International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 08, August-2015

A Survey on Cross Layer Solutions for Routing in Wireless Sensor Network

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***Abstract* - Wireless sensor network is a fast emerging field and gain a lot of attention from the research groups. Energy efficiency is the main and a crucial factor in WSN because sensor nodes have battery support. To increase network lifetime, energy awareness is an essential consideration and routing is the main factor which affects the energy consumption. For this problem cross layer approach has been proven to be an efficient technique than traditional approaches. Thus, paper presents a survey on Cross Layer energy efficient routing solutions proposed so far and comparative analysis for the various cross layer routing. The three main categories for comparison explored in this paper are a type of routing protocol, cross layering used and technology used at each layer. Open issues in proposed routing methods using cross-layer are also discussed.**

Keywords- Cross layer, Energy efficiency, Routing protocol, Wireless sensor network

I. INTRODUCTION

Sensor networks consist of a large number of small sensor devices which are capable of taking various measurements of environment entity such as sound, pressure, temperature, vibrations and so on. Each of these devices is equipped with a small processor and wireless communication antenna and is powered by a battery making it very resource constrained. Typical in WSNs sensors communicate directly with a centralized controller or with satellites, thus sensors and controllers communicate on a single hop. Nowadays, a WSN could be a collection of independent nodes or terminals that communicate with each other by forming a multi-hop ad hoc network. Such WSNs could change their topology dynamically due to nodes mobility [1].

WSNs have several restrictions such as limited energy supply, limited computing power, and limited bandwidth. Energy efficiency has been considered one of the most important design challenges in WSN. In layered approach the transfer overhead is more which consume more energy. Due to these restrictions, cross layer design is evolved for WSNs. Cross-layer protocols do not follow the layered structure as a traditional OSI model follows. In the cross-layered approach, the protocol stack is treated as a system and not an independent individual layer [2]. The cross layer approach for WSNs is more effective than traditional approach. Cross layer approach states that information of two or more layers are used to achieve an optimal objective. The common goal of the cross layer approach in WSNs is to reduce energy consumption. In literature various cross-layer designs given as follows [16].

1) *New interface for information exchange between non adjacent layers*
2) *Merging of adjacent layers for joint functionality and reduced overhead.*
3) *Design coupling between layers*
4) *Vertical calibration between layers*

The rest of this paper is organized as follows. Section 2 explains how cross-layer communication is done for routing. In Sections 3 presents the various proposals for routing using cross-layer approach and classification. Section 4 contains open issues in proposal discussed and Section 5 concludes the paper.

II. CROSS LAYER COMMUNICATION FOR ROUTING

Cross-layer design is the most promising way to write energy efficient communication protocols. Traditional Communication protocols have significant overhead which results in high inefficiency. Goals of cross-layer optimizations in WSNs are reduction of energy consumption, efficient routing, QoS provisioning, and optimal scheduling [4]. Cross-layer design states that parameters of two or more layers can be retrieved and/or changed in order to achieve defined goals. In this paper focus is on one of the goal and that is efficient routing.

The central idea of cross-layer design is that by jointly optimizing the control and exchange of information over two or more layers, significant performance improvements can be achieved by exploiting the interactions between various layers of the protocol stack. However, the drawback to such a design is the potential to destroy modularity of overall system [1].

Fig. 1 shows the cross-layer concept for routing. At the physical layer, through channel estimation the instantaneous signal-to-noise ratio (SNR) of a link is obtained, and this is used to select the data rate, which affects the transmission delay. Then routing protocol at network layer makes a decision based on the delay associated with each link, which will then evenly spread the network load distributions across the available links. Thus cross layering optimizing the performance of the lower layers.

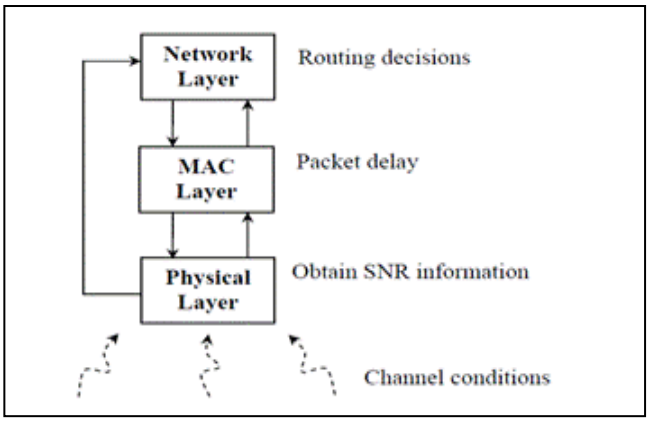

Fig. 1. Cross- Layer Communication for Routing [15]

