ENERGY EFFICIENT DATA GATHERING SCHEME USING CROSS LAYER CLUSTER APPROACH FOR WIRELESS SENSOR NETWORKS

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Abstract

Recent advances in wireless communication technology and research in ad hoc wireless networks have made smart sensing a reality. A Wireless Sensor Networks (WSNs) is composed of a number of wireless sensor nodes which form a sensor field and a sink. These large numbers of nodes, having the abilities to sense their surroundings, perform limited computation and communicate wirelessly form the WSNs. Wireless sensor networks have to achieve minimum energy consumption through making use of efficient energy efficient protocols. In this paper, we present a cross layer approach for optimizing data gathering from sensor nodes and in turn increase the lifetime of the network. Cross layer Cluster Approach makes use of both routing and MAC layers information to reduce congestion, increase packet delivery ratio and minimize energy usage. A cluster approach helps in identifying the energy consumption of the node near to the base station and cluster head is selected based on the residual energy of the sensor nodes. This new approach helps in improving the data delivery ratio for regular traffic and also reduces energy consumption thereby prolonging the lifetime of wireless sensor nodes. Through our simulation results, we prove that the performance of the cross layer cluster approach is better than the traditional layer approach.

Keywords: Wireless Sensor Networks, Data Gathering , Cross layer Design , Energy efficient , Clustering

1. Introduction

Recent advances in wireless and electronic technologies have enabled a wide range of applications of WSNs in military sensing, traffic surveillance, target tracking, environment monitoring, healthcare monitoring, and so on [1]. Every big city is suffering from traffic congestion around the world. A sincere effort is being made to solve the traffic congestion. Congestion can be alleviated by planning managing traffic. A real time automatic traffic data collection must be employed for efficient management of rush hour traffic. The vehicle tracking application is to locate a specific vehicle or moving object and monitor its movement. This work also describes design of WSN for vehicular monitoring. As the power source (battery) is limited, it is important that a design of sensor node is power efficient. A cross layer approach for energy efficient MAC layer in W S N reduces the time spending on data moving i.e. nodal processing time drops dramatically and thus energy consumption is reduced accordingly.

In cross layer design approach, MAC protocol, Clustering, routing several attributes and parameters need to be considered. There is a need for making trade-off between those attributes and parameters while designing sensor networks [2]. The some of the attributes are energy efficiency, scalability, adaptability to network topology, collision avoidance fairness and channel utilization. Out these attributes energy consumption is very important attribute in Wireless Sensor Networks. Sensing, data processing and communications are the three important domains of energy consumption which happens in sensor networks. The reason why MAC layer is considered here in cross layer is because it controls directly the radio of the nodes in the networks. Thus the design of MAC protocols plays an important role in node's energy consumption which influences on the lifetime of sensor networks. The major sources of energy waste of MAC layer are overhearing, packet overhead, collision, over emitting and idle listening[3].

Most of the researchers have proposed single layer communication protocol for designing optimal strategies for sensor networks. This has a limited focus on improving the single layer and does not have overall performance improvement in traditional approach. MAC Protocols have been designed power efficient and generally divided into two categories: On demand wakeup and on schedule wakeup. On demand wakeup protocols [4] make use of some form of out-banding signaling technique through a separate radio to wake up nodes with adding extra cost to the network deployment. Scheduled wakeup MAC schemes can be further divided into asynchronous schemes and synchronous schemes. Asynchronous approaches do not require clock synchronization. It is easier to implement and can ensure network connectivity even in highly dynamic networks. Although simple to implement, asynchronous schemes are less efficient than synchronous schemes and cannot provide guarantees on the worst-case delay. For synchronous scheduled wakeup protocols, TDMA and duty cycling are the most commonly used techniques. . Although TDMA protocols are usually designed to create contention-free medium access for communication, they can schedule the wakeups of the sensor nodes as well. However, TDMA protocols require slot allocation and management, which can be difficult if the network topology is dense and dynamic.

