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A Review of Power Management Approaches for Mobile Ad Hoc Networks

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ABSTRACT

Internal node power management of the wireless network is becoming the most difficult task in the Mobile Adhoc Network. Power outages on any node in the MANET degrade overall communication network performance. Efficient power management solutions are required for all tiers of the MANET protocol. The Physical layer might keep track of the antenna transmission and reception power strategies, as well as the power management plans for idea nodes and sleep nodes. The MAC layer power management could increase the packet delivery ratio, average delay, average jitter, and network delay metrics. The network layer's power management is supported by the link's lifetime and node mobility. TCP/IP protocols enable reliable packet transmission, which improves the transport layer. This survey paper conducted a thorough survey of the MANET protocol stack. This survey paper conducted a thorough investigation of MANET protocol stack power management in order to identify factors that can be improved to achieve a better power management strategy in MANET nodes.

1. INTRODUCTION

Because of the advancement of wireless networks in computer networking, the Mobile Adhoc Network has become critical in establishing a communication network via a wireless medium without the use of an access point. The key obstacles of creating a MANET in terms of features are transmission range limitation, routing overhead, battery power constraint, asymmetric connection, nature of wireless network, packet loss, mobile notes route modifications, frequent network partitioning, and so on.

Among the problems, battery power management is critical in MANET [1] functioning operations. The method of increasing battery power is done by combining packet transmission, synchronization signals, beacon signal creation, and so on. Several routing protocols have been developed to improve battery power usage during packet transport. Even new hybrid protocols are being introduced to improve battery power consumption. Concentrating solely on routing packet transfer is insufficient for consuming battery power; other layers also play an important role in power optimization. Instant physical layer beacon signal, MAC layer link establishment, network layer routing, transport layer connection establishment utilizing the TCP or UDP protocol, application layer usages, and so on.

Major factors include the maintenance of power management in MANET nodes, which is based on the MANET protocol stack, as depicted in Figure 1. Antenna use [2] in the physical layers increases the power optimization so that an efficient antenna is needed to deliver the packets, MAC layer performance considerations [3]. Support for power reduction, optimal routing protocol technique [1, 4, 5] essential to reduce packet loss, Congestion control with TCP synchronization [6]. Improvements for power reduction, as well as maintaining the nodes' links [7] and preventing link failures, and incorporating security elements [8, 9] into the application layers, all help to improve the MANET.

This page provides a survey of how the various levels contribute to MANET's power management. The article is organized so that section II discusses power management in MANET protocol layers, followed by a comparative analysis of power management techniques in MANET in section III, a summary of all the methodologies used in MANET for power management in section IV, and a conclusion to the new technique in section V.

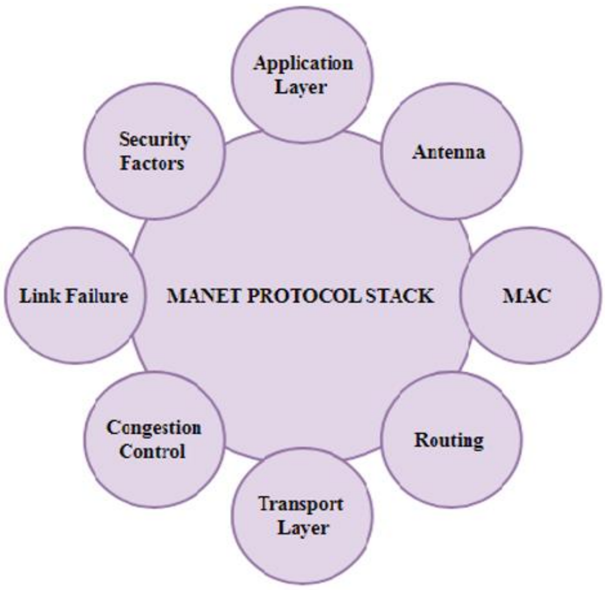

Figure 1. Power Management in MANET nodes

2. MANET PROTOCOL POWER MANAGEMENT

Each layer in the MANET protocol stack is responsible for optimizing power utilization to extend the life of individual nodes. The physical layer requires power optimization through efficient antenna usage, the MAC layer requires power optimization through improved performance factors, the network layer requires power optimization through node selection, life time computation, link details, and so on, and the transport layer requires power optimization via TCP synchronization. This section discusses the relevance of each layer as well as the computing methods, including the necessary equations and parameters.

