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Survey: State-of-the-Art Energy-Consumption Optimization Solutions for Mobile Ad-Hoc Networks

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Abstract

Mobile ad-hoc networks are deployed in different fields and it can be effective in applications that depend on the inter-node interaction such as search and rescue, surveillance, and battlefield reconnaissance. Due to this importance, in this article, we have reviewed the latest energy optimization solutions for mobile ad-hoc networks (MANET). Since the typical layered inflexible architecture is unable to handle the features of MANETs, battery consumption is the primary concern in the context of MANETs. Along with this, authors proposed categorizing energy optimization solutions into seven categories: techniques based on load balancing adaptation algorithms, methods based on multicast algorithms, and schemes based on the radio state adaptation algorithms, position-based routing protocols, schemes based on proactive algorithms, energy efficient reactive protocols, and techniques based on control of transmission energy algorithms. The authors reviewed the suggested resolutions in every domain, providing details on the methodology utilized, metrics for performance assessment, and the advantages and disadvantages related to each suggestion. We believe that the review presented in this article will be been sufficiently useful for researchers to optimize energy consumption for MANETs. Dummy text

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1. INTRODUCTION

A self-configuring collection of mobile devices, or nodes, is referred to as a mobile ad hoc network (MANET). These nodes have the ability to quickly, freely, and dynamically modify their positions and configuration [1]. The growing interest in the application of mobile ad-hoc networks has motivated lot of research works during the recent year. An ad-hoc wireless network is a collection of nodes that come together to dynamically create a network, with no fixed infrastructure or centralized administration [2]. The mobile ad-hoc network's applications such as battle field surveillance, emergency rescue, space exploration, chemical attack detection, combat field reconnaissance, business meetings and other situations. As can be seen from its distinctive features, mobile ad hoc networks experience more network congestion than typical wired networks [3]: (1) difficulties with exposed and hidden terminals; (2) resource constraints; (3) unstable sharing of broadcast channel; and (4) movements of nodes. Controlling congestion in MANETs poses additional requirements beyond just optimizing bandwidth usage and ensuring fair distribution of network traffic. This is because congestion can stem not only from network activity, but also from various external variables such as signal interference, wireless signal noise, node movement, and competition [4]. Most applications of a network are predefined application missions. Thus, the network topology must be strongly connected and all nodes must be collaboratively responding all times to achieve their tasks as they should be. Furthermore, in order to meet the energy and latency requirements, the length of the inter-node communication links may be extremely limited. The middle node that acts as the network's relay often endures heavy network congestion. Energy-efficient dynamic routing is necessary for the mobile ad hoc network since this feature solves the question of how the network is actually useful [5]. However, if a node suddenly fails due to the excessive consumption of power by the node that acts as relay node. This node may cause violate such a connectivity goal and the network to partition into disjoint blocks. As a result, modern systems incur significant state-update cost since each node must keep up-to-date partial knowledge of the network state. Thus leading to decreased network lifetime and increased energy consumption. In our view, describing the various routing protocols and their pros/cons with respect to well-Defined metrics is important to provide the readers key insight on the current state-of-the-art. In this paper, we extensively Survey the recently proposed routing protocols for optimizing energy efficient consumption for MANET networks while systematically identifying their advantages and disadvantages. The aims of this literature review are:

- To analyze e**valuation metrics** on solutions for MANETs in terms of energy consumption optimization.
- To review the current state of research on the existing optimization of energy consumption solutions for MANETs.
- Identify the limitations of the-State-of-the-Art energy consumption optimization solutions for MANETs.

The following describes the structure of this paper: Section 2 analyzes evaluation metrics on solutions for MANETs related to power consumption optimization; Section 3 reviews the current state of research on the existing energy consumption optimization solutions for MANETs; Section 4 Limitations the-State-of-the-Art energy consumption optimization solutions for MANETs; and Section 5 concludes the paper.

2. EVALUATION METRICS

Following are many of the key evaluation metrics that are generally considered while designing optimizing energy efficient consumption routing protocols for MANET networks.

2.1. Network lifetime

This metric leads to enhance the network's lifespan and try to minimize network segmentation. Then any node can contact with other nodes in MANET network. According to [6], the authors proposed that it is necessary to identify the group of MANET network important nodes. The entire network will divide into several sub-MANET networks if these nodes disconnect. In order to ensure connectivity between these sections, we must rely on specific mobile nodes. To split the load across these crucial nodes equally, the forwarding method will need to be adjusted using a "load-balancing" approach. However, problems can arise when multiple parts of the network are connected to nodes that act as relay nodes as shown in Fig. 1. For instance, in the topology of network nodes (N5, N12, N11 and N13) are critical nodes. The network will fragment into numerous smaller networks if a node fails for any reason. Here, it's crucial to make sure that all key nodes have comparable power consumption. In order to optimize network lifespan power consumption. Nonetheless, it is a difficult effort to guarantee that the important nodes' power consumption rate measure is equal. However, when we expect good performance by reducing end-to-end delay, optimizing network lifetime becomes a complicated problem.

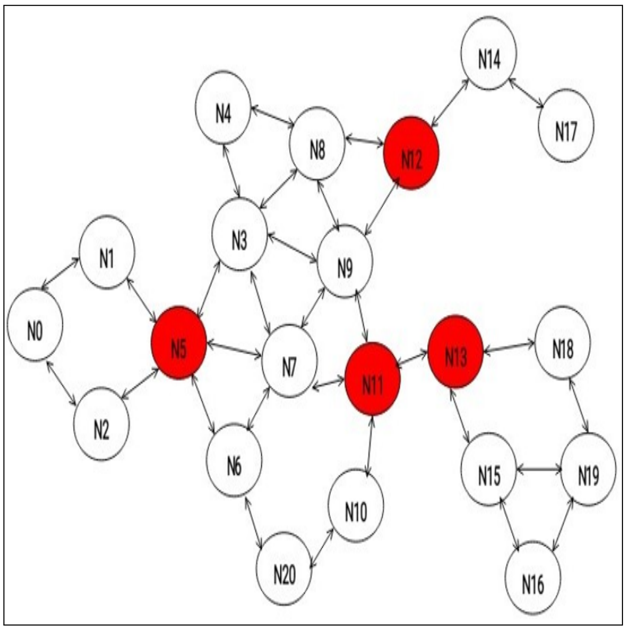

Figure 1. The problem of disjointing MANET network's topology into sub networks.

2.2. Fairness

Fairness, within the framework of a MANET's effort to balance energy usage across all nodes is difficult task [7]. In order to increase the lifespan of AODV Routing Protocols, which are adjusted to improve the networks lifespan in MANETs, AL-Gabri Malek developed a new energy model. For ad hoc routing protocols, energy-saving routing algorithms use two basic concepts: First, send each packet using the least amount of energy possible. Optimizing the network lifetime to the greatest extent feasible is the second goal. Energy suggests that the shortest path might not always be the best one. Their mechanism can optimize energy consumption by choosing the routing path involving the minimum total transmission cost from all possible routing sets, avoiding the unbalanced energy consumption of each node during route selection and route failure caused by too large node energy, thereby prolonging network lifetime. However, this model appropriates for some situations. For example, when the nodes' positions are identified and they don't move, it can perform the balancing of energy consumption.

