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A Survey on Cross Layer Framework based Energy Efficient Routing Protocols of Manets

Manish Devendra Chawhan[1], Ausaf Umar Khan[2*] and Bhumika Neole[3]

[1,2]Department of Electronics and Telecommunication, Yeshwantrao Chavan College of Engineering, India
[3]Deaprtment of Electronics and Communication Engineering Ramdeobaba College of Engineering and Management, India
[1]mchawan1001@gmail.com, [2]ausafumarkhan@gmail.com and [3]neoleba@rknec.edu

Abstract

The expansion of wireless communication systems emphasizes on the different challenges in the design and efficient usage of communication protocols. Generally, for interoperability and efficient implementations with quick distribution, protocol architectures follow strict communication protecting principles. However, because of the absence of management between communication layers, the energy efficiency of such architectures degrades to face demands presented by wireless communication networks. To surmount the limitation of the layered architecture, the cross layer concept turned into a predominant solution. Its fundamental objective is to obtain appropriate communication among communication layers to gain performance enhancements. Also, the energy consumption due to the several processes involved in the routing of packets attracts the researcher to develop the energy efficient routing protocols. This study presents a review on the conception of cross layer technique in a MANET to enhance the performance of communication architecture to gain energy efficiency along with efficient communication.

Keywords: *MANET, Energy efficiency, Cross layer framework, routing protocols, ad-hoc network.*

1. Introduction

Due to absence of centralized administration, MANET eliminates the use of a fixed framework for communication by creating multi hop wireless communication network with the aid of intermediary mobile nodes between the source and destination [1]. The advantages of the MANET during the war, medical emergency, natural disasters, space exploration and crisis response attract researcher attention towards enhancement of secure and efficient communication protocols for MANET [2,3]. The following essential characteristics of MANET are:

1. Dynamic topology
2. Bandwidth and wireless link capacity
3. Limited security
4. Multi-hop communications
5. Energy constrained nodes

Because of these characteristics of MANET, various challenging issues arise in practical applications and implementation. The crucial issue of MANET is the energy consumption of the mobile nodes during the process of communication. The large number of mobile nodes deploy to form the ad-hoc network and each node needs to be active for establishment of communication and to prolong the life of the ad-hoc network. Since most of the mobile nodes in MANET use a battery as power supply and due to limited energy

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resources, it becomes very important to develop the energy and communication efficient routing protocol for executing all the necessary functions and to prolong the network lifetime [4]. If the remaining energy of mobile nodes is insufficient or drained out, then the mobile nodes may leave the network or become dead results in interruption of communication and partition of the network [5]. There are several factors that can influence the energy consumption in MANET are detecting or maintaining the topology change, scheduling the channel assignment, packet transmission [6], selection of the route, channel contentions, congestion [4], signal interferences, multiple access, multipath fading, the strict communication layered architecture of the TCP/IP model, modulation technique and node's radio [2]. The main cause of energy consumption is the strict layered architecture of the TCP/IP model which is inadequate in terms of flexibility, low complexity and portability to work in the changing environment of the MANET. To overcome the limitations of strict layered architecture, a concept of cross layer design is introduced which allows communication between non-adjacent layer of the TCP/IP model.

In this paper, section 2 gives a brief description of routing protocols with their features, section 3 presents fundamental of cross layer approach, section 4 contains a review on energy efficient cross layer approaches utilized to model energy and efficient communication routing protocols to enhance the performance of MANET in sophisticated operations and environment, section 5 provides a comparative analysis of existing energy efficient routing protocol based on the cross layer approach.

2. Categorization of Routing Protocols

The routing protocols of MANET are generally identified as proactive, active and hybrid as shown in the figure 1.

In the proactive or table-driven type of routing protocols, "Hello" packets are regularly broadcast to determine all available routes and mobile nodes in the network are needed to revise their routing table periodically to provide routes to all the nodes. The control packet (RREP) is delivered regularly by the node to provide correct route information. The route discovery time of this kind of routing is low, but may waste bandwidth by assigning control packets even in idle condition. Examples of proactive type of protocols are DSDV and OLSR[7].

In the reactive or on-demand type of protocols, route discovery packets are transferred if there is any data traffic, thus there is no desire of maintaining route all the time. Hence, it reduces routing overhead and may not waste bandwidth by assigning unnecessary control packets. The route discovery happens particularly when there is any demand for forwarding data to destination from source. DSR, AODV and DYMO are the examples of reactive protocols.

