise level will influence to the sensor target message, if it is away from target. One of the open research problems which affect the QoS in WSN is the Funnelling effect, where the sense in the field is forwarded hop-by-hop through the mote in many to one communication towards the sink node. The combination of many to one and hop-by-hop transmit to centralized data gathering at a sink node creates a choke point.
point in the sensor networks. The Funnelling effect increases the transit traffic, delays in delivering the packets as its move closer to the sink, resulting in increasing the packet loss due to the collision and congestion. Already some of the researches have proposed the algorithms for congestion control, source rate limiting scheme and prioritized MAC layer control. Traffic is reduced by using queries and also use the data aggregation techniques from source to destination into a fixed message size5,8,10. But as the literature above shows the minimizing traffic by using the congestion control techniques and data aggregation, whereas this paper shows the literature survey of various solutions to the funnelling problem and importance of data funnelling at the central node. The rest of the paper is organized in following subsections: Section 2 discusses about funnelling effect in support by various MAC protocols, Section 3 analyses different Routing and Data Aggregation Techniques to support the efficient data gathering in funnelling effect in wireless sensor network. Section 4 aims on Case Study. Section 5 is Simulation and Test Bed Results and Section 6 is Conclusion and Future work.

2. Various MAC Protocols for Data Funnelling

Much MAC-protocol is addressed for voice and data communication in wireless networks, the most common protocols are TDMA and CDMA. But to design for WSN, some of the basic design is needed. And for a MAC protocol in WSN, to satisfy a good communication that is energy efficient for long standing network life time, MAC protocol should supports the scalability and adaptability for sudden changes in the network size and it support the dynamic topology to be carried out rapidly and some of the protocols needs to satisfy the QoS service for Hybrid network environment11–13. The secondary basic needs are to support its latency, increase in throughput and effective bandwidth utilization. All the attributes are supported by MAC protocol for effective solution for Funnelling effect14.

2.1 S-MAC

The aim of the S-MAC protocol design is to minimize the energy consumption, increase scalability and collision avoidance15. In general the main cause for energy consumption is idle listening, high collision and overhearing. The S-MAC protocol provides the solution for the above cause 1. Periodic listen and sleep, 2. Avoid collision and over hearing.

2.1.1 Periodic Listen and Sleep

Most of the application in sensor networks, the nodes are simply idle for long time because of no event to detect. During that time the data rate in the network is very low. The sensor nodes no need to keep alive for listening. The protocol S-MAC reduce the listening time making the some of node to periodic sleep.

![Basic Scheme](image)

**Figure 1.** Basic scheme for S-MAC.

The basic scheme of S-MAC for periodic sleep and listen is each node is attempting to sleep mode for period of time and wakeup and listen for any communication from the neighbour nodes e.g. Figure 1.

2.1.2 Choosing and Maintaining a Schedule

Before the actual process starts the node needs to choose the periodic listen and sleep and exchange to its neighbours, because each node needs to maintain its schedule table. There are three ways to choose their own schedule. [1] First the node waits for synchronisation (SYNC) message from other nodes and if it’s not getting so, then the node initiates its sleep time and broadcasts its schedule to neighbours through SYNC message, shows that it’s going to sleep after ‘t’ seconds. The node will be called as Synchronizer. [2] Node called as follower, where it sets its schedule from SYNC message is received from the neighbour, before the node setting its schedule. Broadcasting its SYNC message shows going to sleep mode in t-td seconds. [3] The node broadcasts its own schedule after that it will receive a different schedule from its neighbours, but it will adapt to both the schedules.

2.1.3 Collision and Overhearing Avoidance
Collision is a major problem where energy can be drained and data will be at loss. So S–MAC use a contention based protocol to avoid the collision during communication. Collision Avoidance: Many sensor nodes may send a data to one receiver at the same time, so there will be a chance of collision at the receiver end to avoid that S-MAC procedure of 802.11-A contention based protocol that is RTS/CTS, along with virtual carrier sense and physical carrier sense.