2.3. Reliability

Service that is Reliability guaranteed and continuous for every node is referred to as reliability. It is an important performance measure especially in group-oriented applications that use multicast flows. Delivering the content of real-time multimedia applications must fulfill QoS requirements. With considering energy conservation the QoS should emphasize a lot of metrics, for instance, energy efficiency, throughput, and reliability.

2.4. Packet loss Ratio

Packet's losses occur when the data's rate arrival at a given node exceeds the data's rate of packet transmission. Packet loss in MANETs occurs as a result of queue overflow which is a serious issue because the delay is increased and resources of network are wasted. There could be a number of reasons for packet loss; including interface queue overflow, node mobility, and no availability of next hop nodes. Due to the frequent data transmission from various sources, the forwarding node's queue may overflow, resulting in packet drops and a decline in network performance [8].

2.5. Network Congestion

Actually, when there is more transmitted demand than there is available capacity, network congestion arises. MANET's congestion control is a complex problem that depends on several criteria, including scalability, network architecture, and routing protocols. And to overcome this factor we should take into account to address and control network segregation, problems that related to hidden terminals, mobility of nodes, and constraints on [3]. It can occur because other factors. For instance, noise of wireless signal, competition, and movement [4].

2.6. Consumption of power during packet receiving and transmitting

This metric demonstrates the extent to which the general power usage for sending and receiving packets can be decreased. Singh and Raghavendra [9] introduced method that was Power-Aware Multi-Access Protocol with Signalling (PAMAS), skillfully initiated a method to measure the Energy consumption per Packet receiving and transmitting. The authors achieved optimization by reducing energy consumption per packet receiving and transmitting. The enhancing in other measures (i.e., network lifespan and balancing between all nodes energy consumption) were improved. According to [6], when there is less traffic, using this measurement to evaluate the routes may result in choosing a route that is similar to the ones chosen by the least number of hops metric. So, we can't predict much change in energy consumption performance. Nevertheless, the presence of significant traffic, the chosen route based on this metric may deviate from the one chosen using minimum intermediate node sending measure. Consequently, if there are many nodes along the selected route are highly congested, the power consumption for each packet at these congested nodes will differ. This is due to the potential for greater fluctuations in the level of contention at any node which is congested, ultimately resulting in varying levels of power consumption for each packet. This metric has the potential to prioritize the transfer of packets in excessively congested regions of the network. However, relying on this metric without considering the remaining energy levels of each node may result in an unfair distribution of energy reserves throughout the network. Ultimately, we can determine these metric didn't contribute to prolonging the lifespan of the network.

2.7. Balancing in energy consumption level for all nodes in the network

This metric's basis is the idea that every mobile device in the network is extremely important, and that any node shutting down suddenly for any reason will negatively impact the network's throughput and latency. Additionally, while creating any forwarding system, we must ensure that no single mobile node has more overload than any other [6].

2.8. Reducing price per packet (PPP)

The PPP metric calculates the overall cost of sending a packet through specific routes. The key benefits of this measure include: (1) enhancing the integration of battery-related functions into the routing system design; (2) providing a straightforward indicator of congestion levels along a chosen path. If we wish to increase the lifespan of every node in a network, we must use this measure rather than the power dispersed per packet metrics [6].

3. REVIEWS THE CURRENT RESEARCHES OF ENERGY CONSUMPTION OPTIMIZATION SOLUTIONS FOR MANET

This section includes a list of categorizing and analyzing energy- efficiency consumption routing algorithms for MANET networks. The basic design, operations, benefits and drawbacks of every routing protocol are explained briefly. Moreover, each routing protocol is evaluated based on a given set of metrics. Figure 2 shows the

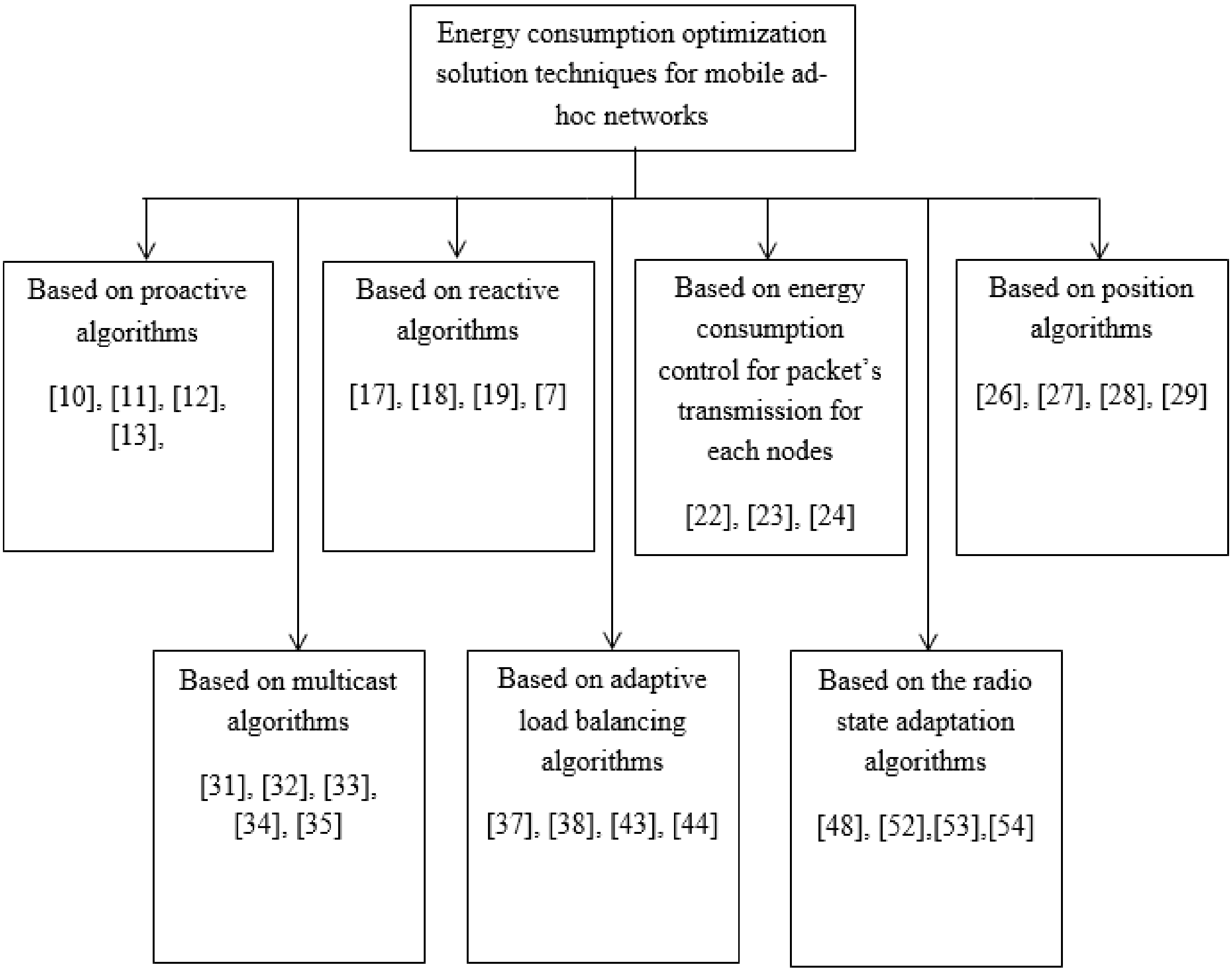

Figure 2. Classifications of energy optimization solutions for MANET networks.

