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ENERGY MANAGEMENT IN WIRELESS SENSOR NETWORKS: CROSS LAYER APPROACH BRIEF REVIEW

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***Abstract*— Wireless sensor network represents a tremendous technology that attracts more and more considerable research attention in recent years. It has emerged as a result of recent advances in low power digital and analog circuitry, low-power RF design and sensor technology. The important drawback of the sensor network are the limited resources therefore hard energy constraints are presented in the network. The efficient utilization of energy has an important role in WSN. Since all layers of protocol stack architecture affect the energy consumption, exploiting interaction between these layers by a cross layer design will result in an efficient energy utilization of the network. In this paper we have discussed about the comparative analysis of the various cross Layer Design protocols.**

***Index Terms*— Cross layer interaction, Energy management, Wireless Sensor Networks.**

I. INTRODUCTION

Since wireless sensor networks have a large number of application they have been research topic for many people from area of telecommunication, electrical engineering, computer science, biology and medicine. The reason behind this rise is that the rapid growth in wireless sensor networks characteristics. The major limitations of sensors are less energy resources, mobility, computational capacity and memory[1]. The open system interconnection model along with these extreme limitations completely reduces network performance and life time, although consume more amount of energy. Network lifespan is an important concern in WSN due to the fact that each node has a limited energy, so the researchers have made some modification to the OSI model regarding with their necessities. Normally optimization of single layer in OSI are take into account, but in design called cross layer design ,two or more layers are taken combined for optimization of network characteristics. Collision, control packet overhead, Idle listening, overhearing and high transmission power are the major source of energy wastage in wireless sensor networks. Collision occurs when two or more node transmit the data at same time with in their transmission range. Collide packet become corrupt and requires retransmission, this will leads some energy consumption and then reduces useful data transmission. Another source of energy consumption is the Idle listening, which means listening to possible traffic when there is no transmission occur. Overhearing is another problem which causes energy wastage which means a node takes up packet that are destined to other nodes. High transmission power also leads to energy wastage.

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II. CROSS LAYER DESIGN OVERVIEW

Cross layer design is a method which can widely be used to improve the overall performance of WSN by exploiting the interactions between various layers of the network protocol stack [2].The main characteristics of Cross Layer design is that, it would take the inter-dependencies between different network layers to get optimal response for different network parameters like Network lifetime, throughput, latency or energy efficiency. A cross layer interaction among different layers such as physical, MAC, network and application layer provides efficient use of limited network resources in an effective way and then improves energy efficiency [3]. Moreover, many WSN applications that cannot be exploited sufficiently in a strictly layered design. For example, the time-varying link quality allows opportunistic usage of the channel, cross layer design performed best in all these cases. The new era of communication requires multiple packets send/receive at the same time. This can also achieved by using cross layer design in communication protocol. In addition, cross layer architecture added the increased quality of service to heterogeneous applications in WSN as compared to layered architectures. Various cross layer designs have been presented here in terms of possible interactions among the Physical, MAC, Network and higher layers.

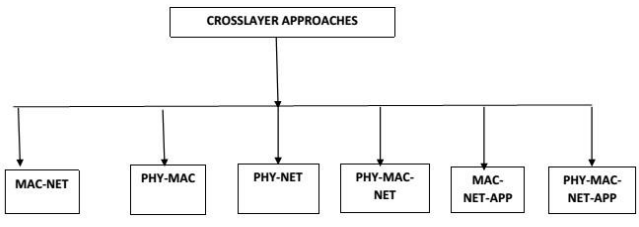

Figure1. Cross Layer Approaches

A. MAC and Network Layers

The interactions between the MAC and Network layers are mostly used in wireless sensor networks and in such

mechanism a joint scheduling and routing mechanism is used to form on-off schedules for data flow in a network where the nodes are not kept active for the entire time. In the following various cross layer approaches which use interaction between MAC and Network layer are presented.