A Hybrid routing protocol comprises of both proactive and reactive types of protocols operates in large ad hoc network segregated into several limited regions. In each region, for determination of routes for all nodes, proactive protocol is used and reactive routing is applied to eradicating the overhead of control packets. Example of hybrid type of protocol is ZRP.

The features and similarities of the routing protocols are presented in the table below:

Table 1. Features of Routing Protocols [8]

Features	Proactive (Table driven)		Reactive (On demand)	
	DSDV	**OLSR**	**DSR**	**AODV**
Multicasting	No	No	No	Yes
Loop Freedom	Yes	Yes	Yes	Yes
On-demand Routing Behavior	No	No	Yes	Yes
Link Support (Unidirectional)	No	Yes	Yes	No
Sleep Mode	No	Yes	No	No
Route Discovery and Maintainenace	No	No	Yes	Yes
Power Conservation	No	No	No	No
Security	No	No	No	No

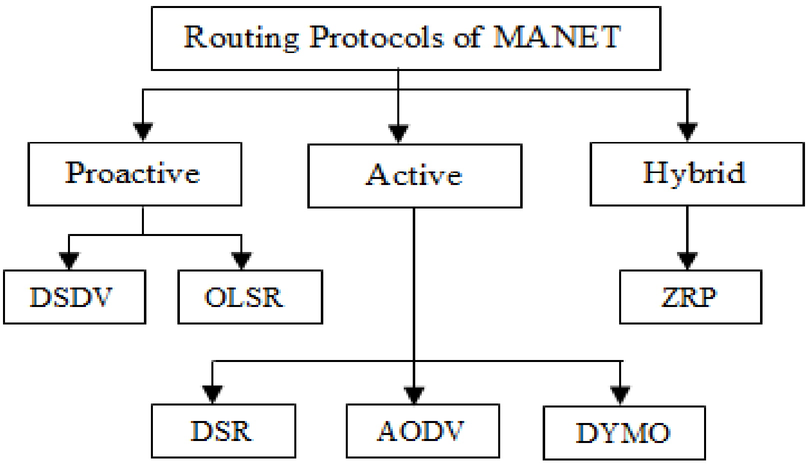

Figure 1. Categorization of Routing Protocols

3. Fundamentals of Cross Layer Framework

The layered communication architecture of the TCP/IP model with their primary functions is illustrated in figure 2. The TCP/IP model is useful and efficient for wired communication systems in terms of reasonable design complexity, portability and flexibility, but it is not efficient for wireless communication systems because of a strict layered model. Dynamics of MANET environments are not flexible enough to handle a strict layered model and therefore result in poor performance. In order to obtain a performance gain, a cross layer approach is introduced which allow management, cooperation and joint expansion of protocols crossing the various layers with preserving the functionalities related to the original layers. The violation of the layered architecture in cross layer design takes place by the creation of the new interface, integration of adjacent layers, vertical calibration across layers and design coupling without new interface [9].

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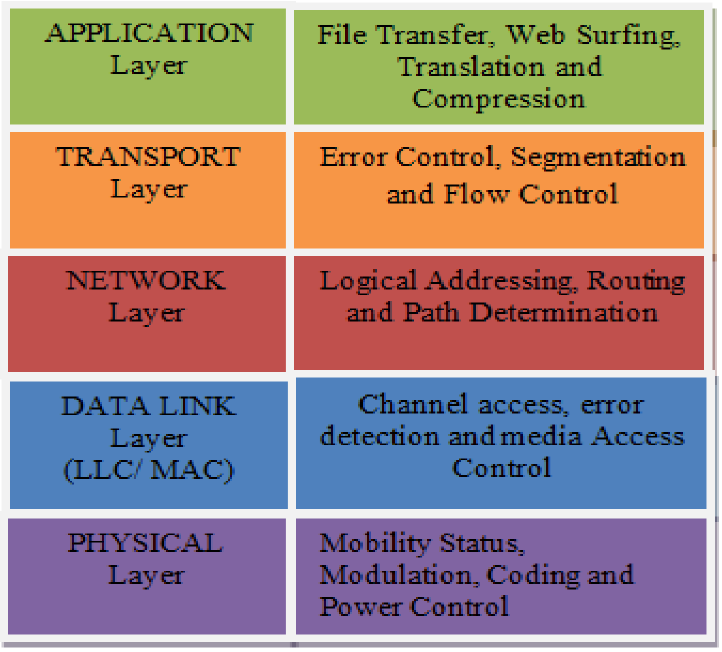

Figure 2. Layer Stack of TCP/IP Model [3]

The interaction between layers in cross layer design is mainly classified into two groups [10]:

1. Information Sharing

The information sharing in the cross layer is divided into two mechanisms:

A. Layered centric mechanism: In this sharing mechanism, any one layer can serve as the central layer to manage cross-layer adaptation depending upon algorithm on the adjoining layers and internal protocol parameters as shown in figure 3. This method of sharing requires a connection to the internal parameters of adjoining layers which defies the strict layered architecture, but enhances the feasible system performance [3].