classification of the surveyed algorithms of routing based on their operation. The most often energy consumption optimization methods in MANET are categorized as follows:

3.1. Energy consumption optimization solutions used proactive algorithms

In proactive schemes, every node updates its table of routing by communicating with other nodes on the state of the network's topology. Because there are no delays in this scheme, proactive algorithm is able to find out the optimal route right away. Routing by using Proactive algorithms based on the method employed. For instance, OLSR depends on link-state algorithm. The most well-known energy efficient routing scheme that based on link state is OLSR routing protocol. Each node uses this information to calculate a path to every destination in the MANET'S. The OLSR protocol chooses a small group of nodes from many neighbor hosts in order to minimize overheads due to TC message traffic. These sets of nodes are known multi point relays (MPR). This class provides an overview of some recent studies on proactive techniques for optimizing energy consumption in MANET'S. Table 1 presents metrics evaluation and performance factors for this category. To efficiently reduce the latency of packet transmission between hobs, the packet delivery rate, and the energy usage of regulating the network's architecture, numerous studies tried enhancing the MPR set selection. In [10], the authors proposed improving techniques of enhancing the Improved Energy-Efficient PEGASIS-Based (IEEPB) Protocol to use K-means algorithm to reduce energy usage and increase network's lifespan. This scheme showed a decrease in data delivery latency, an increase in network lifespan by reducing sensor node energy consumption, a decreasing in the separation among connected nodes by using shorter chains, and a decreasing in the load on the sparse nodes by using sink mobility. This work doesn't consider the energy usage because of controlling to choose local and outer optimal paths, and higher dense network. In [11], the authors introduced a scheme for routing MMSPEED protocol that takes resid-

Table 1: Energy consumption optimization solutions based on proactive algorithms for MANET.

Year	Ref.	Methodology	Problem/ objective	Evaluation	Features	Limitations
2023	[10]	the authors proposed improving techniques of enhancing the Improved Energy-Efficient PEGASIS-Based (IEEPB) Protocol to lower energy usage and increase the lifespan of the network by using the K-means algorithm.	to increase the network's lifetime. Energy economy is the primary concern because sensor nodes have limited energy resources.	This protocol is simulated using the Matlab R2015b simulator	By reducing the power usage, this technique increased lifespan and reduced the time it takes to provide data.	This work do not consider the energy consumption because of controlling to choose local and outer optimal paths, and higher dense network.
2019	[11]	They introduced a scheme for routing MMSPEED protocol that takes residual energy into account, providing real-time traffic with energy-efficient routes	To enhance the network's lifespan .	Network Simulator 3 (NS3) is used for simulation	the traffic load is efficiently distributed across the network's nodes, and the suggested protocol extends the network's average node .	The limitation of this scheme is not suitable in high dense network.
2019	[12]	Jiayu et al. proposed a method by using (EWMA) of (TIM).	to modify the architecture update intervals in algorithm of proactive	They used network simulator 2 (NS2).	Simulation experiments demonstrated that in reasonably stable circumstances, EWMA of TIM efficiently reduces needless protocol overhead and demonstrates superior interruption reduction compared to TIM's immediate value	This work is not suitable in high dense network, and higher mobility.
2015	[13]	Jabbar et al.introduced a multi-metric criterion-based proactive forwarding in MANET'S.	To choose a composite energy cost of the paths by using the route calculation algorithm.	They showed the performance by using ns-2 simulation.	This scheme improved the performance in terms of power consumption, PDR, , and latency.	These work didn't address higher overheads because of more traffic and energy consumption of controlling energy cost for each route.

ual energy into account, providing real-time traffic with energy-efficient routes. The authors examined proactive methods' energy efficiency, with a focus on AODV, DSR, and OLSR routing protocols. Different features of these protocols apply to wireless routing. Network Simulator 3 (NS3) is used for simulation of the AODV and DSR protocols, as well as the OLSR (proactive protocol). The results of this work demonstrated that the traffic load is efficiently distributed across the network's nodes, and the suggested protocol extends the network's average node life. It also makes the protocol more reliable. In [13], they proposed a multi-metric criterion-based proactive forwarding for MANET. The objective of this method is to choose the paths' cost of energy by using an algorithm's route calculation in terms of each node's transmission power consumption and residual energy. This technique reduced PDR, latency, and energy usage of MANET'S. Because of increased traffic and energy consumption in order to limit energy costs for each route, these efforts did not address excessive overheads. Proactive schemes have some benefits such as lower latency, high Packet delivery ratio, but the largest overhead appears in these techniques because of higher mobility of nodes resulting in malfunction of topology instability metric. Jiayu et al. proposed a method to dynamically modify the topology update intervals in proactive algorithms. Simulation experiments demonstrated that in reasonably stable circumstances, EWMA of TIM efficiently reduces needless protocol overhead and demonstrates superior interruption reduction compared to TIM's immediate value [12].

Table 2: Energy consumption optimization solutions based on reactive algorithms for MANET.

Year	Ref.	Methodology	Problem/ objective	Evaluation	Features	Limitations
2023	[14]	the authors introduced a novel algorithm based on genetic algorithms that uses crossover and mutation	to determine the shortest path between nodes, resulting in the most energy-efficient route.	They used NS-2 to make simulation for their protocol	the validation demonstrated that this scheme enhances the performancein terms of overhead, packet delivery ratio, energy consumption, and delay.	This work didn't consider the overall end to end delay because of higher dense networks.
2019	[15]	Er-rouidi et al. Presented An energy-efficient AODV-based routing protocol (EE-AODV).	to acquire precise data related to the energy used for packet transmission.	They used NS-2 to make simulation for their protocol	the EE-AODV compared with AODV, it showed significantly decreasing in the nodes' energy consumption.	The limitation of this scheme is the latency in higher dense networks.
2014	[16]	authors proposed a new method called EPAR.	to determine a node's capacity by considering both the projected energy consumption in sending packets towards a specified link and its remaining battery power.	They used network simulator (NS2).	It showed that despite attaining a high PDR, EPAR lowers the mean delay and exceeding 20 percent of the total power used.	This work didn't ingest high mobility. When the nodes of network are moving fast, the overall time will be extremely high.
2010	[7]	AL-Gabri Malek eta a. proposed a new energy-aware mechanism, called EA_AODV, which is based on AODV.	Increasing network lifespan and minimize power usage by balancing energy usage mechanism.	They showed the performance by using ns-2 simulation.	This work achieves improvement in terms of two important metrics. First, increasing the lifespan. Second, preforming the balance between nodes in terms of energy consumption.	This work didn't consider about the mobility, the overall delay and higher dense networks.

