

Cross Layer Design Approach for Improve Energy-Efficiency in Wireless Sensor Network

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Abstract

Sensors nodes are limited in less energy resources in Wireless sensor network. Energy efficiency is the fundamental concern of WSN, due to the fact that each sensor node in Wireless network operates with an extremely limited energy. Cross layer modification approach allows direct communication between protocols at non-adjacent layers or sharing variables between layers. Developing energy efficiency protocols to optimize energy consumption is most important for energy efficiency in WSNs. Thus our focus is to improve the energy efficiency of sensors in Wireless Sensor Network. One of the ways to improve energy efficiency is using cross layer modification approach. Energy consumption optimization is required at all the layers of wireless protocol stack but most work focus only on optimizing single layer in terms of energy consumption for wireless sensor network. In this paper we propose a cross layer energy efficient approach which optimizes energy consumption of the sensor nodes at the Network Layer, Data Link Layer and Physical Layers of the Wireless protocol stack because energy consumption factors exist in these three layers.

Keywords:

Cross-layer, Cross-Layer Design survey, Wireless Sensor Network

1. Introduction

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. Traditional layered approach has been successful in its ability to provide modularity, transparency and standardization in the wire line networks but might be unsuitable in the wireless networks domain. In the recent years, many research works have been presented for WSNs which are based on the interaction between various non-adjacent layers of the 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 can lead to increase network efficiency and optimized network throughput in Wireless Sensor Network, which motivates to introduce the approach to the Wireless Sensor Network. The Cross-layered approach in Wireless Sensor Network is more useful, energy efficient, scalable and secure than with traditional approaches. Cross-layered approach reduces the transfer overhead by sharing the data among different layers. So there is requirement of a cross layer design approach that will increase energy-efficiency of sensor nodes in wireless sensors network.

2. Why Cross Layer Design

The Cross layer is a co-operation between multiple layers that combine the resources and create a network that is highly adaptive. In Traditional layered protocol architecture one layer can exchange data with protocols in its adjacent layers. A protocol encapsulates data arrived from its upper adjacent layer and forwards it down to its lower adjacent layer. Similarly, it can decapsulate data received from its lower adjacent layer and forward it up to its upper adjacent layer. There is no interaction between any non-adjacent layers as in such a layered architecture. Traditional layered protocol architecture is suitable only for wired networks but it is not suitable for wireless networks. Fig.1 Show the interaction between adjacent layers (Interaction between Network Layer and MAC Layer).

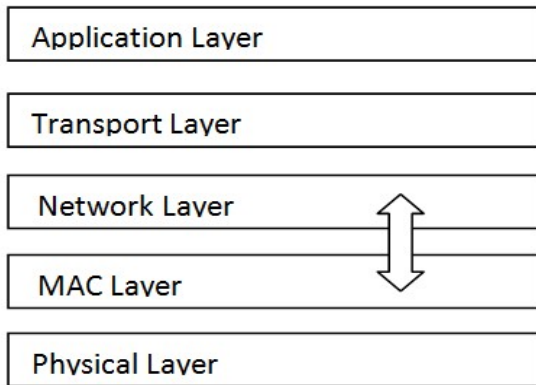


Figure.1.Interaction between Adjacent Layers

To overcome the limitations of protocol designs in wireless networks, researchers have proposed the cross-layer design approach. Cross layer design may be defined as breaking of OSI layer in communication network, Cross layer design allows not only protocol interactions across the layers, but also the possibilities of merging and removal of layers, and the creation of new interfaces and entities for interactions between the layers [19].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. Fig.2 Show the interaction between Non-adjacent layers (Interaction between Physical layer, MAC Layer, Network Layer, Transport Layer and Application Layer).In Interaction between Non-Adjacent layers any layer can interact with any other layer.