III. ROUTING PROTOCOLS USING CROSS LAYER TECHNOLOGY

In this section, we survey the state-of-the-art routing protocols using cross-layer technology for WSNs. Routing protocols are having high impact on lifetime of WSN due to following reasons Firstly most of the routing protocols require the flooding of control packets to determine the routes, which induces an initial waste of energy. Secondly topology changes are very likely to occur because of nodes that leave the network due to energy depletion. Third is constant control messages exchange may be necessary to keep information about routes, which adds the transmission overhead and consuming sensors energy. Thus, from these problems it is possible to see that routing protocols for WSNs must be energy-aware and energy-efficient, adding the least overhead possible to avoid reducing the network lifetime to unacceptable thresholds [4]. In the rest of this section, we present a detailed overview of routing paradigms using cross-layer approach.

Saleem has proposed Cross Layer based Biological Inspired Self-Organized Routing Protocol in [3] for Wireless Sensor Network. The proposed self-organized system is mainly based on route section. The optimal route discovery is tackled by ACO (Ant Colony Optimization). In this proposed protocol energy level and link quality metrics are exchanged from physical layer to the network layer for discovering an optimal route. The algorithm is also capable of avoiding permanent loops which promotes dead lock problem in the running networks. The results clearly demonstrate the protocol's efficiency, better data throughput while minimizing the packet dropping over WSNs.

A new routing protocol has been defined by Zhang in [4] for cross layer channel-aware geographic informed forwarding protocol (CAGIF) by using CDMA as a medium access method. This protocol is a modification of GIF protocol. EAM (efficient-advancement metric) used in this protocol determines relay node position to reach next-hope towards destination node. CAGIF gives 50% less energy consumption and up to 4 times less overhead than GIF by using EAM and three positions (current node, source node and destination node).

Cluster Based Routing Protocol for Mobile Nodes in WSNs (CBR-Mobile) proposed by Awwad in [5], which is used to overcome challenges such as packet loss in parallel with energy consumption. In this paper, author uses cross layer design between medium access control (MAC) and network layer to overcome these challenges. The protocol utilizes the MAC layer and network layer to support mobility for sensor nodes and improve the packet delivery ratio in WSN. Hybrid MAC protocol is used to manage schedule-based and contention-based timeslots. The Author has shown that by using cross-layer design between MAC and network layers, 33% higher packet delivery ratio compared to LEACH Mobile Protocol is achieved.

Babulal has proposed Cross Layer Energy Efficient Routing Protocol XLE2R in [6] which gives cross layer optimization in between PHY, MAC and the Network Layer, Here XLE2R algorithm which depends on interaction from different layers in order to gain longer lifetime for sensor networks is proposed. The mechanism is based on routing decision, which is made with the knowledge of the source and the destination node. This protocol works in four phases and these are finding the location of the destination node, route finding, route maintenance and lastly route re-establishment. Authors have compared XLE2R with traditional algorithm DRS. As the mobile rate increases the lifetime of DSR changes because of the interface, but XLE2R can handle this situation and improve network lifetime.

For distributed wireless sensor network Babulal proposed Energy Efficient Cross Layer Cooperative Cluster (E2CLCC) in [7], which cross layering is in between MAC and network layer to improve the performance of the network. To conserve energy author take into consideration of remaining energy of the node in the selection of cluster head. In E2CLCC routing is done quickly this because of routing is dependent on the address of cluster heads and by failing any node in the route; its CH may use another node to forward packets. Author also proved that the proposed cooperative caching approach which integrates and adopts cross layering is an efficient way to reduce data query delay and improve data accessible in a WSNs compared to the simple caching scheme.