The proposed methods don't mention many important metrics. For instance, scalability, quality of service metrics, and higher mobility of nodes are not considered.

3.2. Energy consumption optimization solutions used reactive algorithms

Reactive protocols establish a route when two nodes need to connect with one another, rather than continuously maintaining a route between every pair of network nodes. A source node first looks for its route in the route table to see if there is a route before sending data to end node. Route discovery becomes on-demand if it is unable to locate a legitimate route and instead searches for a path to the destination. The route is still in hold as long as the connection is maintained [17, 18]. Of all the reactive algorithms for MANET networks, the AODV routing protocol is the most well-known [19]. Energy conservation when transferring multimedia data via single MANETs is greatly impacted by the delay's stability channel. In [14], The energy of the nodes and their distance from one another were deemed important considerations by the writers. One of the most effective reactive routing techniques, the ad hoc on-demand multipath distance vector (AOMDV) protocol, was used to overcome the unpredictable nature of the routing path in MANETs. In addition, the authors introduced a novel algorithm based on genetic algorithms that use crossover and mutation to determine the shortest path between nodes, resulting in the most energy-efficient route. The outcomes of this protocol has compared with current schemes such as AOMDV and DSR. The performance evaluation of this algorithm conducted using several critical measures, including routing overhead, PDR, energy usage, and delay. The validation demonstrated that this scheme enhances the performance of those critical metrics where mentioned above. This work didn't take into account one of the most important metrics of the performance which is the overall end to end delay. In [7], AL-Gabri Malek et al presented a novel energy model that extends the lifetime of modified AODV Routing Protocol, hence extending the network lifetime in (MANETs). For MANET′s routing protocols, an energy-efficient routing algorithm's two fundamental ideas are: First, send each packet using the minimum usage of power as possible. Second, optimize the network′s lifespan to the greatest extent in the network as possible. Energy suggests that the shortest path might not always be the best one. This study proposed a new energy-aware mechanism, called EA$_{AODV}$, which is based on the classical AODV. This work achieves improvement in terms of two important metrics: First, maximizing the network's lifespan. Second, preform the balancing nodes energy consumption. This work didn't consider about the mobility, the overall delay, and higher dense network. In [15], an energy-efficient AODV (EE-AODV) was presented by Er-rouidi et al. Rather than being restricted to a node's current residual energy, EE-AODV considers the level at which energy is consumed during each period. The energy consumption rate enables EE-AODV to acquire precise data related to the energy used for packet transmission. This is accomplished without the need for a difficult computation of these quantities. With the aid of remaining power and the anticipated rate of consumption, EE-AODV determines a node's more precise remaining lifetime. When the EE-AODV was contrasted with AODV, it was shown to significantly decrease the nodes' energy consumption. Authors of [16] presented The Efficient Power-Aware Routing (EPAR) method. It determines a node's capacity by considering both the projected energy consumption in sending packets towards a specified link and its remaining battery power. With minimum value of remaining packet transmission capacity, the path with the highest packet capacity is chosen by EPAR. The mini-max formulation is used to achieve this objective. In various network scales, EPAR was contrasted with two other MANET's routing algorithms MTPR in network with low, medium, and high dense network with considering energy consumption. It was discovered that despite attaining a high PDR, EPAR lowers the mean delay and exceeding 20 percent of the total power used. This work does not ingest high mobility. When the nodes of network are moving fast, the overall time will be extremely high.

3.3. Energy consumption optimization solutions based on nodes′ energy transmission algorithms

In general terms, each node is free to choose its own routing scheme, rate adaption technique, and transmission energy level. Alternatively, the node would detect and interfere with many neighbor's nodes if the transmission energy level was extremely high. In this case, Channel saturation, contentious issues, and collisions could happen. Meanwhile, in the event that the energy level of transmission is below the critical level, a node may detect relatively few neighbors, if any, resulting in an unsuccessful transfer. By choosing the optimal path such that nodes use the minimum power feasible, a transmission of energy consumption control routing protocol reduces energy consumption [23]. To determine the optimal routing path, a energy efficient routing protocol actually employs multiple energy-related metrics. These energy-related metrics include: (1) minimizing the power required to transmit wireless signals across the path; (2) ensuring that the intermediate node has enough residual power of battery; (3) preventing network partitioning due to overused nodes; and (4) choosing the routing path that uses the least power per packet [24]. In [20], Tabatabaei Suggested an intelligent routing technique based on symbiotic organism search (SOS) for MANET networks. Four key factors are considered while implementing the suggested strategy in dynamic environments: bandwidth, the amount of battery life left, the speed of movement, and hops count. According to the simulation results, the symbioses search algorithm's learning process significantly affects network performance and performs better than the FBRP scheme in terms of throughput, data loss, packet delivery, and hop count. This work does not consider the latency, lifetime, and the overload for dense network. In [22], the authors proposed the energy-efficient and link quality-aware routing protocol (ELRPP). This routing scheme features a variable control of transmission power and chooses a route related to three metrics: residual energy, signal-to-noise ratio, and link quality. Control is specifically utilized in the route discovery technique to cluster nodes according to their transmission radii in order to find the nodes with the best transmit power. Consequently, ELRPP extends network lifetime, reduces whole consumption of energy for entire network, and preserves residual power. It increases network throughput and reduces network overhead. This work didn't consider about the scalability of the network, higher mobility, and high dense network. In a multicast situation, Yang et al. [21] investigated consumption of energy and PDR while accounting for each node's transmission energy control. In multicasts case, the packet from the sending node could reach up to several different relay nodes. These relay nodes may send the packet to any one of the several destination nodes before the packet's lifespan expires. The scheme's settings improve power consumption and PDR performance, according to the authors' validation of the plan. This scheme's primary flaw is overhead in highly dense networks.

Table 3: Energy consumption optimization solutions based on energy control for transmission and reception for all nodes in MANET.

Year	Ref.	Methodology	Problem/ objective	Evaluation	Features	Limitations
2023	[20]	Tabatabaei, Shayesteh. Suggested an intelligent routing scheme depended on symbiotic organism search (SOS) for MANET.	To Enhance network performance for instance, throughput, data loss, packet delivery, and hop count.	They used NS-2 to make simulation for their protocol	this protocol performs better than the FBRP scheme in those metrics throughput, data loss, packet delivery, and hop count.	This work didn't consider the latency, lifetime, and the overload for dense network.
2019	[21]	Yang et al. Investigated usage of energy and PDR while accounting for each node's transmission energy control.	Decreasingconsumption of energy and PDR	They used NS-2 to make simulation for their protocol	The validation of their scheme showed that the scheme's parameters enhancing power consumption and PDR.	This scheme's primary flaw is overhead in highly dense networks.
2015	[22]	the authors proposed (ELRPP).	to determine the best transmission of power by grouping them into Clusters based on their transmission radii.	They used network simulator (NS2).	it performs better in randomly situation of network in order to enhancing energy consumption. These variables may raise the network's throughput.	The authors didn't consider the overall end to end delay when they designed the algorithm in terms of choosing a route.