An integer linear program (ILP) model for energy efficient distributed schedule based (EEDS) protocol is proposed in [4]. The ILP model is checked through extensive numerical examples and these results have been combined with the EEDS which is the best method for constructing jointly a routing and a schedule for WSN. The proposed method provide the increased network life time. In [5], a cross layer sleep scheduling based approach called sense sleep trees is proposed. Two sensor nodes are assigned to a fixed number of access trees on a given mesh based wireless sensor network topology, then an iterative algorithm based on a greedy depth first bottom up method is proposed for maximizing monitoring sensitivity in the sleep scheduling. A MAC layer implicit acknowledgement scheme is also suggested here. The proposed method provide increased network life time and excellent power management in Wireless sensor network. A cross layer protocol called MERLIN (MAC and efficient routing integrated with support for localization) that integrates both routing and MAC features is presented in [6]. It employed a multicast upstream and downstream method to relying packets to and from the gateway. Comparison between proposed protocol and joint usage of both SMAC and ESR routing protocol were discussed. The advantages are less latency and increased life time. In [7],An enhanced cross layer protocol for WSN is discussed. Medium access control and routing protocols are considered as the cross layer protocol. For improving energy efficiency and solving the end to end delay problem, the proposed scheme utilizes asynchronous medium access control scheme by using the adaptive duty cycling technique, also a tree based energy aware routing algorithm is used in ECLP to increase the network lifetime. The proposed method didn't considered the traffic conditions in the network. A unified cross layer protocol which replaces the entire traditional protocol architecture is developed in [8]. The basic principle used here is that both the information and the functionalities of communication layers are combined in a single protocol. For performing efficient and reliable communication in WSN a new concept of initiative determination is introduced here. Based on this idea, local congestion control, distributed duty cycle operation and received based contention is performed in the cross layer protocol. The proposed method outperforms in terms of both implementation complexity and network performance. In [9], Significant energy saving have been achieved at the network layer by distributing traffic generated by the sensor nodes to multiple path rather than giving to the single path. By controlling the retry limit of retransmission over each wireless link energy conservation is achieved at the MAC layer. Proposed protocol provide the extended network life time. For achieving the energy efficiency in WSN, a cross layer protocol that combining medium access control and network layer are discussed in [10]. Combining Adhoc on demand vector (AODV) in the network layer along with IEEE 802.11 protocol in the MAC layer are performed in [11]. Since single buffer is used for processing data at all layers, a delay occurred between the upper layer and lower layer. When the packets needs not to be processed further energy wastage performed there. Providing access of the routing table to the MAC layer from the network layer, more efficiently the scheduling can be performed as well as provided significant energy saving. Comparison between the proposed protocols with SMAC is also discussed. In [12], an iteration algorithm is proposed for solving the mixed integer convex optimization problem in which each iteration solved a convex optimization problem. The simulation results that have shown the importance of cross layer design in energy limited networks also discussed the advantages of load balancing, multi hop routing, interference mitigation and frequency reuse in maximizing the network life span. A power controlled MAC called cross layer power alternative MAC (CL-MAC) is presented in [13]. The framework mainly concentrated on energy efficiency and packet collision free WSN. Here data packet have two different power level rather than one fixed value. For choosing appropriate power level to sending data packets a power alternative scheme is discussed. In [14], a routing table based transmission method is used for providing energy savings, collision avoidance and less time delay. The RTS/CTS/DATA/ACK frame is formed to adapt the cross layer scenario and the power alternative scenario. The proposed framework outperforms when compared with the SMAC and PCSMAC from transmission power of nodes to time delay. The authors presented a cross layer optimization of low power listening MAC protocol for WSN [15]. Here proposed a cross layer improvements for MAC protocol that use LPL. High level information of the application is considered for computing the adaptive delays in every sensor node through a multi hop path. Delay based model evaluated at different scenario and compares it with the LPL model and then verified that a delay based model achieved more synchronization. In [16], cross layer design for adaptive data reporting design for WSN is presented. For providing an adaptive quality of service it balances the application requirement and resources. Two cross layer methods are used here. For the routing scheme an optimal route to the data sink is selected and slots for a single node per block can be selected for MAC scheme. RMC, an energy aware cross layer data gathering protocol for wireless sensor networks is presented in [17]. The basic idea is to reduce the overhead caused by managing the transmission schedule by integrating routing, MAC and clustering protocols. RMC is location based protocol and simulation is done under strictly determinate conditions which may not be easy to subject in real sensor networks. In [18], a cross layer protocol is developed for indoor application. For tracking the movement of a mobile entity the proposed protocol is used. According to the movement of the entity the current position is displayed on web page. By using the routing and time synchronization protocol used, the traversed path of entity can also be calculated. Significant energy savings and prolonged lifetime is provided by this protocol by adding a protocol control layer in the protocol stack. By introducing the queries at the base station a proactive and reactive reapplication routing scheme is established in [19] for dealing the messages in the network. The presented framework can be used for a plenty of applications. For improving the energy efficiency in underwater sensor