In the Cross Layer Adaptive Routing Protocol (CLAR) proposed by Chabala in [8], aims to minimize the use of routing control packets and minimizing energy consumption, which in turn prolongs network-lifetime. The author used two algorithms first is DSR and second is distributed route aware medium access control protocol for sensor network (DRMACSN) to propose CLAR protocol . Cross-layer adaptation framework allows to exchange of information between physical layer, MAC layer and network layer in WSN which is shown in Fig. 3

CLAR protocol takes advantage of the information available in the neighbor table maintained by DRMACSN protocol and uses channel quality indicator (CQI) the neighbor table for DRMACSN protocol has information about channel load and simultaneous transmissions (STx) per frame interval. CLAR protocol checks the current

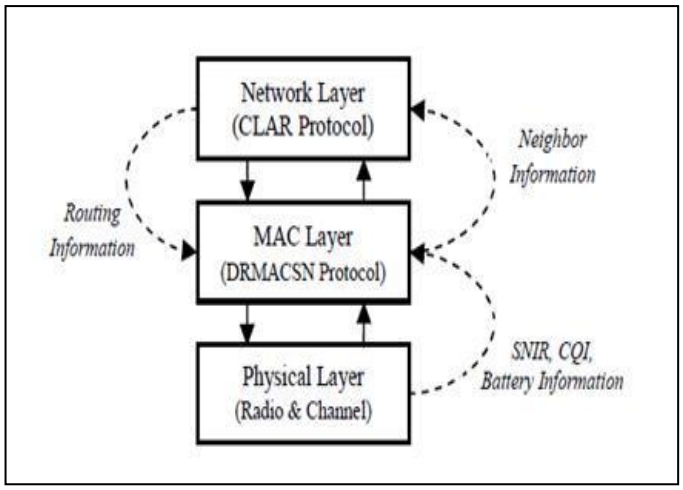

Fig. 2. Cross layer adaptive routing (CLAR) framework [8]

network status before sending any routing control packets.

Thus author proved that CLAR protocol is energy efficient by consuming less energy for same throughput in comparison with DSR protocol and also makes quick routing decisions by maintaining multiple routes to same destination [8].

Thaskani has proposed an energy efficient cross-layer design protocol by using token passing mechanism for WSN in [9]. Proposed energy efficient cross layer approach is designed of an innovative localization scheme to reduce the redundancy. Here author proves that Cross layer mechanism has better energy efficiency and also need less average number of redundant messages when compared to traditional leveling and PASCAL [9].

The New Improved LEACH protocol has been proposed by Gajjar in [10], which is the modification of basic Low Energy Adaptive Clustering Hierarchy protocol. LEACH is a cross layered protocol architecture that combines medium access with routing to collect and deliver data to BS. As in LEACH residual energy and distance of the node from the Base Station (BS) for the Cluster Head (CH) selection is not taken in consideration. Hence the author proposes an Improved-LEACH, in which residual energy and distance of the node from BS are used as parameters for CH selection. Thus, by results, author proved that ILEACH outperforms LEACH in terms of network lifetime, the amount of data transferred to BS against the time taken and energy consumed.

Boubiche has proposed a cross layer communication protocol in [11], which is an improvement of HEEP protocol and used to control the transmission power, and adjust dynamically the coverage of the radio antenna. Here interaction between network and physical layers is mainly exploited. Network layer sends the neighbor table and routing path information to Physical layer. Based on the routing path, sensor nodes reduce their transmission range to only communicate with their closest neighborhood due to which energy dissipation is significantly reduced, which improves the network lifetime. In results author shows the improvements made by our new protocol in terms of energy savings and network lifetime.

The Losningen cross layer approach proposed by Tangammal in [12], which aimed to maximize the lifetime of wireless sensor network. LCLA merged network layer and data link layer to provide retransmission, monitoring and tracking facilities for sensor network. At network layer traffic is balanced by AOMDV protocol and at the MAC layer, the retry limits of retransmission over each wireless link are controlled. Here traffic information from network layer is sent to MAC layer to adjust retry limits. Result shows that proposed model is able to reduce end to end delay and increase network's lifetime by controlling the traffic in the network.

Rani has proposed Efficient Cross Layer Design Adaptive Protocol (ECLAP) in [13], which considers the network, MAC and physical layer together using cross-layer strategy in WSN. The mechanism is adopted to save transmission power between the two nodes and maintain the nodes neighbors' tables interleaving to utilize the transmission energy efficiently. An optimal routing path is constructed by exploiting the transmission power available and neighbor tables of the physical layer to reduce the total energy dissipation. The node's sleep time is prolonged by determining the nodes duty cycle by MAC layer which make of use of the routing information from the network layer. The result presented in the work shown that the network lifetime increased as much as 30% of the Lifecycle of network with other protocol in low mobility scenarios.