- Advantage: The energy waste due to idle listening is decreased by sleep schedules.
- Disadvantage: The RTS/CTS that are used by broadcast data packets will lead the collision. The border nodes have less sleep time due to multiple schedules and it consumes more energy.

Sleep and listen periods are used in network are pre-defined and the value is constant which not suits for variable data traffic are as follows.

### 2.2 T-MAC (Timeout MAC). An Adaptive Energy-Efficient MAC Protocol for Wireless Sensor Networks

Nodes in the network wakes up periodically for communication to its neighbour and move on to the sleep mode until the next communication frame and the nodes communicate to its neighbour by using RTS (request to send), CTS (Clear to send), data and acknowledgement (ACK) for collision avoidance and for reliable communication. During the active period the node will transmit the data and keep listening the active period is comes to an end when any one of the following event is not occurred for a period of time TA.

The list of the activation events are:

- Sharing of periodic time frame
- Receiving data
- Sensing the link during collision
- End of its own communication
- Overhearing information shared between neighbours ended. So the node will go to sleep mode if not an active period, TA finalize the idle listening time per frame and the T-MAC uses the clustering and synchronize techniques from S-MAC. Along with that the additional features are in T-MAC.

#### 2.2.1 RTS functions and TA Selection

RTS Re-transmission. If the node does not receives CTS after sending the RTS the following problem may occur:

1. Collision may happen at receiver end
2. Receiver may be prohibited due to overheard
3. Receiver node may be in sleep mode.

So the transmission node is not received any message within TA and it will go to sleep mode. May be the decision is wrong for the case 1 and 2 because the receiver node is still awaking, so the transmission node should resends the RTS for two more times, if it still not getting the reply from the receiving node, should go to sleep mode.

**Determining TA:**

In general the node should note move to sleep mode while neighbouring nodes are in communication, because the next message may be indented for that node. And the node may not hear the RTS or CTS because it's not in communication range. So the TA should be long to receive the CTS packet.

\[ TA > C + RTS + T \]

- \( C \) = Length of Contention period
- \( RTS \) = Length of Request To Send
- \( T \) = Time for end of RTS and beginning of CTS

Longer TA will consume more energy.

T-MAC define the problem of early sleeping, due to that delaying in data access intended for that node, it give the solution for early sleeping problem using Future Request to Send (FRTS).

### 2.3 MS-MAC (Mobile Sensor- Medium Access Control)

In wireless Sensor Network, QoS like delay, throughput and energy saving is important task in stationary network. But the protocol is used for stationary network will not suits for the nodes in mobile or dynamic due to the frequent connection failure. Suppose the application like sensors in health care where the sensor are fixed with the patients, where we can monitor the status at centralized system, though we couldn't expect the patients will stay stationary. Sensors in battle field and sensors used in coal mining are dynamic network. So whatever the protocol we used for the application in static network will not support create the connection in the network when its in mobile. The supporting protocol for mobile sensor application should use the minimum power consumption to achieve the QoS. MS-MAC protocol is the solution for the above defined problem. It work efficiently for both static and dynamic network and also it uses the minimum energy consumption. It follows up the combination of two well know protocol.
1. It uses the functions of S-MAC to conserve the energy for stationary sensor network.
2. It uses the function of IEEE802.11 to avail mobile adhoc scenario.

To maintain the synchronization, the nodes in the network, broadcasts its schedule through SYNC message so that the neighbours can update their schedule table. And sometimes the neighbour's may never see each other due to various reasons so the each node periodically discovers the neighbour for that the synchronization period, and it appears in every 2 minutes. This scheme will work efficiently when the network is stationary. If the mobile node reached new cluster, a new connection has to be establish, for that the node has to wait for next synchronization period and the waiting time is upto 2 minutes and need to start the process from the beginning. It has a long waiting time and it is not suits for some critical application.