Current MAC protocols for wireless sensor networks can also be broadly classified into contention less and contention based. Contention less MAC protocols are normally based on TDMA approaches which have a natural advantage of energy conservation compared with contention-based protocols since there are no collisions. In contention-based MAC, the nodes can transmit without having any predetermined time assigned to them. The nodes will compete for a shared channel. There will be collisions if multiple nodes access the medium simultaneously. Thus the protocol must provide a mechanism to avoid collisions. Standardized IEEE 802.11 distributed coordination function (DCF) is one such protocol. Current contention-based MAC protocols proposed are usually adopted from IEEE 802.11 standard. To reduce the energy consumption of idle listening, various kinds of schedules and wakeup techniques such as on demand, asynchronous schemes, duty cycling are adopted. S-MAC[3][5][6], D-MAC[7], TMAC[8], SyncWUF[9] are examples of contention based MAC protocols. All these MAC Protocols are about wake-up schemes and listen/sleep schedule allocation and reduce processing time in a node [10].

There are schemes based on the several sources of power consumption. For example, we can achieve the purpose of saving energy by minimizing the idle time and also achieve the purpose by optimizing the route

algorithms [18]. In order to transmit in proper power, adjust the power by optimizing the physical layer [19]. But the schemes above are based on each layer which have many limitations. The parameter of MAC layer may change while optimizing the network layer. So, it is not comprehensive to optimize a signal layer. Hence cross-layer strategy is adopted. There is no research about how to reduce energy consumption with the cross layer design approach and also incorporating cluster formation mechanism which helps in data gathering. In this paper, we can investigate that, there is decrease in energy consumption among nodes in the network using cross layer cluster approach of Wireless Sensor Networks.

This paper is organized as follows: Section 2 discusses related work in the relevant problem. In section 3 proposed cross layer approach is described. Section covers simulation setup and result analysis. Finally section 4 concludes this paper.

2. Related work

There is a lot research work on energy consumption which is based on single layered approach at the beginning. Later in order to improve the efficiency of the sensor network and achieve the goal of energy saving, researchers started incorporating the concept of cross layered design scheme. Van Hoesel started with a cross layered [15] which combines the MAC layer and the routing layer in 2004. Suh C. took a MAC-CROSS protocol[16] for energy efficient. Kong I.Y incorporated PHY+MAC+Routing Scheme[17] by considering the power control in physical later, the scheduling in MAC layer, and the overhead in routing layer. S-MAC [12][13] is an energy efficient protocol but it introduces significant delivery latency and provides poor traffic throughput. RMAC[14] aims to avoid these problems by exploiting the cross-layer information without sacrificing energy efficiency. It uses a setup control frame to establish a multihop route and schedule the upcoming data packet delivery along the route. No matter which schemes we take, our purpose is to transmit the more data with less energy. But the nodes beside the base station have longer schedules than the other nodes. So it is necessary to take an energy efficient cross-layer scheme for avoiding confliction, decreasing the idle listening and averaging the energy consumption of the nodes closer to the base station. Leishu Dong et. al [11]showed that cross layer clustering approach would save energy but here only routing with schedule was considered without focusing on MAC layer which is very much important in energy consumption. In our approach, cross layer (MAC+Routing Scheme) clustering impact was investigated to observe the energy consumption without giving up other attributes of the efficient design of sensor network.

3. Proposed Crosslayer approach

In our proposed approach, MAC Protocol and routing are combined to reduce data moving between them. The MAC Protocol S-MAC is used in wireless sensor networks in which mobile node execute both receiving and sending of MAC frames at the same interface. In [11], IEEE 802.11 DCF protocol is used as MAC protocol with cross layer approach better results are obtained. Since IEEE 802.11 DCF produces RTS and CTS frames which consumes less energy. The same cross layer approach is used with S-MAC protocol and avoiding data movement between MAC and network layer. Every node must perform data movement between NIC (Network Interface Card) memory and host memory twice and looking up the routing table frame de-capsulation and encapsulation. The network layer decides the address of next hop. These operations consume a lot of resources of node such as processing time, memory and energy. But still packets have to be delivered to the desired destination using minimum energy. In [10], a clustering approach is used to find the nodes nearer the Base Station (BS) which work in a longer time, and consume much energy. In this condition, nodes near BS will exhaust their energy in a short time. The nodes far away from BS in one hop are considered, and the nodes wake up randomly in a period, time-synchronized sensors form on-off schedules that enable the sensors to be awake only when necessary.

