Abstract: Wireless sensor networks (WSN) has emerged as a vital area for exploration and enhancement. Many challenges are there in WSN like energy efficiency, routing, load balancing, scalability etc. This research study focuses on routing protocols using cross layer approach. WSN is composed of tiny sensors called sensor nodes. A sensor node performs some functions like acquisition of environmental physical measures, local processing of collected data and their transmission to the sink. A node is alimented by minimum quantity of energy and communicates wirelessly using a radio signal. Major percentage of energy in WSN is consumed during routing from source to destination, retransmission of data on packet loss. The goal of the study is to provide a feasible and flexible solution for routing in WSN using cross layer approach. Cross-layer approaches have proven to be the most efficient optimization techniques for improving the performance of WSN. Cross layered algorithm and protocols are proposed for routing and retransmission scheme. The basic idea behind the protocol approach is to wake-up only nodes belonging to a routing path from source to the base station by exploiting routing information while other nodes leave maintained as long time as possible in a sleep mode. Dynamic scheme provides better performance when some of source nodes collaborate by forwarding packets. The effectiveness of this proposal is demonstrated in terms of energy consumption and latency.

Keywords: Wireless Sensor Network, Cross layer, Dynamic scheme, latency, routing

1. INTRODUCTION

In the last decade wireless sensor network has become a prominent field for research because of its theoretical aspects and practical challenges. This progressive research and recent development in the technology in micro-electro-mechanical systems (MEMS)[1] low power and highly integrated digital electronics have headed to the development of micro sensors. Such sensors are generally designed with data processing, communication and computational capabilities[2].

Sensor nodes send their measurements to the sink(fusion center) via wireless multi-hop communications. The dashed circle is the radio range of a sensor node[3].

A WSN typically consists of a large number of low-power, multifunctional and low-cost wireless sensor nodes. These sensor nodes interact with each other within a short distance in a wireless medium and collaborate to achieve a collective task, for example and industrial process control, environment monitoring, and military surveillance [1]. The basic philosophy behind wireless sensor nodes is that they measure the ambient conditions of the environment and transform them into electrical signals and transferred to the sink making use of radio transmitter. Once deployed, the sensor nodes must be able to independently organize themselves into a wireless communication network. Sensor nodes are battery-powered and must operate without attending for comparatively long period of time[1].

The basic wireless sensor network elements can be characterised as follows: large sensor population (e.g., 64,000 or more client units need to be supported by the system and by the addressing device), large streams of data, ambiguous data, high potential link failure (interference), high potential node failure, electrical power limitations, multi-hop topology, lack of global knowledge about the network, processing power limitations and (often) limited administrative support for the network[9]. The demands placed on the software of wireless sensor networks are very huge. It is expected to be efficient in terms of memory, processor, and power so that it meets strict application requirements. For this reason TinyOS(Tiny Microthreading Operating System) is the operating explicitly designed for the wireless sensor networks[10].

Due to the severe energy constraints of large number of densely organised sensor nodes, it involves a set of network protocols to tool various network control and management functions such as node localization, network security and synchronization. One of the challenges in sensor networks is routing due to several characteristics[1]. Firstly, it is impossible to build a global addressing scheme for the disposition of absolute number of sensor nodes. That is the reason why classical IP-based protocols cannot be applied to sensor networks. Second, in opposing to typical communication networks in all the applications of sensor networks the flow of sensed data from multiple regions (sources) to a particular sink is must. Third, since the data is generated in multiple sensors there is high possibility of data redundancy in data traffic. Such redundancy should be exploited by the routing protocols to improve bandwidth utilization and energy. Fourth, sensor nodes are compactly constrained in terms of transmission power, on-board energy, processing capacity and storage and thus require careful resource management.

To overcome most of the routing problems of wireless sensor networks many algorithms have been proposed as the solution. Routing protocols can be classified as Data-Centric, hierarchical and location based[1].
The performance metric considered in wireless sensor network for communication are referred to as Quality of Service (QoS). QoS protocols in sensor networks have several applications including real-time target tracking in battle environments, emergent event triggering in monitoring applications etc. Energy-aware QoS routing in sensor networks will ensure guaranteed bandwidth or delay through the duration of a connection as well as providing the use of the most energy-efficient path.

Organisation of the paper is as follow: Section 2 of this paper talks about related work i.e. the literature survey regarding the techniques and the methodologies used for the conservation of the energy in the WSN with cross layer approach. Section 3 of this paper talks about the comparison between the methodologies. Section 4 concludes the paper.

1.1. Wireless Sensors Network

Figure 1.1 represents a typical application of WSN i.e. target detection, tracking, and classification. In this application scenario, the measured information from different sensors is to be sent to the sink via multiple hops and the sink to process the measurements. Yet this approach consumes more energy. The data collected by the sensors is raw data and transmission of raw data requires large amount of energy and also increases network traffic which poses high bandwidth demand.