2.1 Physical layer

MANET physical layer power management is based on the consideration of physical layer modulation, noise, antenna power gain, coding schemes, and interference. The physical layer is made up of PHY and antenna components [10]. PHY components include signal transmission, reflection and reception models, MAC schemes, channel distortions, physical parameters, and neighbour node interference. Antenna functions and attributes refer to the antenna components that are employed to capture signals when the antenna is transmitting. The total energy utilized for antenna signal operation included antenna power transmission, antenna power reception, and power required in idle and sleep modes, as estimated by the equation from Eq. (1) to Eq. (4).

Antenna Transmission Power = Power required to transmit signals * Vol * time (1)

Antenna Receiving Power = Power required to receive the signals * Vol * time (2)

Antenna Idle Power = Power required to Idle mode * Vol* time (3)

Antenna Sleep Power = Current required to sleep * Vol * time (4)

2.2 MAC layer

MANET, power control at the MAC layer assessing quantitatively from routing indicators such as energy usage, Packet Delivery Ratio (PDR) [11], Average Delay, Average Jitter, and Network Delay. Energy consumption is assessed in joules, and packet loss in the first or middle node, as well as the lost node, consumes the same amount of energy. The average packet delivery rate refers to the rate at which data is received from the sender. Average Packet Delivery Rate PAvg, derived from the Eq. (5).

$$P_{Avg} = (NTrp * 100 + (n! /! (n-r)!))) / (\lim_{r \to \infty} N_{Sp)}) \quad (5)$$

where, NTrp - Number of Packet received totally.

N_{Sp} - Total number of Packet send.

The *Average End to End Delay* is also important parameter in MAC layer power management, which is computed from the Eq. (6):

$$Delay_{Avg =} \sum (Tr - T_s) / Lim_{r \to \infty} N_{RP} \quad (6)$$

where, N_{Rp} - total number of received packet from all the nodes

T_r - Movement of packet received.

T_s- Packet Send.

The Average Jitter is the variation on delay in each packet which uses many data packets to play a role. The Eq. (7) is used for the Jitter computation.

$$J_A = [\sum (T_r - D_{Avg} - T_s)\ 2] / Lim_{r \to \infty} N_{RP} \quad (7)$$

Throughput of the network is the ratio between amounts of data passing totally in a local connection with time spends for transfer the data which is computed using the Eq. (8).

$$Ta = (\lim_{r \to \infty} N_{RP}) / T_{tra} \quad (8)$$

2.3 Network layer

Power management in network layers is based on node power, link connection, link lifetime, node mobility, and node distance.

2.3.1 Node power

Every node requires residual power to transmit packets; when this power is depleted, packet transmission fails and the route line is disconnected. The formula in Eq. (9) is used to estimate the minimal power required for transmitting and receiving packets at each node.

$$M_n = [\sum^{f}_{n=1} M_{Max} * (M_{Min} / M_{g)}] \quad (9)$$

where, f - total number of n nodes.

M_{Max} - maximum receiving power.

M_{Min} - Minimum receiving power.

M_g - Received power of n^{th} node.

2.3.2 Link connectivity

Link connectivity is the bidirectional connection between the pair of nodes is estimated as follows in the Eq. (10).

$$K_n = 1/f\ [\ \sum^{f}_{n=1} (Kg/t)] \quad (10)$$

where,

t total connectivity.
K_g - connectivity of g th node.

2.3.3 Life time of the link

Life time of the every link is needed for connecting two nodes for sending packets. The link is used for transmitting packets [11]. Due to dynamic topologies changes the link may get to disconnect in MANET, so life time of the link to be estimated in advanced before choosing the route. That could be estimated using energy model shown in the Eq. (11).

$$N_n = 1/f \left[\sum^{f}_{g=1} E_g \right] \quad (11)$$

where,
Eg - Energy dissipation of g th node.

2.3.4 Node mobility

Mobility of the node is an important factor in MANET as shown in the Eq. (12),

$$N_m = 1/|p_h| \sum_{g= Ph} B_g \quad (12)$$

$|p_h|$ - Set of neighbour nodes.
B_g - relative mobility.

2.3.5 Node distance

Distance between the nodes used to estimate the link stability, which is evaluated using the formula in the Eq. (13).

$$R_n = \sum^{f}_{g=1} (U_g, p_h) \quad (13)$$

p_h - Set of neighbour nodes.
U_g - Energy of current node.