network a cross layer protocol called cross layer VBF (CL-VBF) proposed in [20]. The author starting with a discussion about major design challenges in UWSN then cross layer design method is provided as a one of the solution for energy conservation. Various routing protocol for UWSN named focused beam routing(FBR),information carrying routing protocol (ICRP), vector based forwarding(VBF),protocol are used. Some MAC protocol called ALOHA, DACAP, PT-MAC and B-MAC also presented. Here VBF protocol at the routing layer and B-MAC at the MAC layer are considered for proposed protocol. Various performance metric such as packet size, packet delivery ratio, over all energy consumption, total end to end delay are evaluated and founded that the proposed protocol have obtained the increased performance in all this cases. A cross layer protocol for surveillance application is introduced in [21]. The proposed protocol decreases the power consumption due to over hearing and delay for forwarding packets. Each sensor node performs periodic synchronization phase during the deployment state. Before forwarding the packet to the other node each sensor node updates ring identification field in the packet. The protocol creates a ring identifier for that purpose. Based on the stochastic queuing model in realistic channel environment a cross layer framework is developed in [22]. It starting with an investigation in end to end delay distribution in multi hop WSN. The framework works based on the heterogeneity present in the network. For evaluating the performance of the framework a case study with Tiny OS CSMA/CA MAC protocol is formulated. Relation between end to end delay and network parameter are founded here. Significant energy savings is the best advantage provided by this protocol. In [23], proposed a cross-layer protocol called RSSI-based Forwarding (RBF), which was based on a Received Signal Strength Indicator (RSSI) as a routing parameter for multi-hop WSN. Here without using prior knowledge of nodes geographical locations and without maintaining neighborhood routing tables the next-hop node for data-forwarding task is determined. Received power levels are computed for each sensor node in the network when a beacon signal is transmitted by the sink, decision parameter for the nodes to contend the forwarding task of the data packets, these power level are used. A cross layer protocol for improving channel utilization is presented in [24]. Here the whole network is divided into several cells. Contention based CSMA and contention free TDMA are used for dealing the inter cluster communication. When the networks are under high traffic TDMA is used and CSMA is used under lower traffic condition.

B. *Physical and MAC Layers*

Energy efficiency and throughput can be achieved using the cross layer interaction between physical and MAC layers. By applying Energy efficient communication protocol in MAC layer can reduce packet overhead, congestion and there by energy consumption. Using low power modulation schemes in physical layer can reduce the energy consumption. In the following different cross layer protocol which uses interaction between physical and MAC layers are presented.

In [25], authors presented a cross layer approach for realizing dynamic and robust data aggregation in wireless sensor networks. For supporting upper layer data aggregation operation a specially designed MAC protocol called DA-MAC is proposed here. Based on the channel content status obtained from DA-MAC, sensor node determine where and when the aggregation is performed, and sensed out the data. The main advantages are less energy consumption, communication cost and time cost. For reducing packet losses duplicate insensitive aggregation with multipath routing also proposed. A novel cross layer design for multichannel non persistent CSMA is presented in [26]. The method combines adaptive modulation and band width partitioning at the physical layer and adaptive back off at the MAC layer. The energy efficiency is provided by the joint optimization of modulation order and back off probability. Significant energy can be saved by performing cross layer optimization of the entire protocol stack in WSN, but this work faces many difficulties due to some complexity constraints presented on the WSN nodes. In [27], author presented a simplified energy conservation mechanism for WSN. Here a physical layer model is used to check the effectiveness of the cross layer optimization .it is done by adding multiple access interference as a new parameter in the model. By including the MAI in the model the physical layer link reliability considered the effect of network traffic and MAC algorithm behavior. The star topology is used here. By minimizing the transmit power between the nodes and cluster head the CLPC algorithm minimizes the overall energy consumption in the network.one drawback of this technique is that the implementation has significant results only when it performed in a lower number of nodes. For achieving high energy efficiency and low latency in WSN a modified MAC protocol is presented in [28].There is no separate time frame for synchronization and data traffic in this framework. The channel contention is included in contention period rather than listen period. The transmitter only wake up in this contention period and non-transmitters bypasses the same. Adaptive duty cycling and short listen period is achieved from this proposed work..

