Cross Layer Energy Optimization Methods in Wireless Sensor Networks: A Review

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Abstract— **The energy consumption at various protocol layers in Wireless Sensor Network affects the survivability and lifetime of nodes in the networks and hence much attentions is given by the researchers. Because of this, several approaches focuses their studies to the challenge of energy consumption. Many researchers are working on cross-layer techniques to optimize energy and other resources to increase lifetime. In Fact, related to their axes of researches, the scientists are more specified in precise area training the energy which gives rise to several approaches that aim optimization of energy consumption of WSNs. In this survey, we focus on the Cross Layer energy consumption and optimization in WSNs.**

Keywords—CrossLayer, Wireless Sensor Networks (WSNs), Optimization

I. INTRODUCTION

Energy optimization is one of the most primary but decisive factor in determining the success of the of sensors and WSNs based applications due to many severe resource limitation such as the sensors size, power channel unavailability, and location inaccessibility and thus no further handling of sensor devices once they are deployed. Hence, many efforts have been made to minimize the energy consumption of WSNs and increasing the lifetime at different traditional levels and approaches. For example, Min *et al.* [1] aims to reduce the power consumption of sensor node at operating level, Alzoubi *et al*. [2] minimizes the energy consumption in the I/O operations at data transmission levels. Shah & Rabaey [3] works on topology and routing mechanisms. The basic aim here is to reduce the amount of power consumption of few components of the application by reducing the tasks to be performed by the sensors and the networks yet still fulfill the goal of the planned application.

As far as conventional techniques to save the energy, a vital aspect which needs to be investigated more deeply is the integration of the different approaches into a single workable solution. The most important problem with these approaches is that they may succeed in reducing the power consumption in one component of the overall WSN application, but this gain is often negated by an increase in the consumed energy in other components of the application. This causes characterizing the interactions between different protocols and exploiting cross-layer interactions.

Energy consumption may be influenced by all the layers of system design. The traditional layered architecture guides to independent design of different layers and it results in high architectural overhead. Cross-layer design approaches exploit interactions between different layers results in significantly improve energy consumption as well as adaptability to different service, traffic, and environmental variables. In this paper, few recent Cross Layer energy optimization techniques in WSN have been reviewed. The paper is organized as follows. In Section II, we list some motivational factors towards CL approach. In Section III, we discuss some cross-layer approaches in WSN. Section IV discusses some scope of future work in this area and the conclusion in Section V.

II. CROSS-LAYER OPTIMIZATION METHODS

Cross-layer design can include information exchange between different layers, adaptively at each layer to the information, and variety built into each layer to insure robustness [7]. Several studies have been conducted and are based on techniques from the literature.

Han *et al.* [8] proposed a CL location-based node-disjoint multipath routing should be 2-hop based but not 1-hop based to optimize the energy consumption at physical layer. The nodes have ability to control the transmission energy based on its residual energy. The work also focuses on energy-balanced dynamic sleep awake scheduling.

Cuomo *et al.* [9] has proposed a CL approach to deal with the problem of electing Personal Area Network coordinator on topologies formed with the IEEE 802.15.4/Zigbee. The work merges the network formed based on the datalink layer by the IEEE 802.15.4 standard with a topology reconfigure algorithm operating at the network layer. It has proposed a procedure to self-configure a IEEE 802.15.4/ZigBee WSN by electing, in a distributed way, a suitable Personal Area Network coordinator.

Catarinucci *et al.* [10] presented a cross-layer solution, based on the use of a duty-cycle protocol and a new active wake-up circuit. It validated by using a test bed approach which results in significantly reduces in idle listening periods.

Pinto *et al*. [11] has proposed CL Admission Control mechanism aims to increase network lifetime and the energy efficiency of a WSN in a grid topology. It avoids the transmission of the potentially not useful packets. The mechanism uses estimation mechanism to check information end- to-end latency and achieves a decision to accept or drop a packet if it is expected to fulfill or ignore the end-to- end latency deadline.

In [12], the authors have proposed a cross layer resource allocation approach for optimal image transmission quality while assuring energy efficiency. The work optimized across physical, MAC and Application layers regarding p-data and v- data distortion reduction correlations. It is an pixel- position information based resource allocation scheme to optimize wavelet-based coded image transmission quality which strict energy constraint for image applications in WMSNs by exploring these uniquely different importance levels among image data streams.

Dobslaw *et al.* [13] has designed an framework to configure a given network topology by added sink positioning which aims to build a backbone. The backbone with the help of gateway can guarantee the application based constraints in industrial WSNs. The specific constraints may include reliability, maximum latency constraints with demands priority.

Hosni & Ahmad [14] has introduced cross layer optimization that perform better interface between physical, MAC, network and application layers for Smart Grid End to End communication. The work results in improving the source-sink delay considering a cluster-based topology in Grid.

Kader *et al.* [15] has proposed an energy efficient adaptive cross layer scheme to for multimedia content over WSNs. It is based on packet size, channel queue, and path scheduling, so that it can select an optimal video encoding parameters based on current wireless channel state, and schedules packets. It helps in dropping of less important packets in case of network congestion

Approach by Cui's [16] takes into account both the power required for communication and the circuit power as the causes of power taken in small sensor networks., The approach considers power consumption to determine communication paths, link schedules, M-ary Quadrature Amplitude Modulation (MQAM) modulation rates and transmit powers that causes better energy optimization in the network.