Table 1. Analysis for MAC supporting various factors of QOS to attain data funnelling

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Adaptable</th>
<th>Energy Consumption</th>
<th>Scalability</th>
<th>Collision Avoidance</th>
<th>Support Mobility</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-MAC</td>
<td>Yes</td>
<td>yes</td>
<td>Yes</td>
<td>Yes</td>
<td>no</td>
</tr>
<tr>
<td>T-MAC</td>
<td>Yes</td>
<td>yes</td>
<td>Yes</td>
<td>Yes</td>
<td>no</td>
</tr>
<tr>
<td>MS-MAC</td>
<td>Yes</td>
<td>no</td>
<td>Yes</td>
<td>Yes</td>
<td>yes</td>
</tr>
<tr>
<td>Funnelling MAC</td>
<td>Yes</td>
<td>yes</td>
<td>Yes</td>
<td>Yes</td>
<td>no</td>
</tr>
</tbody>
</table>

Funnelling MAC

In Funnelling MAC the sensor nodes are arranged in a grid manner. The Sink node is arranged in a corner. The sink node initiates a beacon whichever the node receives a beacon will perform the TDMA and the other node will perform the CSMA. The transmission power of beacon frame is controlled by sink node by using dynamic depth tuning algorithm.

A is the maximum number of slots
Amax is number of slots available

If A >= Amax the transmission power is reduced by sink node
Amax >= A the transmission power is increased by sink node.

The node which receives a Beacon frame can perform TDMA protocol will be in intensity region, other perform the CSMA. Beacon is sent based on demand. If the system is ideal or no traffic, no beacon frame will send. And based on the traffic arrived at sink node per aggregated route, the sink will initiate the schedule for each node to avoid the congestion and collision.

To compute the schedule, the sink node needs to identify the path head. Path head is first node from the boundary of the intensity region for that path and it counts the number of hops to reach sink node. The data which is received by the path head from outside the intensity region and also the data received around the node is aggregated and forwarded to the next hop in the path.

3. Data Funnelling with Aggregation Technique Based on Routing Method.

In data funnelling and aggregation routing, technique is that the data will be compressed and aggregated, while routing to the controller. Where the controller is high computational and transmission power and it has rights and capability to take decisions based on the data which it receives.

It has sensor nodes to sense and collect the data from environment which is less computational power than controller. Border node is the node while lies near to the target region and is used to compress and aggregate the data and computes the communication cost to controller. The algorithm executes the two phase Setup phase Communication phase

Setup phase

- The sensor field breaks into different region by controller.
- Send the interest packets to the target region through the intermediate node by using directional flooding.
- Intermediate node check target if it is not compute the cost for communication to controller and forward
- Once the packet reaches the target region, the first node receives the packet identify itself is a border node
- Computes the cost and flood the modified query flood to the regionAll the nodes in the region receive the packet from the border node.
Communication phase
- All the node in the target region sampled the data and other data are joined together along the way to border node.
- The border node collects all the sample data from the nodes and compress, aggregate and sends one packet to controller by using probabilistic routing.

3.1 Energy Minimization for Real-Time Data Gathering

In this method the energy will be minimised in the real-time application of sensor network by using Data Gathering Tree.

Let $T = (N, L)$ is data gathering tree, where $N$ is a set of sensor nodes and $L$ is the communication link between nodes, $M$ is defined as leaf nodes in tree. $Ts$ is the sub tree of start from any node. For the above structure, the data is gathered from all the child nodes, which is connected and aggregated by the intermediate node along with its own sensed data. The aggregation is not executed by leaf node M and the sink node. The fused data is transferred to sink via parent node. They define the protocol packet transmission problem (PTP) of network in offline case and online case. In general, for a data gathering tree energy information for all, the nodes were known prior and in the case of online case each node has a local knowledge of the energy function of their parent and children.

3.1.1 Parameter and Other Specification used for Simulation

- Topology-Tree
- simulator was developed using the PARSEC software
- 200 sensors in a unit square.
- The sink node was put at the left-bottom corner of the square.
- The neighbours that a sensor node could directly communicate were determined by a connectivity parameter, $\rho \in (0, 1]$. Specifically, two sensor nodes could communicate with each other only if the distance between them was within $\rho$ threshold distance. The size of raw data from all source nodes was set to 200 bits.