To minimize processing delay between layers, packet is not required to send data twice through same interface. The packet decapsulation of the network layer header is done at MAC layer. Only a portion of network layer header is sent to the network layer to process and establish a route while allowing data frames to resides in NIC memory itself. All the nodes in the network need not have to move the data packet between the MAC and the network layer. Step involves when a MAC layer gets a data frame, it checks the MAC destination

address field in the frame and finds out whether it is intended to it or not. If the data frame belong to it, then it store the MAC frame and removes the MAC header to further examine it. MAC layer itself removes the network layer which is supposed to be done by the network protocols at network layer. Instead of sending complete data frame, only network layer header with destination address is sent to help in finding the next hop address and then transferring next hop MAC address to the MAC layer. Now, MAC layer encapsulates a new frame with next hop address and the data frame reserved in NIC memory. Thus, we can reduce the amount of data moving between layers, processing time and end-to-end delay.

Once after finding the next hop the packets have to be routed through nodes to the desired destination. In wireless sensor network, the route must be chosen before transmitting the packets, and choosing the correct route is the first phase using cluster approach. Sensor nodes dynamically create on-off schedules in a way that the nodes will be awake only when needed and asleep the rest of the time. This can be done in two distinct phases in routing. 1. The setup and reconfiguration phase. The phase takes place during the initializing of the network. And it is shorter in comparison to the steady phase. The routing failure may be happened because of the impact of the external environment. It is necessary to reconfigure the route when it fails. The goal of this phase is to set up the schedules that will be used during the steady state phase and the setup phase corresponds to writing the routing tables. 2. The steady state phase. It takes place between consecutive setup and reconfiguration phase. In this phase, the nodes will transmit the data steadily. Wireless sensor networks are application-oriented. In some applications such as audio and video monitoring, the amount of data needs to be transferred is very huge. The data field in MAC frames will be large too. At the same time, these applications are usually real time applications. Thus, this approach is helpful for these applications. As suggested in [11], we have included the efficient S-MAC protocol and cluster approach for minimizing processing time and energy consumption.

4. Simulation Setup and results

The performance of cross layer cluster approach is evaluated using NS2 discrete simulation[20]. The setup consists of a test bed of 25 nodes randomly deployed in a area of 1500 m^2 x 1500 m^2. Out of 25 nodes 10 nodes are considered to be one hop away from the base station. The MAC protocol S-MAC is incorporated into CLD-SMAC (Cross Layer Design S-MAC) and consume energy for reading, writing and comparing a bit. As processing time increases, energy consumption also increases. Processing delay include header processing, data movement between layers and routing table lookup. In addition, it is helpful to use cluster approach for routing data between the nodes whose residual energy is greater. The simulation parameters are listed in the Table 1.1.

Table 1.1 Simulation Parameters

Number of Nodes	25, 50, 75, 100
Simulation Time	60 seconds
Initial Energy	1000 joules
Transmit Power	3.0 Watts
Receive Power	2.0 Watts
Idle listening Power	0.04 Watts
Number nodes one hop near to BS/total nodes	10/25, 20/50, 35/75 and 45/100
Transmission Range	25 meters

The primary purpose of our simulation is to evaluate the node processing delay and end-to-end processing delay of CLD- SMAC. We establish UDP connection between source node and the base station. At 1.0s, udp packets are sent to the base station from source node. The size of the packet is 50 bytes. We assume that the period is 5.0s, so the sensor network needs to work for 10 periods and the number of the nodes closer to the base station is 10. The simulation result is shown in the figure 1. Figure shows that the performance of Cross Layer Approach is better than the single layer approach.