A cross layer protocol is proposed [17] to achieve efficient routing, MAC and congestion control in a cross-layer manner. It provides a unified cross-layer approach that joins together functionalities of all traditional layers into a single protocol. The design of XLP is based on the initiative determination in cross-layer way. It permits receiver-based disagreement, forwarding, congestion control and distributed duty cycle operation to understand efficient and reliable communication in WSNs. The initiative determination requires comparisons against energy thresholds, and hence, is very simple to implement, on computationally constrained devices. This is the first protocol that joins functionality of all layers from Physical to transport into a cross-layer protocol.

Chen *et al.* [18] proposed a distributed energy-efficient and reliable routing protocol by jointly taking the routing algorithm in network and the power control policy in physical. Based on the analysis to construct a minimum-power route with the reliability constraint in WSN, a distributed cross-layer routing protocol with adaptive transmission power control is proposed.

In [19], the authors proposed a distributed cross-layer routing protocol with adaptive transmission power control which is based on the analysis to minimum-power route with the reliability constraint in WSN.

Table 1 provides a summary of the energy efficient cross-layer solutions in WSN.

Proposals	**Layers Involved**	**Concepts**
Han *et al.* [8]	Physical, MAC, and Network layer	Location-based node-disjoint multipath routing should be 2-hop based but not 1-hop based to optimize the energy consumption at physical layer..
Cuomo *et al.* [9]	Physical, MAC and Network layer	Deals with the problem of electing Personal Area Network coordinator on topologies formed in accordance with the IEEE 802.15.4/Zigbee.
Catarinucci *et al.* [10]	Physical and MAC	Based on the use of a duty-cycle protocol and a new active wake-up circuit. It significantly reduces in idle listening periods..
Pinto et al. [11]	Physical and Network	Admission Control mechanism designed to increase network performance and the energy efficiency of a WSN in a grid topology.
Wang *et al.*[12]	MAC and link layer	An image-pixel-position information based resource allocation scheme to optimize wavelet-based coded image transmission quality.

Dobslaw *et al.* [13]	Network and Application	Framework to configure a given network topology by added sink positioning which aims to build a backbone.
Hosni & Ahmad [14]	Physical, MAC, network and application	For Smart Grid End to End communication. The work results in improving the source-sink delay.
Kader *et al.* [15]	Network and Application	Can select optimal video encoding parameters based on current wireless channel state, and schedules packets.
Cui *et al.*[16]	Physical and MAC layer	Considers both causes of power consumption to jointly determine communication paths, link schedules, MQAM modulation rates and transmit powers.
Vuran & Akyildiz [17]	Physical, MAC, Transport, and Network	Joins all layers to give unified CL
Chen et al. [18]	Physical and Network	Based on the analysis to construct a minimum-power route with the reliability constraint in WSN, a distributed cross-layer routing protocol with adaptive transmission power control is proposed

Table 1: Cross-Layer solutions in WSN

III. SCOPE OF FUTURE RESEARCH

Some directions for future research are given next [21-23].
In the application layer, strict QoS parameters may need to be satisfied depending on the running application. But, this may affect the WSN lifetime, so further study is required to be carried out to confirm the behaviour of the used multimedia coder on the sensors energy consumption.
Also, all of the work at application layer is based on simulation and analytical, so work on real deployment is need to be investigated.
There is no agreement on the approaches for routing in WSNs. Some has considered clustered networks, others have considered flat routing, and also some has taken centralized routing. The number of sensors and distance between sensors affect the performance of each and every approach.
Mobility in sensors is rarely considered. The changing behaviour of network topology of energy constraint node is very difficult to manage. So, mobility issues must be considered in developing the routing protocols in WSN.
At network layer, Multiple-Input-Multiple-Output effects on routing protocols have not been verified, and spatial diversity has not been explored yet. Also, there is much scope of research in QoS routing as it requires shorter end-to-end delay and energy efficient routing.
Cross-layer approaches may reduce packet overhead on each of layers, and hence energy consumption reduced. The MAC layer can offer other layers with congestion control information and enhance route selection.
At physical layer, properly addressing the efficiency of the different modulation, transmission technologies and bandwidth choices may be considered in cross-layer design, and comparison between them is needed. They are directly related to the channel properties and energy consumption profile; they directly affect the parameters at the upper layers. Hence, there is still much to be done in order to achieve a comprehensive Cross Layer design.
Also, the future work for the research includes the investigation of various networking functionalities such as adaptive modulation, error control, and topology control in a CL fashion to develop unified cross-layer communication module nodes.

IV. CONCLUSIONS

In this paper, an overview of some recent work on cross-layer energy optimization in WSN is focused. These networks are very limited in power and resource. The power efficiency is important at all layers of the traditional stack. In the paper, the focus is on three important things for optimizing energy, routing, energy required and processing. In this context, some work on energy efficiency aimed to maximize the life of the system has been reported.

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