C. *Physical and Network Layers*

Interaction between physical and network layer can reduce many problems in wireless sensor networks such as congestion, load balancing, routing and bandwidth allocation problems. Here various cross layer approach are presented which is formulated by using interaction among physical and network layers.

A novel flooding algorithm that can significantly reduce the number of broadcast packets and collision is proposed in [29]. The proposed method used the signal strength and counter for received duplicate packet as cross layer parameter. Various broadcasting methods are discussed here. They are mainly two types; the first one is flooding using location information which includes distance based method and the second one is flooding without using location information. Probabilistic algorithm, counter based algorithm and neighbor knowledge based algorithm are included here. The framework replaces the location information by signal strength. Based on the received signal

strength each receiver node determine the distance from the sender and there by calculates the back off delay in reversely proportional to the distance. The number of duplicate packets have larger number than the threshold, the packet is dropped. Less collision and high packet delivery ratio are the main advantages. Drawback of this work is the presents of fading in the network. The simulation results shown that the proposed algorithm reduced the delay about 100 milli seconds compared with other designs. The algorithm presented in [30] used for selecting the correct path from the largely available multipath in the network for send the data to sink node. They have then estimated a quality of source parameter for each node in the network. According to this parameter they have calculated the energy consumption, delay and priority of the packet in the network. The simulation results shown that the proposed algorithm acquired the significant extension in the life time. For solving routing and bandwidth allocation problem a cross layer protocol is formulated in [31] have obtaining a trade-off between the energy and throughput. For achieving this, included a parameter called network utility in the framework. The quality of service requirement is achieved by the service provider through this way. Traffic flow assignment and routing tree construction is used for optimizing the network utility. For improving network throughput for multi hop wireless networks a cross-layer optimization is presented in [32]. The throughput optimization problem can be divided into two sub-problems that is multi-hop flow routing at the network layer and power allocation at the physical layer. Data flow rates at each link is depend on the link capacities and radio power level at each node. The power allocation problem is based on the interference as well as the link rate. Here power control and the routing are performed in a distributed manner.

D. Physical, MAC and Network Layers

Throughput, reliability and energy efficiency of a wireless sensor networks can be improved by using the interactions between physical, MAC and network layer. In the following different approaches of cross layer designs are discussed.

Co-operative communication is integrated with a cross layer optimization model is discussed in [33]. MAC routing and physical layer protocols are used as a cross layer parameters. The method applied in two levels, a PER constrained power allocation algorithm is proposed at the per hop level and a cross layer power optimization problem is formulated and solved at the network level. The proposed method achieves both power savings and energy efficiency. In [34], an energy efficient access control algorithm with cross layer optimization in WSN is discussed. For minimizing node energy consumption, proposed a wireless sensor network access control algorithm. Depends on the slotted ALOHA protocol, this algorithm integrates the transmitting probability of MAC layer, power control of physical layer and the automatic repeat request of link layer. Transmitting power level and transmitting probability is calculated theoretically and the relationship between energy usage per bit and throughput per node is determined. The presented algorithm outperforms in terms of energy savings when compared with the traditional layered design. An energy optimization protocol based on cross layer for WSN is presented in [35]. The joint optimization of physical, MAC and routing layer is performed. The main concentration of EOA is on the computation of optimal transmission power routing and duty cycle schedule that increase the WSN energy efficiency. For computing the transmission power level between nodes a feedback algorithm is proposed. Considering transmission power as a metric the routing protocol selects appropriate route for forwarding packets. At the end cross layer routing information is used to form a duty cycle schedule in MAC layer. For improving the intrusion detection identification performance the author presented a cross layer protocol in [36]. Based on quantized data reputation the proposed method integrates genetic algorithm, anti-phase synchronization, ant colony optimization and a trust at the physical, MAC and network layers. Optimal schedule of transmission frequencies is obtained by applying genetic algorithm at the physical layer. Collision free transmission scheduling is provided by anti-phase synchronization at the MAC layer. Scalability is one of the drawback of this approach. For obtaining intrusion resistant routing among the nodes , ant colony optimization is applied at the network layer, here the ants are act as a mobile software agents which study the behavior of the network and then determine the effects caused by the intrusion. Both network and environment changes are taken for evaluation. For obtaining the uncertainty in aggregation results a trust model is used here. Because of using bio inspired routine for sensor data and aggregation results are suboptimal the cryptographic technique can be avoided here. Based on the collision degree and energy level routing adjustments are performed in [37] called collision aware routing protocol (CARP). Energy level is calculated by using initial energy and residual energy. The ratio of initial energy and sum of initial energy and residual energy gave the energy level. The protocol deals route discovery and maintenance in an on demand way by taking collision related information from each layer. A cross layer scheme called CLB (Cost link Based) for Routing is proposed in [38]. For improving network lifetime proposed protocol uses multiple paths between sensor node and sink node, thereby balances the traffic inside wireless sensor network. Based on network topology link distance can be calculated and link cost highly depends on cross layer design that neglects the paths with nodes, having limited energy than specified threshold. A Cross Layer Energy Efficient Routing Protocol called XLE2R in [39] which gives cross layer interactions in between PHY, MAC and the Network Layer, proposed protocol mainly concentrating the extension of network life time. Routing decision, which is made with the knowledge of the source and the destination node are taken in an energy efficient way. For finding the location of the destination node, the protocol divided into three phases which are route finding, route maintenance and route re-establishment. Presented protocol compared with traditional algorithm DRS. The simulation results shown that proposed work provided an increased lifetime. In [40], Efficient Cross Layer Design Adaptive Protocol (ECLAP) is proposed which considers the network, MAC and physical layer together