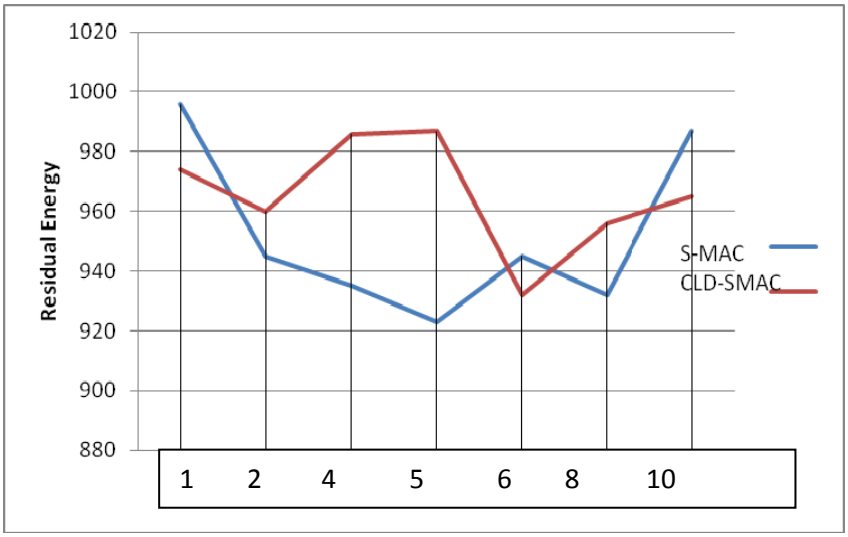

Figure 1. Residual Energy of each node which is closer to Base Station

Every node in the network is capable of forwarding traffic to any destination and always it tries to find a best route to every packet. The cross layer cluster approach not only helps to route in best path, it also saves energy which is depicted in the figure 2. In this scenario a network with 25 nodes randomly distributed along with 10 nodes placed one hop away from the Base Station. The length IP header is 20 octets with packet length of 1156 octets which is the average value between 0-2312. As discussed earlier the header processing is done in the MAC layer and header information is sent to network layer to find the address of next hop.

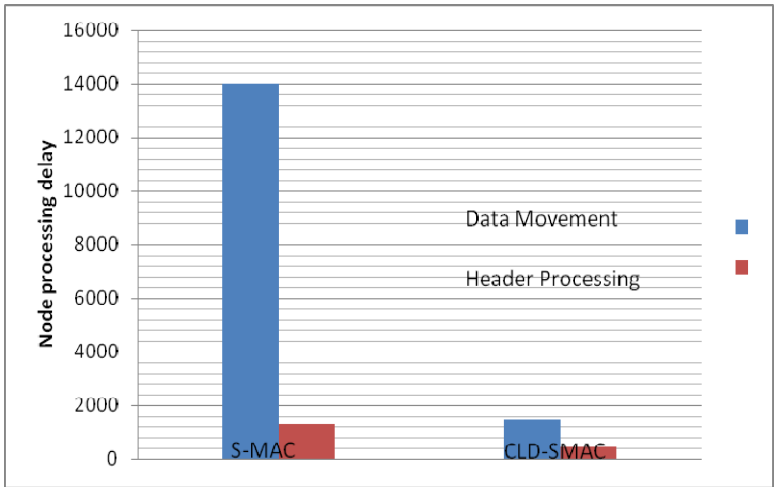

Figure 2. Node Processing Delay for S-MAC/CLD-SMAC Protocol

Figure.2 presents the nodal processing delays of S-MAC and CLD-SMAC, it is obvious that CL-SMAC outperforms S-MAC in terms of the nodal processing delay. Thus, it is desirable that the energy efficiency of CLD-SMAC will be better than that of other MAC protocols