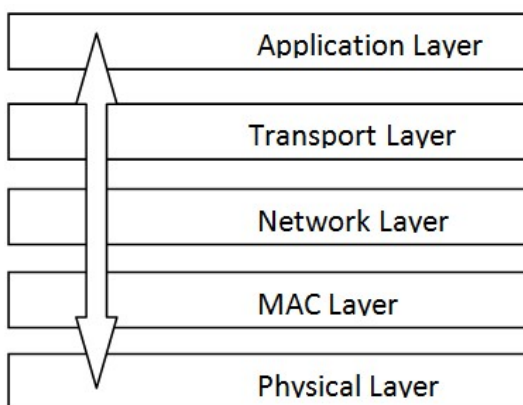


Figure.2. Interaction between Non-Adjacent Layers

3. 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]-[7]. The complete literature survey have discuss in [8]-[18]. Munish gupta et al. [8] 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. [9] 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 perform 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. [10] proposed a Decomposition and Combination (D & C) approach to compute suboptimal solution and also an iterative algorithm is proposed for the D & C approach. Proposed iterative algorithm can also provide significant improvement on the performance of network lifetime. Morteza Mardani et al. [11] have developed a parallelized distributed algorithm which scales well in the network size and exhibits low computational complexity. Jain-Shing Liu et al. [12] 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 on achieving the joint objective by using the distributed computation. Herman Sahota et al. [13] 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. [14] have describes 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. [15] have constructed the sensor ontology and the special inference ruler 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. [16] 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. [17] have proposed the sensor ontology which replaces the entire traditional layered protocol architecture that has been used so far in WSN. XLM significantly improves the communication performance and outperforms the traditional layered protocol architectures in terms of both network performance & implementation complexity. Chia-Hung Tsai et al. [18] have proposed linking the asynchronous power-saving protocol and the continuous query-processing problem together. This link emphasizes on increasing the overlapping of query paths for energy efficiency.

4. Performance Analysis of AODV and Bellmanford Routing Protocols in WSN

Since deployment of large sensor nodes is very difficult in real so, we develop a simulation environment to verify throughput and average end-to-end delay factor of routing protocols like AODV and Bellman ford routing protocols, for this purpose we are using QualNet 5.0.2 Simulation modeling tool. We are using some parameters and their values for simulation which are Summarize in Table 1.

1. Throughput

Throughput is defined as total number of packets received by the Base Station. Throughput measure the effectiveness of a routing protocol.

2. Average End-to-End Delay

Average end-to-end delay is the average time in which packets send from sensor node to base station.

Table 1: Simulation Parameters

Parameter	Value
Sensor nodes	1,2,3,5,7,10,11,16
Destination node	17
Buffer Size	1024
Terrain Range	100m x 100m
No. of nodes	16
Frequencies	2.4GHz
Traffic Type	CBR
Channel Type	Wireless channel
Protocols	AODV,BELLMAN FORD

The effectiveness of AODV and Bellman ford are verified in the experiment, the sensor nodes in Wireless Sensor Network are distributed randomly in the 100m * 100m area.

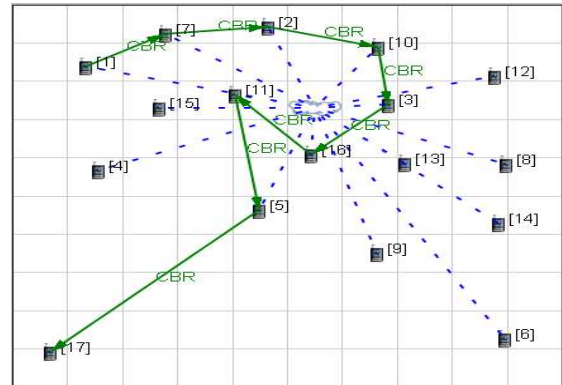


Figure.3. Simulation Environment

In this simulation environment (Fig.3) sensor node 1, 7, 2,10,3,16,11,15 are co-operately pass their data to the destination (Base Station) running simulation is shown in Fig.4. In Running simulation sensor nodes are sending packets to destination node 17.