Greedy Incremental Tree (GIT) algorithm was used for constructing the data gathering tree.

3.2 Adaptive Data Fusion for Energy Efficient Routing in Wireless Sensor Networks

Adaptive Fusion Steiner Tree (AFST) is used for optimised transmission cost and fusion cost and also it makes a fusion decision based on the data and distance received from the sensor nodes and it performs the energy efficient routing process compared to MFST (Minimum Fusion Steiner Tree). In Minimum Fusion Steiner Tree the intermediate nodes in the sensor network will aggregate the data received from all other nodes and attach its own data along with the aggregated packet in outgoing packet. In this case some of the algorithm given the solution for transmission cost and some algorithm given the solution for fusion cost but both the cost are link dependent and not supporting the fusion decision making based on the needs.

Disadvantage of Minimum Fusion Steiner Tree.
Fusion is performed by the intermediate node along the routing, but energy will be wasted for less redundant or correlation data means for little information redundant spends high fusion costs.

Parameter and other specification used for simulation

- 100 sensor nodes are equally distributed in 50mX50m
- Assume packet size is 400 bytes generated by each node.
- $rc$ is maximal communication radius.

3.3 On the Data Gathering Capacity and Latency in Wireless Sensor Networks

In the fundamental approach of data gathering scheme in WSN if they satisfy to improve the capacity and Latency indirectly, they fail to satisfy the energy efficiency in WSN. Here Energy efficiency is improved with increasing the capacity based on the following functionalities.

Assume $s(n)$ is the sensor nodes, $d(n)$ is the sink node, where $n$ is to be the nodes, then the set of sources nodes is considered to be $s(n) \leq n-1$ and data collection point is $d(n) \leq n - s(n)$ and $n - s(n) - d(n)$ relay node which forward the data to the sink. The study says data aggregation is done by dividing the sensing region into smaller cells and single correlated data from each cell is forwarded to the sink node. As per the algorithm the source nodes are allowed to send the data matches with the slot colour and the node colour can generate the new packet, if the transmission is not allowed then node can act as forwarder. If the node colour is not match with the slot colour, then it can collect the data if node is a leader.
3.4 An Efficient Data Gathering Routing Protocol in Sensor Networks Using the Integrated Gateway Node

It consists of Integrated Gateway Node (IGN), virtual node, where it trying to solve the vulnerability of flat structure and hierarchical structure. The virtual gateway nodes form a cluster like hierarchical and flat structure routing protocols like SPIN and Flooding are communicated through the virtual nodes and improved the energy efficiency and other data gathering techniques based on matrix is defined and power efficient gathering method also address in this paper.


Generally sensing data will be forwarded through the minimum energy path to the sink node and it causes the imbalanced energy distribution. To overcome this problem EBRP sends the packet through dense energy resource area to protect the other nodes having minimum residual energy. During this process the EBRP faced the looping problem; at last it gives the solution for looping problem by detecting and eliminating the loop. EBRP is increase the life time of the network by balancing the energy and also the functional life time. The following configuration parameters are used for Simulation:

Node Deployment:
- Area: 70 m square
- Type: Grid
- Network architecture: Homogeneous, Flat
- Total Nodes: 289
- Sink at: (35,35)m
- Used for Event driven application with TOSSIM platform with TinyOS.

4.1 CASE STUDY-1: Data Collection in Wireless Sensor Network for Noise Pollution Monitoring

This study defines real time data collection for monitoring noise pollution using WSN which is done in European countries to monitor the environmental noise in the urban area and based on the analysis its need to reduce or protect the high level noise, by using efficient data gathering protocol, through a Wireless sensor network as an implementation tool, due to the lack of manual data collecting because of increasing time. Problem definition and requirements The general property of the noise is free propagation from the source and also shadowing and reflection of noise will be there in the environment, so what happens in measuring the accuracy of noise level is good in source sensor node but computational method shows an inaccuracy. For that, the following requirements are needed. Hardware: needs to capture the high sampling rate Sampling: noise levels may be varying with time. So the noise levels will be computed with variable time intervals.