Energy efficiency has been considered as the main challenge in the WSN. In this paper, we analyse some recent progresses on designing energy efficient information processing algorithms in WSNs. One approach for energy efficiency is to reduce the rate of transmission to reduce communication power consumption. Second approach is to keep awake only the necessary nodes for the transmission of the raw data to the sink. The third approach is the cross layer protocol.

![Cross-layer Protocol Design](image)

**Figure 1.2 Application based cross-layer protocol design**

1.2. Routing

Routing can be classified as dynamic routing and static routing:

1.2.1. Dynamic routing

Dynamic routing is a networking technique that provides optimal data routing. Dynamic routing enables routers to select paths according to real-time logical network layout changes. In dynamic routing, the routing protocol operating on the router is responsible for the creation, maintenance and updating of the dynamic routing table. Dynamic routing uses multiple algorithms and protocols. The cost of routing is a critical factor for all organizations. The least-expensive routing technology is provided by dynamic routing, which automates table changes and provides the best path for data transmission.

Typically, dynamic routing protocol operations can be explained as follows:

1. The router delivers and receives the routing messages on the router interfaces.
2. The routing messages and information are shared with other routers, which use exactly the same routing protocol.
3. Routers swap the routing information to discover data about remote networks.
4. Whenever a router finds a change in topology, the routing protocol advertises this topology change to other routers[4].

Dynamic routing is easy to configure on large networks and is more intuitive at selecting the best route, detecting route changes and discovering remote networks.

1.2.2. Static routing

Static routing is not a routing protocol; instead, it is the manual configuration and selection of a network route, usually managed by the network administrator. It is employed in scenarios where the network parameters and environment are expected to remain constant. Static routing performs routing decisions with preconfigured routes in the routing table, which can be changed manually only by administrators. Static routes are normally implemented in those situations where the choices in route selection are limited, or there is only a single default route available. Also, static routing can be used if you have only few devices for route configuration and there is no need for route change in the future[5]. Static routing is considered the simplest form of routing.

1.3. Cross layer approach

Layering systems are the norm in the design of communication protocol stacks. For sensor networks, and smart routing specifically, given the need to conserve sensor energy and maximize application performance, cooperation between several layers in the protocol stack is crucial. This can only be achieved in a cross-layer architecture. Cross-layer design ensures that the route that best meets both performance and energy requirements can be determined.

![Cross-Layer Design Protocols](image)

**Figure 1.3. Various Cross-Layer Design Protocols**

Figure 1.3 presents a number of general ways in which a typical layered architecture can be modified by cross-layer design:

- Creation of new interfaces for information flow between non-adjacent layers(Figures 3a-c);
- Merging of adjacent layers for joint functionality and reduced overhead (Figure 3d);
- Design coupling between layers, i.e. one layer assumes information arriving from another (Figure 3e); and,
- Vertical calibration between layers (Figure 3f).
In next-generation wireless sensor networks (WSNs), a number of these protocols may be used.

2. RELATED WORK

2.1. SCSP(Sleep, Collect and Send Protocol)

S-MAC and B-MAC are the most popular protocols of MAC in WSN. S-MAC is known for energy consumption minimisation and self-organisation support. S-MAC consists of sleep and active state where in the nodes keeps switching among these states. This provides synchronisation mechanism while minimising energy consumption. The protocol uses an RTS/CTS transmission scheme and provides adaptive listening and avoids overhearing unnecessary traffic. It divides the long message into smaller sub fragments and transmits them in burst.[7].

A B-MAC support for low power listening and provides the power management. In this the nodes periodically keep switching between the active mode and sleep mode. When the node wakes up it checks whether the channel is active, if so the node stays awake and receives the incoming packet, else if the channel is inactive then the node goes back to sleep. SCSP has the advantages of both protocols and provides further enhancements. This combination avoids S-MAC synchronisation overhead and improves throughput.[7].

The protocol makes use of a simple but very efficient routing protocol that does not need route maintenance or detection and works mutually with the MAC layer to boost its fault tolerance properties.

2.2. E2XLRADR (Energy Efficient Cross Layer Routing Algorithm with Dynamic Retransmission for Wireless Sensor Networks)

There are number of algorithms and protocols that have been developed for reducing energy consumption by periodically switching to listening and sleeping modes, by avoiding collision and overhearing and message passing etc. But there are still many things to be done for improving these protocols and algorithm[8].