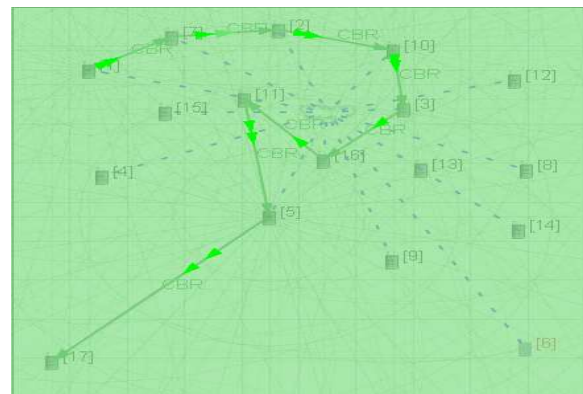


Figure.4. Running Simulation

5. Simulation Results

QualNet 5.0.2 simulator is used to implement the AODV and Bellman Ford routing protocols. The Performance of the AODV and Bellman Ford is evaluated. Table 1 lists the parameters used in the simulation. The key performance measures are throughput and Average end-to-end delay. Simulation result shown in fig. 5 and fig. 6. In fig.5 show result throughput, Throughput means total number of packets received by the base station.

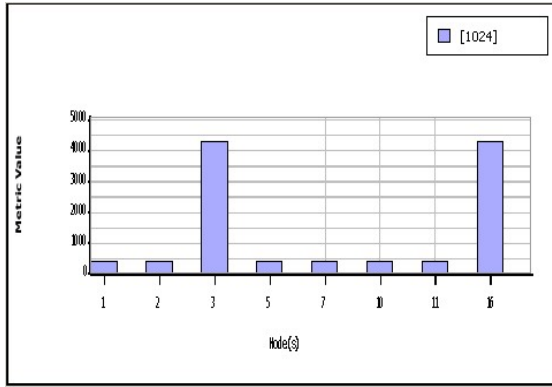


Figure.5. Throughput (bits/s)

In Fig.5 shown total number of packets received by base station. sensor nodes 1,2,3,5,7,10,11,15 are sending packets to base station, there are base station received different-different packets from sensor nodes.

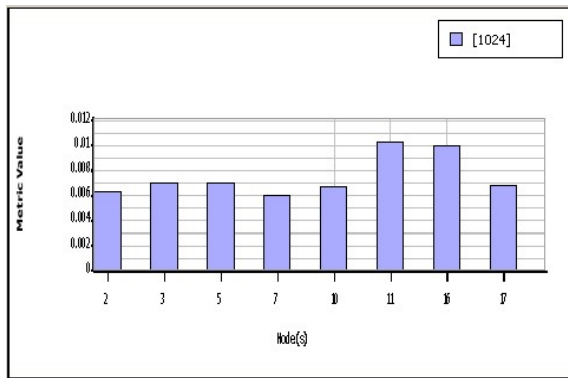


Figure.6. Average End-to-End delay

In Figure.6, routing protocols shows low end to end delay. In Fig.6, All sensor nodes are sending packets to base station without delay.

6. Proposed Cross Layer Design

Proposed cross-layer design approach allows interaction between layers. In this approach, each layer interact with other layers and each layer has knowledge about others layers. We design our cross-layer energy efficient approach as in Fig.7. Firstly at Physical layer we calculate RSSI (Received Signal Strength indicator) Value of Sensor nodes from Base Station and send these RSSI values to Network layer, and use a Cross-layer routing algorithm, Cross-layer routing algorithm provide facility to all sensor nodes by using this routing algorithm sensors nodes find location of base station and communicate with base station. Secondly at Network Layer we check RSSI

value of sensor nodes and if node has larger RSSI value then select this node as data forwarding node

from sensor nodes to base station, Thirdly at MAC Layer we focused on avoiding collision and overhearing for this purpose a Scheduling technique is used here. Scheduling technique makes schedule of all sensor nodes that are coming from Network layer and provide error free transmission. Scheduling technique also increase flexibility. Scheduling technique provide high-quality data service, a multilevel of sensing coverage and network connectivity. In wireless sensor networks with battery-operated devices, energy saving mechanisms is of paramount importance in order to maximize network lifetime. Energy conservation is important during periods with no activity and also during occurrence of events. It is critical to reduce traffic overhearing since the transceiver consumes similar energy for idle listening as transmission but this scheduling technique provide easy way for solving traffic overhearing problem. It Create a schedule for all sensor nodes, every sensor node transmit data when channel is free.

