EECLD: Energy Efficient Cross Layer Design for Wireless Sensor Networks

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Abstract -- In Wireless Sensor Network, Sensor nodes have limited energy efficiency. Energy efficient protocols are required to improve the network lifetime for the wireless sensor network. Conventional protocols design is very critical for energy efficiency. In this paper, we propose an energy efficient cross layer design (EECLD). Simulation results show that the proposed EECLD significantly improves energy efficiency compared to the design of the conventional protocol.

Keywords--Cross-layer design, WSN Protocol stack, Sensor nodes, Wireless Sensor Network.

I. INTRODUCTION

Wireless sensor network (WSN) consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants and to cooperatively pass their data through the network to the main location. In traditional communication networks, the Open Systems Interconnection (OSI) layered architecture has been widely adopted and has served many communications systems well in the past; however, evolving wireless networks of today are seriously challenging this design philosophy. The layered architecture defines a stack of protocol layers in which each layer operate within its well-defined function and boundary, and thus allowing changes to the underlying technology at each layer without imposing the need to change the overall system architecture. The traditional layered approach has been successful in its ability to provide modularity, transparency, and standardization in the wireline networks but might be unsuitable in the wireless sensor networks domain. In recent years, many research works have been presented for wireless sensor networks which are based on the interaction between various non-adjacent layers of the wireless sensor network stack. Cross layer design is a co-operation between multiple layers that combine the resources and create a network that is highly adaptive. The cross layer design approach can increase the energy efficiency of sensor nodes in a wireless sensor network. The Cross-layered design approach in a wireless sensor network is more useful, energy efficient, scalable and secure than with traditional approaches. Parameters which can be optimized by Cross layered design approach are throughput, network lifetime, quality-of-Service, resource constraint, scalability, functionality. The traditional layered approach follows strict layering principles and provides a platform for designing interoperable systems, but it suffers from more transfer overhead. So Cross-layered approach is used to minimize this overhead by having data and information shared among different layers. So there is a requirement of a cross layer design approach that will improve network lifetime of sensor nodes in wireless sensors network. Proposed EECLD approach will be more energy-efficient as compared to conventional protocols.

II. NEED OF CROSS-LAYER DESIGN

The cross layer design is a technique of breaking of OSI hierarchical layers in communication networks. The breaking of OSI hierarchical layers includes, Merging of layers, Creation of new interfaces, Providing additional interdependencies between any two layers. Cross layer design has emerged as an important research area in Wireless sensor network. In Open System Interconnection (OSI) layered architectures, each layer has definite functionalities of a communication system and allows interaction between non-adjacent layers, but it does not allow interaction between non-adjacent layers. cross layer design approach has been proposed for this purpose. In recent years, many research works have been presented for WSN which are based on the interaction between various non-adjacent layers of network stack [2]. Growing interest and penetration of wireless Sensor networking technologies is underlining new challenges in the design and optimization of communication protocols. Traditionally, protocol architectures follow strict layering principles, which ensure interoperability, fast deployment, and efficient implementations. However, lack of coordination between layers limits the performance of such architectures due to the specific challenges posed by the wireless nature of the transmission links [1].

To overcome such limitations, the cross-layer design has been proposed. Its core idea is to maintain the functionalities associated with the original layers but to allow coordination, interaction and joint optimization of protocols crossing different layers. The traditional layered approach provides a platform for designing interoperable systems, but it suffers from more transfer overhead. So, Cross layered approach is used to minimize this overhead by having data and information shared among different layers.

III. RELATED WORK

A few cross-layer design approaches have been proposed for Wireless Sensor Network. There is a considerable amount of surveys in the literature that discuss WSN technologies in general [1]-[9]. The complete literature survey has discussed in
[10]-[20]. Munish Gupta et al. [10] has developed a cross layer energy efficient protocol which optimizes energy consumption of the sensor nodes at the Network, MAC and Physical layers of the protocol stack as most of energy consuming factors exist in these three layers, the optimization of energy consumption using cross layer approach is better than the single layer approach. Zeeshan Ali Khan et al. [11] proposed an adaptive routing metric which helps in minimizing the energy consumption as well as meeting the real-time deadlines of the application. Routing metric performs well under different application deadline cases as it takes into account the effect of congestion on a particular path by periodically estimating the delay values. Hui Wang et al. [12] proposed a Decomposition and Combination (D & C) approach to compute the suboptimal solution and also an iterative algorithm is proposed for the D & C approach. The proposed iterative algorithm can also provide a significant improvement on the performance of network lifetime. Morteza Mardani et al. [13] have developed a parallelized distributed algorithm which scales well in the network size and exhibits low computational complexity. Jain-Shing Liu et al. [14] have proposed a cross-layer optimization approach that can seamlessly accommodate routing, scheduling and stream control to simultaneously meet the diverse objectives with the aid of network utility maximization. Cross layer optimization is capable of achieving the joint objective by using the distributed computation. Herman Sahota et al. [15] have designed the MAC Layer to save energy during the wake-up synchronization phase. PD-MAC is more energy efficient than Sensor-MAC (SMAC) for the application. Yong Ding et al. [16] have described the several key characteristics of WSN, communication link and cross layer algorithm (CLA) is provided which based on power control. CLA Provides real-time communication without compromising the energy awareness of the existing energy aware routing protocol. This enables even distribution of energy expenditure to sensor nodes. Qingxu Xiong et al. [17] have constructed the sensor ontology, and the special inference rule for MAC is defined by adopting computation geometry algorithms. By combining application semantics, MAC Protocols can directly deal with application & control the data transmission. Atif Sharif et al. [18] proposed Lightweight congestion aware reliable Transport Protocol (LCART) has been evaluated against TCP-Westwood + (TCP-WW+), TCPWestwood, (TCP-WW), TCPNewReno & TCPReno for 24 mote ad-hoc topology. LCART outperforms others in terms of good throughput, average E-2-E data packet latency, average packet drop. Ian F.Akyildiz et al. [19] have proposed the sensor ontology which replaces the entire traditional layered protocol architecture that has been used so far in WSN. XLM significantly improves communication performance and outperforms the traditional layered protocol architectures in terms of both network performance & implementation complexity. Chia-Hung Tsai et al. [20] have proposed linking the asynchronous power-saving protocol and the continuous query-processing problem together. This link emphasizes increasing the overlapping of query paths for energy efficiency.