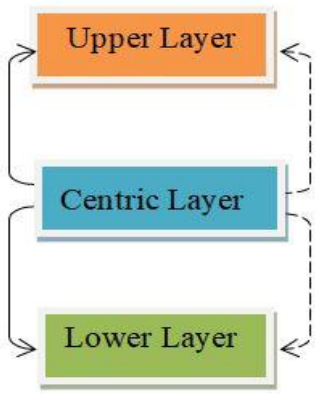

Figure 3. Layered mechanism [3]

B. Centralize[illegible]anism, the resource availability and the variety of environments are examined by an integrated monitoring system, i.e., a middleware, to secure the coordination between the resource allocation through different applications as well as nodes, and for revising the internal protocol specifications of each layer, as shown in figure 4. The concept requires the collection of all the information in the middleware or centralized system deliver by each layer characterizing its protocol specifications and algorithms. Also, each layer executes the responses demanded through the central optimizer. The concept also defies a strict layered architecture [3].

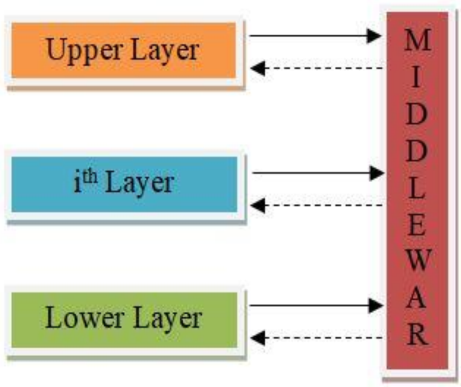

Figure 4. Centralized mechanism [3]

2. Design Coupling

In this interaction, new algorithm or protocols are designed by the coupling of two or more layers [9] to get advantages of existing layered architecture or avoid the limitations of it without creating new interface. More effective cross layer techniques can partly or fully integrate the functionality of adjacent layers [10]. A design coupling provides further optimizations, consistently significant further than the layering models. Thus, design coupling enhances the performance benefits for approximately all of the interoperability and modularity benefits of layering. A design coupling experiences so much turned out effective for optimizations that focus on specific scenarios or specific technologies [10].

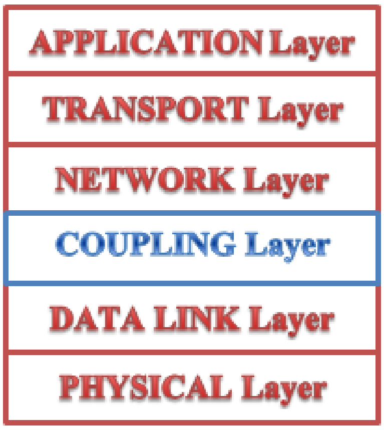

Figure 5. Design Coupling without new interface [11]

4. Literature Survey

One essential objective of a routing algorithm is to maintain the mobile node's connectivity as long as feasible with correct and dynamic routes between two nodes. To achieve the objective, utilization of mobile node's energy should be minimized not merely during active but also during passive condition. In this section, detailed investigation of existing energy efficient routing protocols is done.

Weng et al [4] have introduced the cross layer approach based MTEC algorithm at the network layer and ACW algorithm at the MAC layer. The proposed cross-layer model, i.e., combination of MTEC and ACW, revealed low energy utilization for data communication and prolong network lifetime than existing protocols along with improvement in communication parameters. The MTEC algorithm chooses the MTEC path for low energy consumption for the successful data transmission on the basis of the available energy of a node, the ratio of successful transmissions of data, the sum of channel events and the data congestion capacity of a node. The ACW algorithm helps nodes to maintain high successful transmission with further conveniences for maintaining a channel to conserve energy at the MAC layer. This cross layer approach MTEC with ACW helps in energy utilization with high throughput.

Ahmed et al [12] have proposed an optimized cross layer power control approach by combining the physical layer for transmission power modification and the MAC layer for getting information about the RSS value of a node. Modification of transmission power facilitates the node to adjust the transmission range dynamically at the physical layer. The nodes are placed in either high or low signal strength fields depending on the RSS value provided by the MAC layer. Each node calculates minimum value, average value, and maximum value of RSS using an effective transmission power control mechanism for figuring out the RSS value.