using cross-layer strategy in WSN. For reducing total energy dissipation, an optimal routing path is formed by exploiting the available transmission power and neighbor tables of the physical layer. The node's sleep time can increased by determining the nodes duty cycle by MAC layer which make of use of the routing information from the network layer. The simulation result shown that the network lifetime improved as much as 30 percent of the Life cycle of network with other protocol in low mobility scenarios. An Energy Optimization Approach based on Cross-Layer for Wireless Sensor Networks named as EOA was discussed in [41,which consider the joint optimal design of the physical, medium access control (MAC), and routing layer. The focus of EOA is on the computation of optimal transmission power, routing, and duty cycle schedule that optimize the WSN energy efficiency. They have first proposed a feedback algorithm that computes the proper transmission power level between nodes. Then, routing protocol can make use of the transmission power as a metric by choosing route with optimal power consumption to forward packets. Finally, the cross-layer routing information is exploited to form a duty cycle schedule in MAC layer.

E. MAC, Network and Application Layers

For avoiding congestion presence in WSN the authors proposed a cross layer protocol in [42]. The route selection process performed in an efficient way by considering all the nodes are aware about their congestion status and delay measurements. A congestion mitigation scheme is also discussed here. This is achieved by sending feedback by the MAC layer to the network layer. The application layer balances its traffic generation rate. By performing congestion avoidance and mitigation the proposed work improves a reliability of a network also provided reduced delay. In [43], the authors propose a cross layer design scheme for data reporting, which aims to balance application requirements and resources in order to provide an adaptive quality of service. For this proposal, two different cross-layer methods are utilized. For the routing scheme, new interfaces into the Network layer are required, such that an optimal route to the data sink can be chosen. For the MAC scheme, the application layer is designed to specifically interact with a TDMA MAC, such that slots for a single node-per-block can be chosen

F. Physical, MAC, Network and Application Layers

Based on the middleware in WSN the authors presented a cross layer protocol in [44] for the quality of service support. The main aim of this proposed work is to achieve quality of service requirements by reducing the energy consumption in WSN. For achieving this aim the author formulated a framework that consist of three main parts called quality of service antology, quality of service agent and sensor node quality of service protocol stack. The quality of service protocol stack again divided into two shared data bases across physical, MAC, network and application layer. The framework can be adapted in any WSN. For reducing the effects of the propagation conditions in power system a cross layer protocol for cognitive radio communication is proposed in [45]. Switching between different spectrum bands while considering channel environments for finding a channel with low noise signal. To support various quality of services, a suboptimal distributed control algorithm is used here. Maintaining the source of existing flows by conforming the availability of resources, a flow control is used in the work. On demand routing action data scheduling is also formulated to ensure the data delivery in the network. The delay can be reduced in an approximate value of 20ms through this protocol.

III. CONCLUSION

Energy management is an important issue in WSN. Cross layer interaction provide good performance than the single layer protocol stack. In this paper various cross layer approaches are reviewed. The literature shown that MAC layer is a common part in most of the design and also MAC-Routing schemes provide better results over their counterparts in terms of energy management.

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