IV. PROPOSED EECLD

Proposed EECLD allows interaction between layers. In this approach, each layer interacts with other layers by using cross layer optimization buffer. Cross layer optimization buffer allow each layer to interact with another layer. We design EECLD as in Fig.1.In EECLD we are using a Cross layer optimization buffer (CLOB) which perform many functions. If sensor nodes want to send packets or sense data to the base station, then sensor node checks its sensing range from the base station. If sensing range of the sensor node is feasible for sending sensitive data to the base station. Sensor node sends data to CLOB and CLOB check channel whether it is free or not. If the channel is free, then CLOB set time schedule of the Sensor node.CLOB dispatch data to Physical layer and from where data is accessed by the end user.

Fig.1.EECLD

Time Scheduling Algorithm for Avoid Collision

1. If Sensor nodes(SN) wants to send packets to Base Station(BS)
2. SN check its sensing range from BS
3. If BS is in sensing range, then SN sends SD to CLOB
4. CLOB check Ch whether it is free or not
5. If Ch=free then set Ch= SD
6. Set SD = Ti
7. Dispatch SD from CLOB to PL
8. PL = SD
9. Repeat Step 1 to 8
Notations used:
CLOB = Cross layer optimization buffer
SN = Sensor Nodes
BS = Base Station
Ch = Channel
SD = Sense data
Pl = Physical Layer
Tt = Time slot

V. PERFORMANCE ANALYSIS OF EECLD

We develop a simulation environment to evaluate the efficiency of EECLD. For this purpose, we are using QualNet 5.0.2 simulation modeling tool. We are using some parameters like Average jitter, Throughput, Average end-to-end delay.

1. Average jitter

Data from source to destination will reach the destination with different delays. A packet’s delay varies with its position in the queues of the routers along the path between source and destination, and this position can vary unpredictably. This variation in delay is known as Jitter.

2. Throughput

Throughput means a total number of packets received by the Base Station. Throughput is the average rate of successful message delivery over the communication channel.

3. Average End-to-End Delay

Average end-to-end delay is a time in which data sent from sensor node to the base station. Due to queuing and different routing paths, a data packet may take a longer time to reach its destination. The end-to-end delay experienced by the packets for each flow the individual packet delay is summed, and the average is computed.

Table 1: Simulation Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Sensor nodes</td>
<td>1, 2, 3, 4, 5, 6, 7, 8, 9, 10</td>
</tr>
<tr>
<td>Destination node</td>
<td>11</td>
</tr>
<tr>
<td>Buffer Size</td>
<td>1024</td>
</tr>
<tr>
<td>Terrain Range</td>
<td>100m x 100m</td>
</tr>
<tr>
<td>No. of nodes</td>
<td>10</td>
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</tbody>
</table>

The performance of the proposed EECLD is verified in the experiment, the sensor nodes in Wireless Sensor Network are distributed randomly in the 100m * 100m area. In this simulation environment (Fig.2) sensor nodes 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 are cooperatively pass their data to the destination node (Base Station) running simulation is shown in Fig. 3.

In Running simulation sensor nodes are sending packets to destination node 11 (Base Station).

![Fig.2.Simulation Environment]
In Fig. 4 Show Average jitter. Data from source to destination will reach the destination with different delays. In Fig. 5 Show Average end-to-end delay, Average end-to-end delay is a time in which data sent from sensor node to the base station. In Fig. 6 Show Throughput, throughput means a total number of packets received by the Base Station.
VI. CONCLUSION

In this paper, we have proposed an energy-efficient cross layer design (EECLD) to improve the energy efficiency of sensor nodes in a wireless sensor network. Proposed EECLD will optimize energy consumption at Physical layer, Data link layer and Network layers of the Wireless sensor network protocol stack (Simplified Protocol Stack of OSI Model). Proposed EECLD allow Communication between layers non-adjacently and each layer has knowledge about another layer like Application layer has knowledge about MAC Layer, and MAC Layer has knowledge about Network layer and Network layer has knowledge about Physical and Data link layer. In Proposed EECLD, a CLOB allow exchanging information between three layers. In Proposed EECLD, Time Scheduling algorithm make a schedule to all sensor nodes that are coming from the network layer. Proposed EECLD will be more energy-efficient approach as compared to existing approach. Proposed EECLD will improve energy-efficiency of sensor nodes in wireless sensor network.

Acknowledgment

Our special thanks to Prof (Dr.) K.K.Raina, Vice-chancellor, DIT University, Dehradun for his support and guidance.

Ethics

This Research paper is original and not published in any conferences or in any journal.

REFERENCES


of world academy of science, Engineering and Technology volume 22 July 2007 ISSN 1307-6884.


x. Munish Gupta, Dr. Paramjeet Singh, Dr. Shveta Rani, “Cross-Layer energy efficient protocols for WSN: A Survey”, Apeejay journal of computer science and applications, 2012, ISSN: 0974-5742(P)