The expressions for calculating the minimum, average, and maximum receiver signal strength are given below:

$$A_{RSS} = \frac{\sum_{i=1}^{m} RSS_i}{n} \qquad \ldots\ldots..(1)$$

$$A_{Min_{RSS}} = \frac{\sum_{i=1}^{Min_{node}} RSS_i}{Min_{node}} \qquad \ldots\ldots\ (2)$$

$$where\ RSS_i < A_{RSS}$$

$$A_{Max_{RSS}} = \frac{\sum_{i=1}^{Max_{node}} RSS_i}{Max_{node}} \qquad \ldots\ldots..\ (3)$$

$$where\ RSS_i > A_{RSS}$$

In expression (1), (2) and (3), m is the sum of single hop neighbor nodes of node Xi with RSSi represents the sum of the received signal strength value of neighbor nodes. A_{RSS} represents the average value of RSS, while $A_{Min_{RSS}}$ And $A_{Max_{RSS}}$ represent the minimum and maximum value of RSS, respectively. Using these values, the communication region can be determined by each node. The RSS value is inversely proportional to the transmission distance, i.e., a low value of RSS can cover the large communication area and vice versa.

Auon & Wang [2] have proposed two algorithms based on cross layer design by taking up a bottom-top approach. The first routing algorithm is based on CPLNC which jointly

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enhance the operation of the routing protocol by employing energy efficient transmission strategy and energy efficient routing at PHYsical layer and NETwork layer respectively. The second algorithm based on HARQ also jointly enhances the performance of PHYsical layer, MAC Layer and NETwork layer. The two energy-efficient routing algorithms based on the cooperative ARQ approach are CCB-SPR and CONSP, counts as the best energy-saving route based on the cooperative link costs and computes a shortest route by employing the NCR algorithm based on Distributed Bellman-Ford algorithm respectively.

Rath et al [13] have proposed the power delay optimized algorithm based on cross layer design for military applications. The proposed power delay cross layer framework introduces a friendly packet between the two layers to reduce the overhead of route selection by providing essential data to the upper NETWORK layer from the DATA LINK layer. The proposed cross layer approach has introduced another technique at the MAC layer called an improved channel access compatible to work with PDO-AODV to achieve better results for efficient communication and optimized power consumption.

Bhoge et al [14] combine the NETWORK layer for less buffering with the TRANSPORT layer to control congestion and route failure. The proposed cross layer based energy efficient algorithm named DERDM prolongs the network lifespan and achieves the energy efficient communication. Simulation results present14 yield less delay and better PDR as compared to well established routing protocols like AODV and DSR.

Helen & Arivazhagan [15] have developed a cross layer energy and communication efficient routing protocol using BCO technique named ICLBR. The proposed routing algorithm uses cross layer approach and BCO technique to find the most efficient and shortest path for data transmission. This proposed algorithm helps to provide the solution for the congestion problem, optimum energy usage, to prolong the network lifetime and link failure. The minimum use of control overhead in the algorithm helps to achieve high throughput and PDR.

Mehta & Lobiyal [16] have modified the AODV to cross layer energy efficient AODV (CLEE-AODV) routing protocol. The cross layer between the MAC layer and the NETWORK layer is used to implement the specific changes in route discovery process and to adjust the transmission power of a node to increase the life span of the network by minimum utilization of energy resources. The proposed CLEE AODV yields better result in terms of total transmission power, energy efficient, the average energy consumption per node and throughput as compared to AODV.

5. Comparative Analysis

In this paper, the concept of cross layer has been presented with various energy efficient and communication protocols. In this section comparative analysis of existing energy efficient protocols has presented in the table below:

Table 2. Comparative Analysis of Existing Energy Efficient Protocols

Year	Author	Cross Layer	Proposed Approach	Outcomes
2013	Weng et al[4]	NETWORK and MAC Layer	MTEC- ACW	Low energy consumption, better throughput and less PDR.