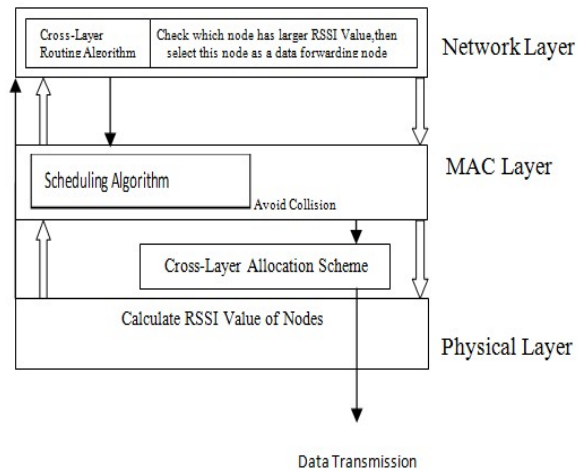


Figure.7. Proposed Cross layer design

We are using a cross-layer allocation scheme which improves the efficiency and guaranteeing fairness among users by exploiting multiuser diversity, frequency diversity, as well as time diversity. Cross layer allocation scheme represents an emerging technology to enable efficient resource management and quality of service support for wireless sensor networks. Cross layer allocation scheme handle multiuser transmission in a single communication channel and share resources in MAC Layer and Physical layer. Cross-layer routing algorithm at Network layer is shown in Algorithm 1. Algorithm 1 shows the functions between sensor nodes and Base station. Scheduling algorithm at MAC Layer is shown in algorithm 2. Scheduling algorithm make schedule of all sensor nodes that are coming from upper layer (Network layer). It check the channel whether it is free or not, if channel is free then

give a time slot to sensor and dispatch packet to Cross layer allocation buffer (CLAB). CLAB check frequency, Channel and time slot of sensor nodes and if channel is free then dispatch packets from CLAB to Physical Layer.

Table 2: Notations used

S_N	Sensor nodes
B_S	Base Stations
B_D	Buffer data
P_N	Packets
CLAB	Cross layer allocation buffer
T_s	Time Slot
Ch	Channel

Algorithm 1: Cross-Layer Routing Algorithm at Network Layer

1. S_N wants to send packets to B_S
2. S_N check its sensing feasibility from B_S
3. If B_S is in sensing range then S_N sends RQ msg for packets sending to B_S
4. If RQ msg received by B_S then it sends back response message RM1 to S_N for sending packets
5. S_N Sends packets to B_S
6. If B_S receive packets of S_N then it sends response message RM2 to S_N for confirmation of packets received successfully
7. If B_S is not ready to receive data, S_N waits for response message RM1
8. Repeat step 1 to 6

Algorithm 2: Scheduling Algorithm at MAC Layer

1. If buffer data $B_D = P_N$ Then
2. Check Channel Ch whether it is free or not
3. If Ch=0 then set Ch= P_N
4. Set $P_N = T_s$
5. P_N dispatch to CLAB buffer
6. CLAB Check Ch is free or not
7. If Ch=0 then
8. Dispatch P_N from CLAB
9. Repeat Step 1 to 8

7. Conclusion

In this paper, we have proposed a cross layer design approach for improve energy-efficiency and system throughput in wireless sensor network. Proposed cross layer design approach 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 cross layer design

approach allow Communication between layers non-adjacently and each layer has knowledge about other 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 cross layer design approach, Scheduling algorithm make schedule to all sensor nodes that are coming from network layer and cross layer allocation scheme allow multiuser transmission in a single communication channel. In future research work, we will simulate Proposed cross layer design approach in QualNet 5.0.2 Simulator modeling tool and verify the proposed cross layer design approach and then validate the result with the existing cross layer design approach. Proposed cross layer design approach will be more energy-efficient approach as compare to existing approach.

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