3.4. Energy consumption optimization solutions based on position algorithms

Whereas the decision of routing is depended on the destination node's position, which is determined by location services, a position-based routing algorithm uses each node's geographic location to determine the optimal routing path [25].

In [26], Suganthi, R., et al. Proposed a novel Efficient Energy Balanced Less Loss Routing (TER) protocol for MANET biased on trust with the help of location information. Through careful selection of the intermediate forwarding nodes, this protocol enhances network performance. Using the Efficient Parameter (EP), the Source Node selects a single neighbor to be its next hop node. The residual energy, distance, occupied queue space, and that node's velocity are used to compute the EP. The node that uses the most EP is proposed as the node that follows. By lowering the quantity of channeling messages, this protocol lowers the network's path-finding overhead. By reducing the likelihood of data loss, it enhances throughput and improves PDR.

In [27], Saoud, Bilal. et al. Introduced a novel routing strategy for WSN to reduce energy usage and increase WSN lifetime. A new technique is proposed that considers the energy at each sensor node to determine the optimal choice of cluster head (CH). This technique has been proposed based on Firefly Algorithm. According to experimental findings, this scheme performs better energy consumption and packet delivery between sensor nodes and base station than the examined routing protocols. This protocol performs increasing in network lifetime. The main limitation is the confusion between selecting the best route to the outer clusters and the best route inside own cluster. In [28], the authors introduced a novel routing algorithm biased on position called The Localized Energy-Aware Restricted Neighborhood (LEARN) location routing protocol. This considers being an intriguing energy-efficient method. The node chooses the neighbor node with the maximum energy mileage, for instance, the distance traveled per energy consumption unit. This node chooses as the next node in order to ensure a route with higher energy efficiency. the LEARN method operates as a greedy routing algorithm. One constant component of the ideal energy consumption is the entire amount of power used by the identified path. In terms of speed and latency, LEARN performs similarly to a standard location-based routing protocol. Because LEARN only considers the energy usage of the path and ignores other important considerations while choosing the optimal neighbors. These variables may

Table 4: Energy consumption optimization solutions based on position algorithms for MANET.

Year	Ref.	Methodology	Problem/ objective	Evaluation	Features	Limitations
2023	[26]	Suganthi, R., et al. Proposed a novel Efficient Energy Balanced Less Loss Routing (TER) protocol for MANETs based on trust with using of location information.	To Enhance network performance. Using the Efficient Parameter (EP) through careful selection of the intermediate forwarding nodes.	They used NS-2 to make simulation for their protocol	this protocol lowers the network's pathfinding overhead. By reducing the likelihood of data loss, it enhances throughput and improves PDR.	This protocol didn't consider the solution for many struggles. For instance, inaccurate location, and overheads because of broadcasting.
2023	[27]	Saoud, Bilal, et al. introduced a novel routing algorithm strategy for WSN based on Firefly Algorithm	Reducing energy usage and increase WSN lifetime.	They used NS-2 to make simulation for their protocol	this scheme performs better energy usage and packet delivery between sensor nodes and base station than the examined routing protocols. This protocol also performs increasing in network lifetime.	The main limitation of this protocol is the confusion between selecting the best route to the outer clusters and the best route inside own cluster.
2006	[28]	the authors introduced a novel routing algorithm (LEARN)	to ensure the high-efficient power of a path.	They used network simulator (NS2).	it performs lower energy consumption. Those variables may raise the network's throughput per energy usage scale.	The authors didn't consider the overall end to end delay when they designed the algorithm in terms of choosing a route.
2010	[29]	he authors proposed scheme to optimize energy consumption (LEER) algorithm.	to improve energy efficiency and decrease the overall latency.	They showed the performance by using ns-2 simulation.	This scheme optimized the overall end to end delay and enhanced energy consumption	This work didn't consider about the scalability of the network, higher mobility, and high dense network .

raise the network's throughput per energy consumption scale. The authors didn't consider the overall end to end delay when they designed the algorithm in terms of choosing the path. In [29], the authors proposed scheme to optimize energy consumption which called The Location-aided Energy-Efficient Routing (LEER) algorithm. During the route discovery phase, each node has a table which contains the node location data for the entire network. The sender node could determine its destination's location from this table. Less route discovery messages are used by intermediate nodes in LEER to send packets to their destination. This is acquired by having a GPS and an appropriate packet block that has the following contents: the message-ID, the source location (X,Y), the destination location (X,Y), the packet's total length, and the packet's data. This scheme optimized the overall latency, but it do not consider about scalability in larger networks.

3.5. Energy consumption optimization solutions based on multicast algorithms

Multicast flows are used by group-oriented applications, where specific quality of service requirements must be met for the real-time applications data delivery. Strict quality of service requirements must be met while saving energy and taking the present application's QoS profile into account [35]. In [30], the authors presented a new multicast routing method using source packet dumping. Peer-to-peer networks' multicast routing was the main focus of this approach. Based on hop distance limitations, connectivity routes between providers and group members are created as single or multi-hop configurations. In order to ensure effective data distribution, they also suggested a probabilistic data transmission method. The validation results demonstrated how well the recommended routing protocol performed in relation to the characteristics of MANET. This method provides efficient

Table 5: Energy consumption optimization solutions based on multicast algorithms for MANET.

Year	Ref.	Methodology	Problem/ objective	Evaluation	Features	Limitations
2023	[30]	the authors presented a new multicast routing method using source packet dumping.They also proposed a probabilistic data forwarding technique.	To guarantee efficient data dissemination	They used NS-2 to make simulation for their protocol	This method provide efficient data distribution, and it is robust against topology modifications.	Some nodes suffer from higher energy consumption because they act as intermediate nodes which do more tasks than others.
2015	[31]	They introduced a new protocol (RERMR).	This routing algorithm aims to extend lifespan of network and enhance path dependability and forwarding rate.	They have simulated their results using NS2.34 simulator.	This work Optimized many performance metrics. For Instance, latency, overhead, packet losses ratio, Stability.	The most drawback of this work that depends on assumptions which are impossible to practice in reality.
2018	[32]	the authors suggested a new (REA-MAODV) routing protocol	To guarantee routes to be more energy-efficiency	They used network simulator (NS2).	The results demonstrated these scheme, on average, used 45% less energy and had a more balanced use of energy than MAODV. Additionally, this method managed to lower network end-to-end latency (21%) and increases PDR (19%).	This scheme didn't take into account high mobility And high dense network
2008	[33]	The authors introduced the Predictive Energy-efficient Multicast Algorithm (PEMA)	to address overhead and scalability concerns.	They showed the performance by using ns-2 simulation.	this approach better for the scalability of greater density networks.	This scheme didn't consider the overall end to end delay, and the network lifetime
2019	[34]	They introduced a new scheme (WEEM).	To select the optimal route with highest lifespan	They showed the performance by using ns-2 simulation.	this algorithm achieves higher packet delivery ratios and alive node ratios with least cost of controlling.	This scheme didn't take into account higher mobility And higher dense network