2.4 Transport layer

Reliable packet transmission is done in TCP protocol in MANET transport layer. So transport layers support responsibility of packet delivery by giving ACK signal to the sender so that the retransmission of packet will not be initiated [12].

Old ACK and New ACK time was used in TCP protocol to inform the source about the packet received. Received Packet Rate of the destination using the formula in the Eq. (14).

$$RPR = (D_{nap} - D_{oap}) / (Tnak - T_{oack}) \quad (14)$$

where, D_{oap} - Number packets received at Toack,
D_{nap} - Number of packets received at Tnack,
T_{oack} - Old ACK time,
T_{nack} - New ACK time.

3. COMPARISON ANALYSIS

This chapter conducted a thorough comparative analysis of the MANET power management protocol by introducing many classifications, as shown in Tables 1 to 6, along with the methodology utilized and the benefits and drawbacks of each method.

3.1 Based on mobility awareness

The authors of the MANET Research paper conducted research on mobility-aware energy-based power optimization. Al-Gabri et al. [4] conducted study utilizing the LEA-AODV method to determine energy reduction, but the results produced better load balancing. RREQ modified the methodology of study conducted on Woungang et al. [5] to develop the Energy Field. Gu and Zhu [1] used the Route Energy Comprehensive Index to achieve success in energy consumption. The study [12] achieved energy consumption utilizing the network lifetime by enabling the RREQ. Alghamdi [13] employs the LBMMRE-AOMDV procedures to achieve maximum residual energy.

Table 1. Summary of mobility awareness

Authors	Methodologies	Merits
Al-Gabriet al. [4]	LEA-AODV	Distribute Load Balances
Woungang et al. [5]	RREQ modify	Energy Field
Gu and Zhu [1]	Route Energy Comprehensive Index	Energy Consumption
Al-Gabri et al. [4]	Network Lifetime By Enabling The RREQ	Energy consumed
Alghamdi [13]	LBMMRE-AOMDV	Maximum Residual Energy

3.2 Based on topology management

Groups of study work carried out with the goal of power management could benefit from topological management, as indicated in Table 2. Chaudhry and Tapaswi [14] used the Optimized Power Control technique to manage power, and the results were good in terms of transmission power, delay, and energy consumption, however they failed OPC-CC. Namdev and Mishra [15] used M AODV methods to reduce delay and overhead, although Link Breakage was challenging to reduce. Rahmani et al. [16] used the Automata-Based Topology for power increases; the outcomes generated the Self-Aware, Self-Adaptive, and Self-Adjust Topology, however Routing Topologies became laborious.

Singh et al. [17] developed the Secure Optimized Link State Routing Protocol, which produced the link and message without relying on a third party but did not provide for attack detection. Sridhar et al. [18] employ the POR Algorithm to change the network capacity; nonetheless, the research fails due to poor network performance The TESAODV approach reduced network lifetime in the study however the research failed to maintain energy levels. Rao and Singh [3]used the KF-MAC approaches to obtain QOS parameters, but the findings yielded maximum delays.

3.3 Based on the algorithms

A set of research studies was conducted for power optimization employing algorithms, some of which achieved good metrics but failed on others, as summarized in Table 3. Musthafa et al. [19] apply the SNDA methodology to gather power in MANET nodes. The research results in Reliable Communication; however it requires greater emphasis on Security. Vij et al. [20] used the Game Theory-Based Model approach for Node Energy Level, and the simulation resulted in Propagation Delay and High Overhead. Nobahary and Babaie [8] applied the Credit-Based Method algorithm for power optimization research to Managing Less Energy

Consumption, but they only obtained Generic Network Features.

The IDSM approach employed by Veeraiah and Krishna [9] to obtain dependable QoS produced results that did not meet the overall performance requirements. Abirami and Sumithra [21] employ the NCV-AODV algorithm for Enhanced Neighbour Credit Cost, but the researchers were unable to control the delay, therefore the delay remains high. Jim and Gregory [22] rely on an artificial immune system Increases the Packet Delivery Ratio and reduces Package Loss, but does not lower packet loss. Ponnusamy [23] employ the Energy-Efficient Method to provide Reliable Data Transmission, but the results show that the overhead increased. Ramesh et al research is supported by the MSD-SNDT method [24]. According to the simulation studies, energy consumption is very low while utilization is high.