2015	Ahmed et al[12]	PHYSICAL and MAC layer	CLPC	Energy efficient, less end-to -end delay, better PDR and less routing overhead.
2016	Auon and Wang[2]	PHYSICAL, NETWORK and MAC Layer	CPLNC- HARQ	Energy efficiency
2016	Rath et al[13]	NETWORK and DATA LINK layer	PDO-AODV	Energy efficiency, prolong the network lifetime and less end-to-end delay.
2016	Helen & Arivazhagan[15]	PHYSICAL and MAC Layer	ICLBR	Energy efficiency, congestion control, long network lifetime and avoid link failure
2017	Bhoge et al[14]	NETWORK and TRANSPORT layer	DERDM	Energy efficiency, better PDR and less delay
2017	Mehta & Lobiyal[16]	NETWORK and MAC Layer	CLEE-AODV	Energy efficiency and throughput

6. Conclusion and Future work

From the literature, it is concluded that the energy efficiency of an ad-hoc network is a crucial parameter in the evaluation of an ad-hoc network performance to provide feasible and efficient communication between two mobile nodes against the characteristics of the MANET. The various existing Cross layer frameworks have been presented in the literature which provide energy and communication efficiency for optimized power consumption with better throughput, less delay and congestion control as compared to well established reactive routing protocols like AODV and DSR. The advantage of Cross layer design to provide management and coordination between non adjacent layers enhances the performance of the routing protocol against the strict layered architecture. So, in the future research, there is a need of a cross layer design based energy efficient routing protocol with security and congestion control for MANET.

Appendix

List of Abbreviations

Abbreviation	Full Form
MANET	Mobile Ad hoc Network
OSI	Open System Interconnection
TCP	Transfer Control Protocol
IP	Internet Protocol
DSDV	Destination Sequenced Distance Vector routing

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OLSR	Optimized Link State Routing
DSR	Dynamic Source Routing
AODV	Ad hoc On-demand Distance Vector
DYMO	Dynamic Manet On demand
ZRP	Zone Routing Protocol
RREQ	Route Request
RREP	Route Reply
MTEC	Minimum Transmission Energy Consumption
ACW	Adaptive Contention Window
MAC	Medium Access Control
RSS	Received Signal Strength
SNR	Signal to Noise Ratio
HARQ	Hybrid Automatic Repeat Request
CCB-SPR	Cooperative Cost-Based Shortest-Path Routing
NCR	Non-Cooperative Routing
CONSP	Cooperation Over Non-cooperative Shortest Path
CLPC	Cross layer Power Control
PDO	Power Delay Optimized
BCO	Bee Colony Optimization
PDR	Packet Delivery Ratio
ICLBR	Intelligent Cross Layer based Bee Routing

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Authors

Manish Devendra Chawhan, is working as an Associate Professor in Yashwantrao Chavan College of Engineering, Department of Electronics & Telecommunication Engineering, India. He did BE and M-TECH from YCCE, Nagpur. He is PhD in Electronics Engineering from Nagpur University. His area of research is Wireless Communication & Networking. He has a teaching experience of 19 years .He has published & presented 28 papers in various National and International Journals & Conferences. He has been approved a grant from the Department of Science & Technology (DST) for research in wireless Communication & Networks. He has also received a grant of from All India Council of Technical Education (AICTE) for Skill and Personality Development of Students. He was a reviewer in The IEEE International Symposium on Signal Processing and Information Technology (ISSPIT) held in Luxor, Egypt and Journal of Communication and Networks published by Korea Informatics and Communication Society. He has delivered various expert lectures on Bluetooth technology, wireless communication and networks, optical fiber communication, Cross Layer Design, Microcontroller Architecture and chaired sessions as judge in national and international conferences. He has taken workshops in Signal Processing using Matlab, Bluetooth technology, Optical Fiber Communication. He is an approved supervisor for PhD.

Ausaf Umar Khan, received his BE degree in Electronics and Telecommunication Engineering from Anjuman college of Engineering & Technology, India in 2013 and M. Tech degree in VLSI design from Yeshwantrao Chavan College of Engineering, India in 2015. He is currently working as Junior Research Fellow on DST-SERB funded project titled 'Energy and Communication Efficient Protocol of Mobile Ad-Hoc Network using Cross-Layer Approach' and pursuing PhD degree in Electronics Engineering from RTM Nagpur Univeristy, India. His research interests include protocols and algorithm design, cross-layer optimization and network security. He has presented and published papers in reputed conferences and journals.

Bhumika Neole, received her Bachelor of Engineering (Electronics Engineering) in 2001 from Priyadarshini College of Engineering and Architecture, RTMNU, Nagpur and M-Tech (VLSI) in 2007 from RCOEM, Nagpur. She has been awarded Ph.D. from VNIT in 2018. She has published 10 research papers in International Journals and Conferences, 1 Copyright and 1 Patent. Since 2004, she has been working as an Assistant Professor in RCOEM, Nagpur. She is member of IEEE and also a life member of ISTE.