data distribution, and it is robust against topology modifications. In [31], they introduced a new protocol known as Residual-Energy-based Reliable Multicast Routing (RERMR). This routing algorithm extends the network's lifespan and enhances path dependability and forwarding rate. An energy model that monitors the nodes' remaining energy is used in this technique to select paths with high power nodes in order to maximize the network lifetime. It enhances data transmission by choosing the most dependable route for data forwarding. A model network is also utilized in this algorithm to assess a path's reliability. RERMR selects a higher-quality path with lower energy consumption and packet loss while reducing the number of route request packets and retransmissions. This work optimized many performance metrics. For instance, latency, overheads, packet losses ratio, stability are enhanced. The most drawback of this work is that depends on assumptions which are impossible to practice in reality. In [32], the authors suggested a reliable and energy-aware multicast ad hoc on demand distance vector (REA-MAODV) routing protocol which is based on MAODV (multicast ad hoc on demand distance vector) protocol. REA-MAODV is a dependable and energy-conscious routing mechanism. This method finds energy-efficient multicast routes from a source node to a collection of destination nodes. In addition to updating shorter, high-consumption tree branches, this algorithm which is multicast routing protocol can also create a multicast tree with supporting branches. Three steps were taken in order to improve the MAODV protocol: (1) choosing a path with high energy consumption, (2) selecting a procedure, including auxiliary branches, and (3) preserving the multicast tree technique. According to the simulation results in NS-2, REA-MAODV had better energy consumption balance and used, on average, 45% less energy than MAODV. Additionally, this method managed to lower network end-to-end latency (21%) and increase packet delivery rate (19%). For large-scale mobile ad-hoc networks, the authors introduced the Predictive Energy-efficient Multicast Algorithm (PEMA) [33]. Network statistical characteristics are used by PEMA to address overhead and scalability concerns. This scheme do not consider about the information of route or network topology Because it depends on other metrics to choose the optimal route while taking path energy values into account. For example, nodes' positions, the average density, and the special unicast routes from the sending node to others. The fact that the algorithm's speed depends on the group's size makes this approach better for the scalability of greater density networks. In [34], they introduced a new scheme called the Weight-based Energy-efficient Multicasting (WEEM). In this algorithm, the optimal path is determined by taking the one with the highest lifespan. Weight of the path is determined by considering three factors: First, residual energy. Second, nodes in a path's capacity transmit multicast packets. Third, multicast destinations numbers, those are located along that path. The path with minimal delay is given priority if multiple paths have equal weight. Comprehensive simulation findings showed that compared to other protocols, this algorithm achieves higher packet delivery ratios and a live node ratios with least cost of controlling.

3.6. Energy consumption optimization solutions based on adaptive load-balancing algorithms

A load balancing algorithms with energy efficiency based on distribution makes good use of under utilized full of energy nodes to choose the best route and distributes the load especially among them appropriately. By properly choosing the route, these schemes primarily focus on effectively distributing the load among underutilized, higher-energy-rich nodes. However, in these kinds of designs, the shortest path may not always be chosen. However, the objective of these algorithms is not to calculate the minimal power consumption path; rather, they try to keep some low-energy nodes from being overused, which extends the network's lifetime [40]. In [36], the authors proposed developing of an Enhanced Monarch Butterfly Optimization Algorithm (EMBOA) for the route in MANET in order to attain an enhanced data delivery rate. Initially, the base aim is to balance load and optimize routing for energy efficiency using several optimization techniques. Several optimization algorithms are employed in the clustering process of nodes from the mobile component of mobile ad-hoc networks. By improving the data delivery ratio with the least amount of routing overhead, estimating residual energy and bandwidth aids in load balancing. Next, the EMBOA is utilized to lower energy consumption while increasing the efficacy and efficiency of multipath multicast routing and load balancing in MANET. This work outperforms the present by about 5% in terms of MANET routing performance. In [37], Angel, M. Anuja et.al. Introduced Hybrid Emperor Penguin Optimization (EPO) to address load balancing, improve security, and lower energy usage in wireless sensor networks. The Atom Search Optimization (ASO) algorithm and the hybrid EPO algorithm are merged to enhance the EPO algorithm's updating capability. To increase WSN performance, three main goal functions, load balancing, increased security, and lower energy usage, should be taken into consideration. By using the suggested hybrid EPO, the best clustering strategy achieve load balancing. A significant drawback of several energy-aware approaches [6, 41–44] is that they were predicated on a static network model. This premise streamlines their investigations, but it also practically limits the validity of their proposed results. It is challenging to predict which policies, or which class of policies, will work in various circumstances. Kim et al. [38] suggested a novel routing parameter called the drain rate that forecasts a node's lifetime based on the traffic situation at the time. They presented the Minimum Drain Rate (MDR) mechanism, which establishes pathways by combining the drain rate and remaining battery capacity. This scheme describes how a high node with higher level of energy along a route may not be guaranteed to properly maintain the battery's energy throughout the course of heavy traffic conditions if its residual power measure is the only one taken into account. This implies that a node may accept if it is sufficiently skilled related to the residual energy parameter. Some authors designed their algorithms based on The link disjointed route strategy. This rule does not provide a connection that unites every path, even though it permits the same relaying node. Disjointed-based routing schemes can offer a number of benefits over non-disjointed-based routing strategies, according to Mueller et al [39] investigated multipath routing problems in MANETs. Multiple paths can be established between a single source and a single destination node thanks to multipath routing. Usually, it is suggested to offer load balancing or to improve fault tolerance, or the dependability of data transmission. The restricted bandwidth between nodes in MANETs makes load balancing very crucial. This scheme didn't consider the high dense network, high mobility and the energy consumption because of using multipath technique. However, completely

Table 6: Table 6: Energy consumption optimization solutions based on load balancing adaptation algorithms for MANET.

Year	Ref.	Methodology	Problem/ objective	Evaluation	Features	Limitations
2023	[36]	the authors proposed developing of (EM-BOA) for the route in mobile ad-hoc networks	to attain an enhanced data delivery rate. Initially, and to balance load and optimize routing for energy efficiency using several optimization techniques.	They used NS-2 to make simulation for their protocol	This work outperforms the present by about 5% in terms of MANET routing performance.	This scheme didn't consider the energy usage by using multipath and the latency
2022	[37]	Angel, M. Anuja et.al introduced (EPO), and (ASO) algorithm and the hybrid EPO algorithm are merged to enhance the EPO algorithm's updating capability	to address load balancing, improve security, and lower energy consumption	The designed communication stack consisting of three layers (Application, Network and MAC) has been developed in NesC with the goal of deploying a testbed on actual sensor devices running the TinyOS operating system.	This scheme optimizes load balancing, increases security, and reduces energy usage.	This work didn't consider delay for the whole network, and mobility
2002	[38]	They presented the (MDR) mechanism,	This scheme forecasts a node's lifetime based on the traffic situation at the time.	They used network simulator (NS2).	Enhances high load balancing	This scheme did not consider the latency and high mobility And the overall usage of energy
2004	[39]	Mueller et al. investigated multipath routing problems in MANETs.	To overcomes the most issues of multipath routing. The main aim is to maximize the reliability of data transmission	They showed the performance by using ns-2 imulation.	This work outperforms reliability, load-balancing, and conservation of energy	This scheme didn't consider the high dense network , high mobility and the energy consumption because of using multipath technique

estimating discontinuous paths in MANET is not always feasible under high mobility conditions [45].