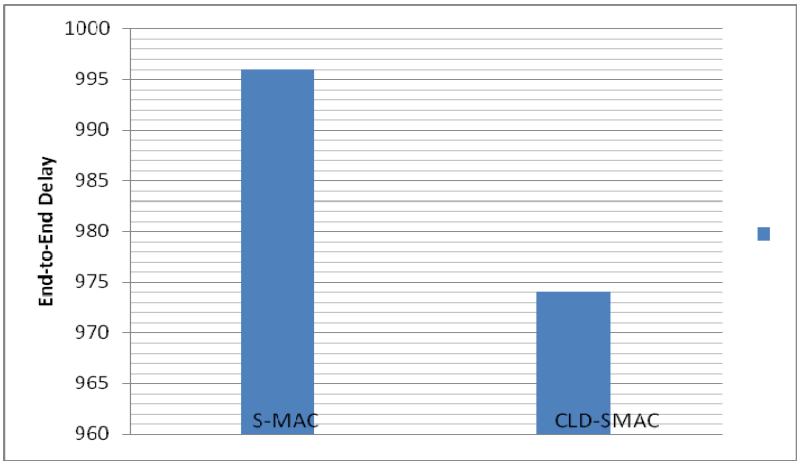

Figure 3. End-to-End Delay for S-MAC/CLD-SMAC Protocol with 50 nodes

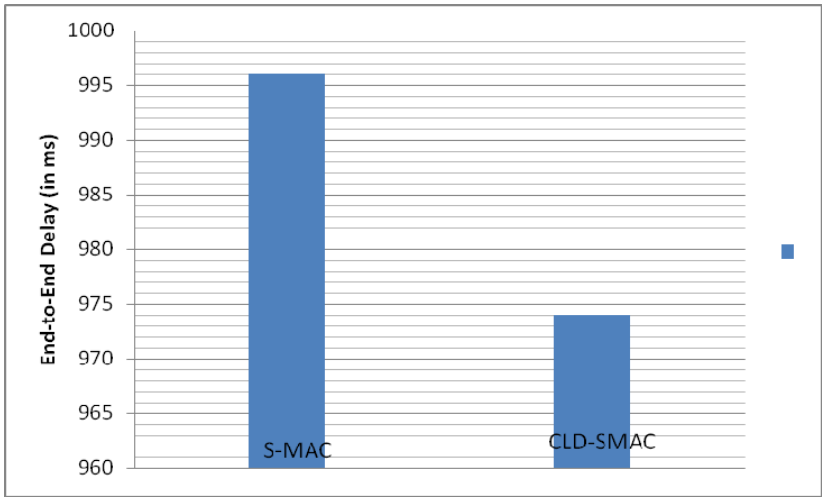

Figure 4. End-to-End Delay for S-MAC/CLD-SMAC Protocol with 100 nodes

From Figure 3 and Figure 4, It is very clear that CLD-SMAC out performs in terms of the end-to-end processing delay for 50 and 100 nodes. We can see the improvement when the network density changes.

5. Conclusion

There are various MAC layer protocols proposed for sensor networks. Many schemes have improved the existing MAC protocols and routing algorithms to extend the lifetime of wireless sensor network. In wireless sensor network, node energy has become a key problem and interesting research area. The routing path could be chosen depending on network layer protocols. The data moving, however, causes a portion of energy consumption that can not be neglected for each packet transferring. We propose an energy efficient cross-layer cluster scheme for prolonging lifetime of wireless sensor network by integrating S-MAC MAC Protocol. Through averaging the energy the nodes consume and reducing the idle listening and minimizing collision, the goal of save energy consumption is achieved.

The simulation results show significant improvement regarding the nodal processing delay and the end-to-end processing delay and also we have proved that the proposed scheme is feasible to the sensor network. Results show that there is a good progress in energy saving through processing delay and finding out residual energy for the entire sensor network. The performance of proposed cross layer cluster approach shows better

results than before compared with S-MAC. In this direction, there are open research problems on optimizing energy consumption through cross layer approach with different protocols for Wireless Sensor Networks.

6. References

[1] I.F. Kyildiz, W. Su; Y. Sankarasubramaniam, E. Cayirci, "A survey on sensor networks," IEEE Communications Magazine, Vol. 40, Issue 8, pp.102 - 114 , Aug. 2002.