Hasani and Babaie [25] used the Fuzzy-Dependent SN Detection Method to find more active nodes for power maintenance, but the findings were unexpected, and the system was too expensive. Nobahary et al. [26] used game theory in their research on nodes cooperating to play a repeated game, although the overall efficiency of the study was not met. Hadi et al. [27] applied the AODV Using a Wireless Network technique to improve packet delivery, although the findings yield a lower packet delivery ratio.

Table 2. Summary of topology management

Authors	Methodologies	Merits	Demerits
Chaudhry and Tapaswi [14]	Optimized Power Control	Good Performance in Transmission Power, Delay, and Energy Consumption	Failed OPC -CC
Namdev and Mishra [15]	M AODV	Reduced Delay and Overhead	Link Breakage
Rahmani et al. [16]	Automata-Based Topology	Self-Aware, Self-Adaptive, and Self-Adjust Topology	Routing Topologies
Sri et al. [6]	POR Algorithm	Changing the Network Capacity	Poor Network Performance
Singh et al. [17]	Secure Optimized Link State Routing Protocol	Link and Message Without Depending on the Third Party	Failed to Consider Attack Detection
Sridhar et al. [18]	TESAODV	Reduced the Network Lifetime	Unable to Maintain Energy Levels
Rao and Singh[3]	KF-MAC	QOS Parameters	Maximum Delay

Table 3. Summary of algorithmic methods

Authors	Methodologies	Merits	Demerits
Musthafa et al. [19]	SNDA	Reliable Communication	Severe Security
Vij et al. [20]	Game Theory-Based Model	Node's Energy Level	Propagation Delay High Overhead
Nobahary and Babaie [8]	Credit-Based Method	Managing Less Energy Consumption	Generic Network Features
Veeraiah and Krishna [9]	IDSM	Reliable QoS	Not Satisfied the Overall Performance Parameters
Abirami and Sumithra [21]	NCV-AODV	Enhanced Neighbour Credit Cost	Delay Remains Also High
Jim and Gregory [22]	Artificial Immune System	Increases the PDR	Package Loss
Ponnusamy [23]	Energy-Efficient Method	Reliable Data Transmission	Overhead Is Increased
Ramesh et al. [24]	MSD-SNDT	Energy Consumption is very Less	Vitality Utilizations
Hasani and Babaie [25]	Fuzzy-Dependent SN Detection Method	More Active Nodes	Power Consumption Is High System Too Costly
Nobahary et al. [26]	Game Theory	Nodes Cooperate to Play Repeated Game	Overall Efficiency Is Not Satisfied
Hadi et al. [27]	AODV Using A Wireless Network	-	Less Packet Delivery Ratio

Table 4. Summary of cluster head

Authors	Methodologies	Merits	Demerits
Kumar et al. [28]	ORS	Better Throughput, Lower Latency, Lower Jitter, PDR	-
Venkatesh and Chakravarthi [29]	HAMBOCHLD	Energy Waste Reduced	-
Goyal et al. [30]	HAODV	PDF, END, Routing overhead	-
Raj Kumar and Bala [31]	EECAO	-	Lengthy Lifetime
Al-Najjar [32]	ACO	Network Lifespan and Residual Energy	Two Cluster Heads
	PDR and NLT metrics	Uniform Distribution of Energy	-
Devika and Sudha [33]	C-SEWO	Innovative Design	-

3.4 Based on cluster head

A set of study work was completed by forming the clustering head to generate power management in MANET, as summarized in Table 4. Kumar et al. [28] uses the ORS to gain better throughput, lower latency, lower jitter, and PDR. Venkatesh and Chakravarthifor MANET [29] employs HAMBOCHLD Cluster formation to achieve achievement in energy waste reduction. Goyal et al. [30] employs HAODV approaches to improve packet delivery ratio, end-to-end delay, and reduce routing overhead. Raj Kumar and Bala [31] employ the EECAO approach, but the study fails by yielding the Lengthy Lifetime. Al-Najjar [32] employ the ACO technique to increase network lifespan and residual energy; however the best results require two cluster heads. Devika and Sudha's [33] research used PDR and NLT measures to achieve consistent energy distribution and utilize the C-SEWO approach [34] for innovative design.