4.1.2 Data Rate and Latency

For this application whatever the data is sensed by the sensors will not require immediate reach to the sink. For that each sampling of data will be converted into 1 value per second and the collected value is made into packet and at last delivered to the sink node with collections of data. Network topology: The topology should not change to the entire communication and packet will be reached to the destination in multi hops because of the spatial distribution of sensors.

4.1.3 Data Collection

Once the nodes are deployed, the data is captured by the sensors is transferred to the base station for the
Table 2. Analysis of data funnelling with aggregation technique based on routing method

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Data Aggregation</th>
<th>Energy Saving</th>
<th>Optimal Fusion Cost</th>
<th>Optimal Transmission Cost</th>
<th>Fusion Decision</th>
<th>Collision</th>
<th>Capacity</th>
<th>Latency</th>
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<tr>
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<td>Yes</td>
<td>yes</td>
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<td>yes</td>
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<td>MST</td>
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<td>Yes</td>
<td>yes</td>
<td>Yes</td>
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<td>-</td>
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<tr>
<td>SPT</td>
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<td>Yes</td>
<td>no</td>
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<td>-</td>
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<tr>
<td>Data gathering capacity and latency</td>
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<td>IGN</td>
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<td>-</td>
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<td></td>
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<td>EBRP</td>
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<tr>
<td>Data gathering with Compressive sensing(CS)</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>No</td>
<td>yes</td>
<td>low</td>
</tr>
</tbody>
</table>

permanent storage. There the further processing will take place. They use the Collection Tree Protocol (CTP) and an existing protocol and D-MAC protocol for the communication purpose. By analysing the various communications protocol, they finalise this CTP and DMAC is more suit for their application. CTP is implemented in using TinyOS. Developed customised and computational noise level meter by using a suitable data collection protocol.

4.2 CASE STUDY-2: Wireless Sensor Network Deployment for Integrating Video-Surveillance and Data-Monitoring Precision Agriculture over Distributed Crops

This project deals with data collection and monitoring the crops in real-time application. In this project the crops are monitored in two different ways to improve the production of the crops by using wireless sensor network.

- Monitored the intruders or animals using video surveillance, because it affects the production.
- The other one is monitoring the production process. The above monitoring system is executed through data gathering, data transmission and video surveillance.

4.2.1 Problem Definition

Integrating the video surveillance and the data monitoring using IEEE802.15.4 network is not executed before in any other agriculture application, so this project provides the solution to the integrating video surveillance and data transmission over the IEEE 802.15.4 in real-time application. This project is not considering the other parameters like energy efficiency. Data gathering system. Data transmission to the gateway through multi-hop will be easy in the simulation. But in the real-time applications, the field will be separated by small group of crops and distributed in nature and the farmers should need to change the parameters to improve the production. All the deployed sensor nodes will sense and capable to sample the data like measuring the temperature, motion detection and identification are transmitted directly to the gateway; it’s a common device for permanent storage in the communication phase. To attain the above data gathering system they used various devices which consists of collection of sensor nodes need to sense the temperature, pressure, soil moisture and pH.

4.2.2 Overall Data Gathering Scenario
Multi hop data transmission will be easy in simulation but in real time application its quite difficult, because of transmission, receiving and internal process, the performance of the node may be degraded. In this project the data will be communicated directly to the crop gate way so that the data will be reached to formers premises in time. And also address the integration problem of data monitoring and video surveillance through IEEE 802.15.4. For data communication they used Star topology which is many to one concept because of the IEEE 802.15.4 to satisfy the standard and also for low cost communication.

5. Conclusion and Future Work

This paper gives the overall survey of various solutions to the funnelling effect and data gathering techniques Wireless sensor network. The solution is provided only for the static network as technically say homogeneous sensor network. The collections of solutions for funnelling effect fail to support if part of the node in the network is dynamic called Hybrid network. Hence, our future work will be focused on providing the QoS for hybrid network.

6. References


33. Available from: www.simplelabs.co.in.