XLRA is divided into five phases:

1. Finding the destination location.
   In the first phase when the source S has data to send to Destination D, Source S checks where Destination D is, whether it is in its sensing area or not. If so then S sends an r-request message to know whether D is in ready for receiving the data or not. If so, D sends back the acknowledgement ack1 message saying “ready to receive”. Then S sends data directly to D, after successfully receiving data D sends ack2 message to confirm that data is received. If D is not in the receiving state, S waits for D to be in the ready state. If S does not receive the acknowledgement ack1 message within the fixed time Tt it resends the r-request msg. Tt is fixed.

2. Route Finding.
   In the second phase when the source has data to send but the destination is not in the sensing area then the source sends r-request message to the farther intermediate node in the sensing area. The farther node acknowledges and hence the source node sends data to that intermediate node. Now it’s the intermediate node’s job to send the data to the maximum sensing range and to the destination node.

3. Dynamic Scheme for retransmission for maximum number of transmission.
   In the third phase Each node needs the information about the route and the number of hops to determine the value of Kmax(maximum number of retransmission).

4. Route Maintenance

Each maximum distance intermediate node in route is capable enough to monitor its potential increase of interference and decrease in residual energy level. When node cannot find its next maximum distance node it sends route recovery message.

5. Route Re-establishment

Route re-establishment is necessary when condition of sensor networks change greatly and route maintenance is not able to recover the lost link. This decision is only dependendent on the potential interference and residual energy of the current node.

By summarising the above approach we can conclude that dynamic scheme provides better performance when some of the source nodes cooperate by forwarding packets and when these kinds of sources are well distributed in the network. The limited number of re-transmission has direct impact on the end-to-end throughput and delay[8].

2.3. Data-centric protocol.

In sensor network applications it is impossible to assign global identifiers to each node because of its huge node depletion. This makes it difficult to select specific set of sensors nodes to be queried. Because of this difficulty we go for data centric routing, in this the sink sends queries to some and waits for data from those regions. Attribute based naming is necessary since the data is being requested is in the form of queries. SPIN is the first data-centric protocol.

2.3.1 DRUG(Data-centric RouLutin6) protocol

This protocol works on two basic ideas. First to function efficiently and to save energy, there is a need for the sensors to communicate with each other about the existing data within them and also about the data they are seeking for. If we go for exchanging of the data among the sensors, this operation is very expensive in terms of energy instead we go for exchanging of the metadata. Second, nodes in a network must observe and adjust to changes in their own energy resources to lengthen the functioning lifetime of the system. This is the main feature of the DRUG protocol[11]. Figure 4 depicts the DRUG protocol model.

Node A starts by advertising its data to node B (1). Node B responds by sending a request to node A (2). After receiving the requested data (3), node B then sends out advertisements to its neighbors (4), who in turn send requests back to B (5-6).

Drug protocol makes use of three main messages:

1. ADV- new data advertisement. This message contains the metadata.
2. ACK- request for data. This message contains the metadata.
In LEACH nodes are organised themselves in the form of clusters and for each of the cluster a head is chosen. All other nodes send data to the head and the head is responsible for processing of the data and forwarding the processed data to the base station. According to the system’s lifetime the cluster heads are changed. Each node must take the responsibility to act as cluster head. The functioning of the LEACH is divided into two phases: set-up phase and the steady phase. To begin with, it starts with the set-up phase where in the clusters are formed and cluster head is chosen. This is followed by the steady phase where in the nodes transmit their data[12].

2.4. Hierarchical protocol

In this kind of routing protocol, clusters of nodes are formed. For each of these clusters a head node is dynamically assigned. These head nodes communicate directly or through the upper heads with the sink[12].

2.4.1. Leach(Low-Energy Adaptive Clustering hierarchy)

The approaches discussed above has to be compared to find out the change and improvement in the performance. In this paper we discuss the comparison in the following table.

<table>
<thead>
<tr>
<th>Approach</th>
<th>Paper title</th>
<th>Authors</th>
<th>Parameters or methodology</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCSP</td>
<td>An Energy Efficient MAC Cross-layer design for wireless Sensor Networks.</td>
<td>Bilel Nefzi, Hugo Cruz Sanchez, Ye-Qiong Song</td>
<td>Sleep and Active modes</td>
<td>Boost in Fault tolerance . Performance improved</td>
</tr>
</tbody>
</table>

4. CONCLUSION

Wireless sensor networks consists of protocols and algorithms with self-organizing capabilities. Wireless sensor networks having many challenges but this study focuses mainly on Energy Efficiency issue in wireless sensor networks. This paper talks on different techniques used for efficient usage of energy such as protocol based, algorithm based and cluster based. Comparison of these techniques is also shown. Performance of these techniques can be improved with a suitable techniques. Future work concentrates on designing protocols on MAC Layer and Network Layer to maximize lifetime of the Wireless Sensor Network.

REFERENCES


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