3.5 Based on mobility aware cluster

The cluster node formation was investigated based on node mobility, as shown in Table 5. Braik et al. [35] use the AGS-ROA method of clustering to reduce route failure. Venkatasubramanian [36] adopts the EPO-FGA approach for mobile node lifetime. Hamza and Vigila [34] utilize the HPSO-GA method for node energy. Hamza and Vigila [37] use EEMST approaches, but this extends the lifespan. Sivapriya and Mohandas [38] used the MKMPE approach, which resulted in higher packet loss. Saravanan et al. [39] use the E-CFSA for effective power usage. Bisen et al. [40] achieve the best performance using the E-MAVMMF methods. Arulprakash et al. [41] use the EBDC methods for reduced energy consumption.

3.6 Based on transmission range

Finally group of researchers undertaking the research on the power optimization could be done with the support of nodes transmission range, summarizes in the Table 6. Izharul et al. [42] employs the ATP-AODV approach to save a significant amount of energy; however the goal of producing ATP-latency fails. Jiao and Guo [7] implemented the metric norm throughout the routing process to balance the network's energy consumption, but it also extended the network's lifespan. Park et al. [2] employs the MTPR and MHR methods to reduce control, and employs neighbour nodes to send hello messages in order to maximize network throughput, which causes minor delays. Wang et al. [12] used the optimal transmission radius for flooding in large-scale networks to achieve an average setting time.

Table 5. Summary of mobility aware in cluster

Authors	Methodologies	Merits	Demerits
Braik et al. [35]	AGS-ROA	Reduce Route Failure	-
Venkatasubramanian [36]	EPO-FGA	Mobile Node's Lifetime	-
Hamza and Vigila [34]	HPSO-GA	Node Energy	-
Hamza and Vigila [37]	EEMST	-	Prolong The Lifespan
Sivapriya and Mohandas [38]	MKMPE	-	Packet Loss
Saravanan et al. [39]	E-CFSA	Effective	-
Bisen et al. [40]	E-MAVMMF	Best Performance	-
Arulprakash et al. [41]	EBDC	Reduced Consumption of Energy.	-

Table 6. Summary of transmission range

Authors	Methodologies	Merits	Demerits
Izharul et al. [42]	Dynamic & Adjustable	Low-Cost	Each Node Having An Optimal Number Of Close To Three (3) Neighbour's
Jiao and Guo [7]	ATP-AODV	Saved A Large Amount Of Energy	ATP-latency
Park [2]	Metric Norm During The Routing Process	Balanced The Network's Energy Consumption	Extended The Network's Lifespan
	MTPR and MHR	Reducing Control	
Wang et al. [12]	Neighbour Nodes They Use Hello Messages	Maximization Of Network Throughput	Creates Some Delays
Izharul et al. [42]	Energy Efficiency By Optimizing The Transmission Power	Throughput Maximization	-
Jiao and Guo [7]	Optimal Transmission Radius For Flooding In Large Scale Networks	Average Setting Time	-

4. PERFORMANCE COMPARISON OF MANET WITH EXISTING METHODS

Table 7 summarizes several methodologies and algorithms with respect to the supporting parameters. Some methods support specific MANET parameters, whereas others do not.OPC approaches presented in study achieve the performance elements of power management, delay, energy, overhead, and congestion control but do not achieve PDF, load management, or security characteristics.Rahmani et al. [16] presented the M-AODV approach, which covers delay, energy, and overhead but does not support other parameters. The AUTOMATA approach is provided by study [43] yields just energy. The POR methods proposed by study [36] support only power, delay, and energy parameters, whereas the OLSR methods proposed by study [44] achieve only security characteristics.

Finally Sridhar et al. [18], Rao and Singh [3], Musthafa et al. [19], Jim et al. [22], Abirami and Sumithra [21], Ponnusamy [23], Rahmani et al. [16], Singh et al. [17], Ramesh et al. [24], Hasani et al. [25], Nobahary and Babaie [8], Hadi et al. [27], Kumar et al. [28], Venkatesh and Chakravarthi [29], Raj Kumar and Bala [31], Sahu and Patil [43], Al-Najjar [32], Devika and Sudha [33], Braik et al. [35], Saravanan et al. [39], Bisen et al. [40], Arulprakash et al. [41], Sivapriya and Mohandas [38] achieves only one parameters are fails to other parametersby using the methods TESAODV, KF-MAC, SNDA, AIS, NCV-AODV, EE, AUTOMATA, OLSR, MSD-SNDT, FSN, SNMN, SNAODV, QOS, CHLD, EECAO, ACO, CLU, C-SEWO, AGS-ROA, E-CFSA, E-

MAVMMF, EBDC, E-CFSA, E-MAVMMF and MKMPE methods respectively.