Gao has proposed Cross layer Multihop Routing CLMHR protocol in [14] to increase the network lifetime by using an energy efficient routing protocol for WSNs. Here they have considered Location aided routing protocol for efficient routing. CLMHR combined three terms first is the equilibrium of candidate relay node's residual energy and second is the distance from the source node to the destination or next hop and lastly the cross-layer design idea. The author compared CLMHR with LAR and proved CLMHR protocol not only avoids some nodes to take on the overweight communication load, but also to reduce the number of repeatedly transmitted communication data. When the network died, the residual energy for most nodes is more equilibrium and their ratios are distributed between10% to 85%.

A. Classification of routing protocols using Cross layer Technologies

The Table I summarize the comparison of the protocols covered in this survey. We have included in the table whether the protocol is utilizing data aggregation or not, since it is an important consideration for routing protocols in terms of energy saving and traffic optimization. Scalability is also considered. Table II summarizes the classification based on protocol at each layer like physical layer, MAC layer, Network layer and cross layer considered means which parameter is exchanged from one layer to another layer.

TABLE I. COMPARISION OF DIFFERENT CROSS LAYER TECHNOLOGIES

Year	Protocol	Protocol type	Data aggregation	Scalability
2009	CAGIF	Location based	NO	FAIR
2009	CLBISORP	Multi hop based	NO	-
2010	CBR-Mobile	Cluster Based	YES	POOR
2010	XLE2R	Multi hop based	NO	FAIR
2011	CLAR	On-demand	NO	POOR
2011	E2CLCC	Cluster Based	YES	GOOD
2011	Token based CLD	Token Passing Based	NO	-
2012	Enhanced HEEP	Cluster Based	YES	-
2012	Improved LEACH	Cluster Based	YES	FAIR
2012	LCLA	Multi hop based	YES	GOOD
2013	ECLAP	Proactive	NO	GOOD
2013	CLMHR	Location-based	NO	FAIR

IV. OPEN ISSUES

Most of the routing algorithms are implemented using simulators. So to check the performance of algorithms, the real WSN test bed must be used. In [5] they have suggested to use different energy consumption levels during different sensor states. Next issue is mobility of node and packet loss must be considered while designing routing algorithm for mobile ad-hoc sensor network. In clustering algorithm, clustering and cluster head selection is challenging issue because it creates overhead.

V. CONCLUSION

The multiple number of cross-layer approaches that address the challenges faced by the WSNs, proves that there is still need for further optimization of these networks, and that cross-layering is efficient to accomplish that. Routing protocols have more impact on the network lifetime. Thus, in this survey most of the recent research on routing protocol using cross layer approach has been gathered and discussed. Proposals have shown that there are different categories of routing protocols, and that each of them has their own set of advantages.

TABLE II. CLASSIFICATION BASED ON PROTOCOL AT EACH LAYER AND CROSS LAYER CONSIDERED

Year	Protocol	Authors	Cross layering Considered	Technologies used at each layer		
				Network	MAC	PHY
2009	CAGIF	Zhang	Wireless channel condition and geographic location are exchanged from MAC and physical layer to Network Layer	CAGIF	CDMA	-
2009	CLBISORP	Saleem	Energy level and link quality metrics are exchanged from physical layer to network layer.	BIOSARP	-	Calculation of remaining power.
2010	CBR-Mobile	Samer	Scheduling and contagion information is shared	LEACH	CSMA/TDMA	-
2010	XLE2R	Babulal	Link state information from MAC layer and residual information from PHY layer in use at network layer.	-	-	Calculate residual energy
2011	CLAR	Chabala	Neighbor information exchange from MAC layer to Network layer.	-	DRMACSN	Calculate CQI
2011	E2CLCC	Babulal	Data center information is exchanged in between MAC and network layer	-	TDM	-
2011	Using Token Passing-	Thaskani	Sectored and token information of MAC layer is used in the network layer	Innovative localization Scheme	Token passing	-
2012	Enhanced HEEP	Boubiche	Network layer sends neighbor table and routing path information to Physical layer.	HEEP	-	Transmission power control (TPC)
2012	Improved LEACH	Gajjar	Residual energy and distance of node from CH is sent to the network layer	LEACH	TDMA	Monitor residual energy
2012	LCLA	Tangammal	Traffic information from network layer is sent to MAC layer to adjust retry limits.	AOMDV	Retry limits controlled	-
2013	ECLAP	Rani	MAC layer makes use of the routing information from the network layer	Incremental Shortest path Tree Heuristic approach	RTS/CTS	Transmission Power Control
2013	CLMHR	Gaol	Residual battery information is exchanged from physical layer to the network layer	-	Sensing channel	-

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