3.7. Energy consumption optimization solutions based on adaptation of the radio state algorithms

Without a doubt, in the current era of the technological and electronic Renaissance, smart cities and electronic services are growing every day. Numerous services offered by both the public and private sectors have evolved into intelligent electronic systems that rely on algorithms and software. In accordance with work policies, the smart city environment is made up of numerous associated apps and components. The connection between wireless sensing networks and smart cities became evident, though, as many smart city applications primarily rely on sensing and wireless sensors, as illustrated in Fig. 1 [50, 51]. In mobile ad-hoc networks such as wireless sensor network that based on sleepy mode algorithms proposed to overcome wasting the nodes' power with inefficiently energy consumption. For instance, the network node's power consumption during packet exchange is substantial. A wireless node's communication to another could be overheard by any potential neighbor in a mobile ad-hoc network. These nearby nodes all use a lot of energy even though the transmission in question has

Table 7: Energy consumption optimization solutions based on adaptation of the radio state algorithms for MANET.

Year	Ref.	Methodology	Problem/ objective	Evaluation	Features	Limitations
2021	[46]	proposed a new routing technique for WSNs as an improvement on EESAA protocol	schedule sensors mode between active and sleep modes to maximize network lifetime	They used NS-2 to make simulation for their protocol	The results showen that there is significant improvement in first node dead, network lifetime, cluster's head selection, and throughput compared with EESAA Protocol	The main drawback in the I-EESAA is the centralization in the propose scheme latency.
2019	[47]	Savaglio et al. Proposed new scheme based on learning MAC architecture called (QL-MAC).	decreasing energy consumption without harmful effects on the other network parameters.This offers a double benefit of 1) solving this minimization problem without the necessity of predetermining the system model and 2) providing a self-adaptive procedure to topological and other external changes.	The designed communication stack consisting of three layers (Application, Network and MAC) has been developed in NesC with the goal of deploying a testbed on actual sensor devices running the TinyOS operating system.	This scheme has significant implications for IoT services and, generally, high-density wireless communications. Low energy consumption , High scalability	This work don't consider the coexistence of intelligent and conventional nodes.
2017	[48]	The authors proposed a routing mechanism that based on AODV. This method called (EPAAODV) protocol,	The main issue is network lifetime. This technique aim to increase AODV's energy efficiency and network's lifetime	They used network simulator (NS2).	This method compared to AODV, the suggested protocol uses less energy, has fewer dead nodes, improves PDR, and has higher throughput	This scheme don't take into account the latency and high mobility
2008	[49]	Sun et al. developed Receiver-initiated MAC (RI-MAC)	To address the sources of power usage because of the issue of idle listening. The most aim is to decrease the cost based on duty cycling	They showed the performance of RI-MAC by using ns-2 simulation and measurements of an mplementation in TinyOS in a testbed.	RI-MAC outperforms X-MAC's previous asynchronous duty cycling technique in terms of throughput, packet delivery ratio, and power efficiency across an extensive range of traffic loads.	This scheme don't consider the high dense network and high mobility

nothing to do with them [9]. In [46], the authors proposed an Improved –EESAA (I-EESAA) routing protocol for heterogeneous wireless sensor networks (WSNs), which is an enhancement over the Energy Efficient Sleep Awake Aware Sensor Network Routing Protocol (EESAA). Numerous algorithms are used in the I-EESAA protocol for data transmission, sensor mode scheduling, grouping, cluster head selection, and clustering. The grouping concept, which tries to build groups of sensors with the same application type and located in the same communication range, is the basic principle of I-EESAA. One sensor in each group will remain in active mode after the group's form, while the other sensors will go into sleep mode. This scheme performs some improvement in terms of network's lifetime, the first node dying, cluster head selection process, and throughput comparing with EESAA Protocol. Some researchers designed their algorithms based on asynchronous low-duty cycle [52–54].

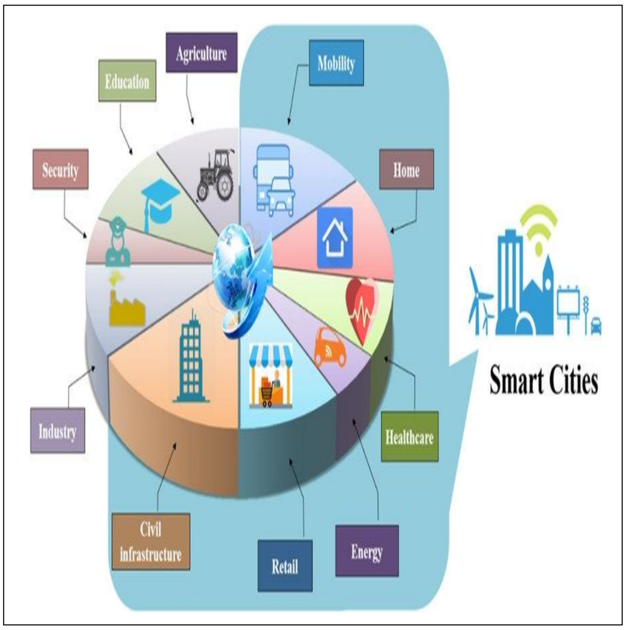

Figure 3. Internet of things (IOT) Applications for Smart Cities [51].

These methods only function well at lower traffic rates. As soon as rising of traffic intensity, such a policy's delivery of packet, energy consumption efficiency, and latency significantly deteriorate. In this case, Sun et al. [49] developed Receiver-initiated MAC (RI-MAC) to overcome the problem of high channel capturing period caused by longer preamble transmission, which may cause nodes to transmit later than usual because they must wait longer for the channel to become free. This algorithm tries to shorten the channel capture time under changing load scenarios. It is simple to implement mechanism sleepy mode and it may be included into well-known routing protocols like AODV. For instance, the authors [48] proposed a routing mechanism that based on AODV. This method called Efficient Power Aware Ad hoc On-Demand Distance Vector (EPAAODV) protocol, which makes use of the "power-save" concept to increase AODV's energy efficiency and increase network's lifetime. In [47], Savaglio et al. proposed new scheme based on learning MAC architecture called Quality-learning MAC (QL-MAC). The primary goal is to give a traditional MAC design a self-adjustable capability. The traditional MAC architecture may adjust to itself in response to different dynamic network changes, such as changes in topological order. In conclusion, these schemes which based on energy save algorithm have many limitations. First, higher delay because some nodes are in sleep mode cannot receive or transmit any packets. As a result, increasing in end-to-end delay in whole network and needing to retransmitted packets again are occurred which causes to increasing energy consumption. Second, since the objective is to increase network capacity and completely eliminate energy consumption, the nodes which act as intermediate between source and destination in any energy-inefficient path can not be placed in sleep mode [55].

4. LIMITATIONS OF THE STATE OF THE ART ENERGY CONSUMPTION OPTIMIZATION SOLUTIONS FOR MANETS

The limitations of reviewed solutions are identified in this section.