[2] Demirkol, C. Ersoy, F. Alagoz, "MAC protocols for wireless sensor networks: a survey," Communications Magazine, IEEE. Vol. 44, Issue 4, pp:115 – 121, April 2006.

[3] W. Ye and J. Heidemann, "Medium Access Control in Wireless Sensor Networks," USC/ISI technical report ISI-TR-580, October 2003.

[4] C. Schurgers,V.Tsiatsis, M.B. Srivastava, "STEM: Topology management for energy efficient sensor networks," IEEE Aerospace

[5] Conference Proceedings. Vol. 3, pp:3-1099 - 3-1108, 2002

[6] W. B. Heinzelman, A. P. Chandrakasan, S. H. Balakrishnan, "An Application-Specific Protocol Architecture for Wireless Microsensor Networks," IEEE Transactions On Wireless Communications, vol. 1, pp.660-670, October 2002

[7] W. Ye, J. Heidemann, D. Estrin, "Medium access control with coordinated adaptive sleeping for wireless sensor networks". IEEE/ACM Transactions on Networking. Vol. 12, Issue 3, pp.493 – 506, June 2004

[8] G. Lu, B. Krishnamachari, C. S. Raghavendra, "An adaptive energyefficient and low-latency MAC for data gathering in wireless sensor

[9] networks," Proceeding of the 18th IEEE International Parallel and distributed processing symposium, 2004

[10] T. V. Dam, K. Langendoen, "An adaptive energy-efficient MAC protocol for wireless sensor networks," Proceedings of the 1st

[11] international conference on Embedded networked sensor systems, pp. 171 – 180, 2003

[12] X. Shi; G. Stromberg, "SyncWUF: An Ultra Low-Power MAC Protocol for Wireless Sensor Networks." IEEE Transactions on Mobile

[13] Computing, Vol. 6, Issue 1, pp.115 – 125, Jan. 2007

[14] Yanping Yu, "A Cross Layer Approach for Energy Efficient MAC Layer in Wireless Sensor Networks", Proceedings of the IEEE conference, pp. 1-3, 2008

[15] Leishu Dong et. al "An Energy Efficient Cross-Layer Clustering Scheme for Wireless Sensor Network", Proceedings of the IEEE conference, pp. 2010

[16] W. Ye, J. Heidemann, D. Estrin, "Medium access control with coordinated adaptive sleeping for wireless sensor networks". IEEE/ACM Transactions on Networking. Vol. 12, Issue 3, pp.493 – 506, June 2004

[17] W. Ye, J. Heidemann, D. Estrin, "An energy-efficient MAC protocol for wireless sensor networks,". IEEE INFOCOM, Vol.3, pp.1567-1576, June 2002

[18] S.Du, A. Kumar, S. D.B. Johnso, "RMAC: A Routing-Enhanced Duty-Cycle MAC Protocol for Wireless Sensor Networks," IEEE INFOCOM, 2007.

[19] Van H L,Nieberg T,Wu J,et al. Prolonging the lifetime of Wireless Sensor Networks by Cross-layer Interaction. IEEE Wireless Communication,2004.

[20] Suh C,Ko Y B,Son D M,et al. Energy Efficient Cross-Layer MAC Protocol for Wireless Sensor Network. Proceedings of the APWeb 2006 International Workshops.

[21] Kong I Y,Hwang W J. Lifetime Maximization by Cross-Layer Interaction in Wireless Sensor Networks. Proceedings of the 8th International Conference Advanced Communication Technology.

[22] Tarun Banka, Gagan Tandon, Anura P. Jayasumana. Zonal Rumor Routing for Wireless Sensor Networks. Proceedings of the International Conference on Information Technology: Coding and Computing (ITCC'05).

[23] Sooksan Panichpapiboon,Gianluigi Ferrari,Ozan K.Tonguz. Optimal Transmit Power in Wireless Sensor Networks. IEEE TRANSACTIONS ON MOBILE COMPUTER,VOL.5,NO.10,OCTOBER 2006.

[24] NS2 Network Simulator. www.isi.edu/ns/nsnam