Next groups of research from the authors from Vij et al. [20], Nobahary and Babaie [8], Venkatasubramanian [36], Hamza and Vigila [34], Kumar et al. [28], Thanappan and Perumal [45], Reddy and Mungara [46], Phakathi et al. [47], Ravi et al. [48], Alghamdi [49], Satyanarayana et al. [50], Vinayakan et al. [51] and Saraswathi et al. [52] were achieved two metric parameters by using the methods of GAME THEORY, CREDIT-BASED, EPO-FGA, PSO-GA, EEMST, CC, GAME THEORY, ML, QOS, FUZZY, HFO, FRAMEWORK, CONJUNCTION, AOMDV, HGFNN respectively.

Another set of research done by the authors Veeraiah and Krishna [9], Namdev and Mishra [15], Sri et al. [6], Goyal et al. [30], utilizing the methodologies of IDSM, M-AODV, POR, HAODV, QOS and obtains just three parameters. Finally, the two research studies conducted by the authors of Chen and Liu [53] and Rashmi et al. [16] employing QoS and OPC approaches, respectively, produce the most number of performance metrics,as shown in Table 7. Research on power management is still ongoing to accomplish all kinds of parameter metrics.

Table 7. Summary of power management method with supporting performance

Article	Methods/ Algorithm	Power	Delay	Energy	Congestion Control	PDR	Overhead	Security	Load
Sridhar et al. [18]	TESAODV			√					
Rao and Singh [3]	KF-MAC		√						
Musthafa et al. [19]	SNDA		√						
Jim and Gregory [22]	AIS				√				
Abirami and Sumithra [21]	NCV-AODV		√						
Ponnusamy [23]	EE						√		
Rahmani et al. [16]	AUTOMATA			√					
Singh et al. [17]	OLSR							√	
Ramesh et al. [24]	MSD-SNDT			√					
Hasani and Babaie [25]	FSN			√					
Nobahary and Babaie [8]	SNMN			√					
Hadi et al. [27]	SNAODV					√			
Kumar et al. [28]	QOS					√			
Venkatesh and Chakravarthi [29]	CHLD								√
Raj Kumar and Bala [31]	EECAO			√					
Sahu and Patil [43]	ACO			√					
Al-Najjar [32]	CLU			√					
Devika and Sudha [33]	C-SEWO	√							
Braik et al. [35]	AGS-ROA		√						
Saravanan et al. [39]	E-CFSA			√					
Bisen et al. [40]	E-MAVMMF			√					
Arulprakash et al. [41]	EBDC			√					
Sivapriyaand Mohandas [38]	E-CFSA			√					
Vij et al. [20]	MKMPE					√			
Nobahary and Babaie [8]	GAME THEORY		√				√		
Venkatasubramanian [36]	CREDIT-BASED	√		√					
Hamza and Vigila [34]	EPO-FGA	√				√			
Kumar et al. [28]	EEMST	√				√			
Thanappan and Perumal [45]	CC		√	√					
Reddy and Mungara [46]	GAME THEORY		√	√					
Phakathi et al. [47]	QOS		√	√					
Ravi et al. [48]	FUZZY		√	√					
Alghamdi [49]	HFO		√	√					
Satyanarayana et al. [50]	FRAMEWORK		√	√					
Vinayakan et al. [51]	CONJUNCTION		√	√					
Saraswathi et al. [52]	AOMDV		√	√					
Veeraiah and Krishna [9]	HGFNN		√	√					
Namdev and Mishra [15]	IDSM	√	√	√					
Sri et al. [6]	M-AODV		√	√			√		
Goyal et al. [30]	POR	√	√	√					
Chen and Liu [53]	HAODV	√	√	√					
Rashmi et al. [16]	QOS						√	√	√
Sridhar et al. [18]	QOS		√	√			√	√	√
Rao and Singh [3]	OPC	√	√	√	√		√		

5. CONCLUSION

This survey article elaborates on the importance of power management in MANET nodes to achieve better performance. Initially, all the layers' responsibility for power management with the support of computation methods of each layer was discussed. Later, the different power management techniques with respect to the topology, transmission range, clustering nodes, and mobility was discussed. Finally, the comparative study of all the methods with the performance factors, Full-fledged power management can be obtained when all performance variables are met by the nodes. More study is needed to ensure that all performance factors in MANET are met in order to achieve an efficient power management strategy in the MANET protocol stack.

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