4.1. Limitations of energy consumption optimization solutions based on proactive algorithms

Mobility: mobility is considered one of the most issues in those techniques in terms of enhancing energy consumption because those techniques depend on the network's topology. In proactive algorithms, each node changes its routing table by exchanging information with other nodes about the topology of the network. The nodes need to update their routing table frequently when the network's topology has been changing because of the movement of nodes. However, those techniques unsuitable for higher mobility.

- Memory utilization: utilizing the node's memory is very high because of overheads as a result of updating the database of network's topology and routing table.
- Higher consumption of energy: this limitation occurs because of higher overheads and updating routing table frequently. Those algorithms are suitable in terms of energy consumption optimization when the network is fixed and lower density.

Scalability: increasing size of network faced many challenges because each node in MANET contain routing table to choose the optimal path and play as a router to forward data from one to another. However, limitation of scalability is appears due to updating messages are uncontrolled with high movement, and each node requires memory with high capacity to save database of network's architecture and information of routing table.

4.2. Limitations of energy consumption optimization solutions based on reactive algorithms

- Significant delays: Path computation or frequent transmission of forwarding data is not necessary for reactive routing. Once packets of data need to be sent, a reactive algorithm creates a way. In the event that the node lacks knowledge of the most recent pathway because the nodes don't contain routing table. However, the latency is very high due to the node need to wait to find out the route in order to forward packets to the destination.
- Unsuitable for real-Time applications: this limitation occurs because of the higher latency in those tech-

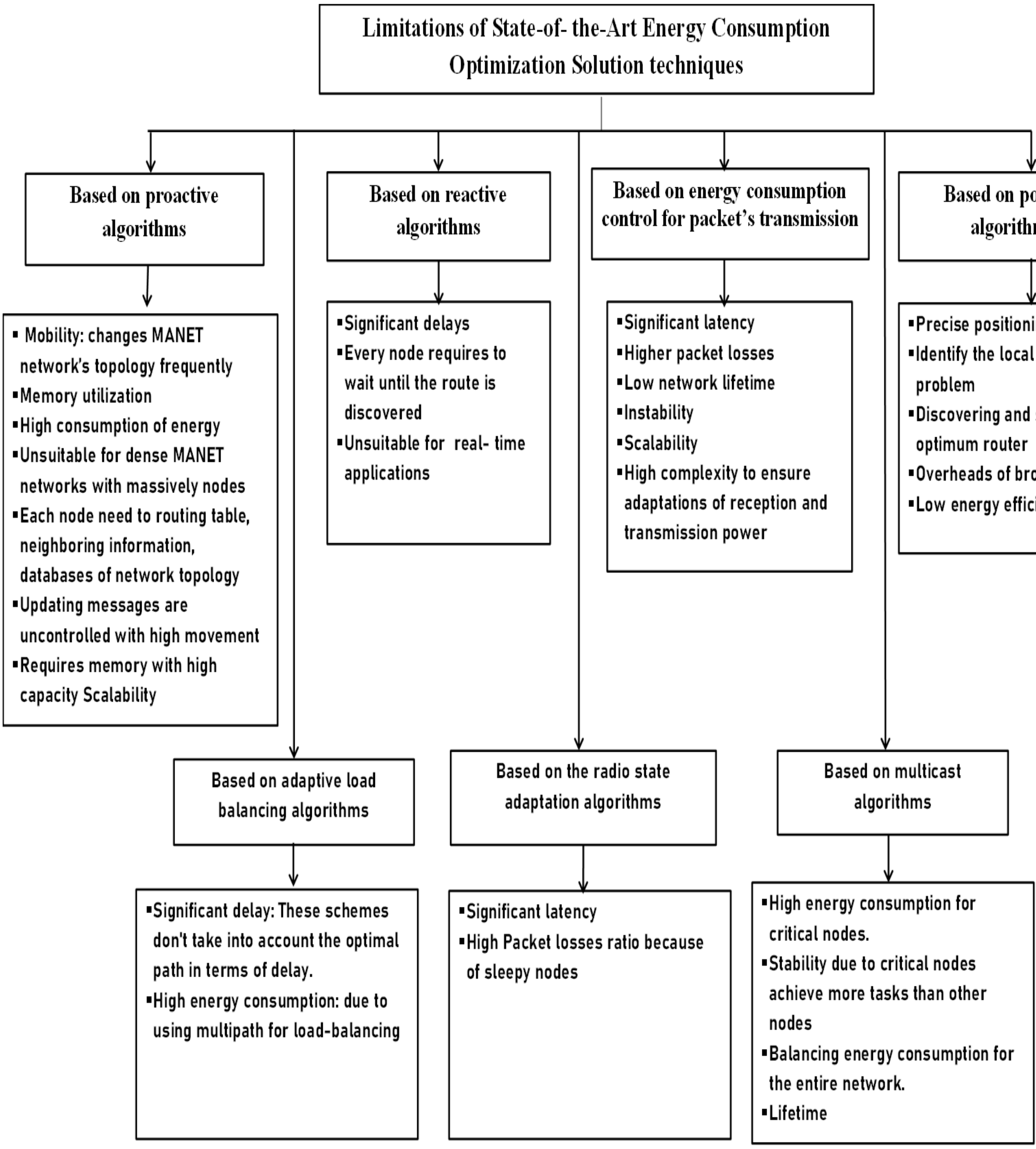

Figure 4. Limitations of state-of-the-art energy consumption optimization solutions for MANET.

niques due to every node requires to wait until the route is discovered.

4.3. Limitations of energy consumption optimization solutions based on energy consumption control of packet's transmission algorithms

· Those schemes need to meet the difficult requirement of intricate adjustments of packet's power transmission. Because there exists a significant chance causing network's separation, anytime the packet's power transmission is adjusted to lesser levels, the result is excessive delay and losing packets. Additionally, scalability and stability face many challenges due to higher complexity to ensure adaptations of packet's power transmission.

4.4. Limitations of energy consumption optimization solutions based on position algorithms

The purpose of trying to determine the optimal route, those algorithms seek to depend on the geographical position of every single site. The limitations of those schemes are: first, determining the precise position of each node. This limitation complex choosing the optimal path locally and choosing the outer optimal route to send the packet to node locate in another cluster. Second, higher overheads of broadcasting to decide which cluster the node should belong to. However, all these limitations lead to inefficiently consume the power of battery due to higher overheads and finding the precisely positions for whole clusters and which nodes should belong to the identified cluster.

4.5. Limitations of energy consumption optimization solutions based on adaptive load balancing algorithms

The affordability of intermediary hubs with a suitable energy value determines the transmission algorithms' preference, regardless of the path's size. Thus, those kinds of algorithms have an impact on the network's total latency efficiency. It's not constantly a given which the routes chosen to load distribution were the optimal ones for purposes in power savings when using many accessible routes automatically.

4.6. Limitations of energy consumption optimization solutions based on the radio state adaptation algorithms

Those techniques raise the network's entire latency because sleeping state prevents nodes from sending or receiving data. Consequently, the need for transmitting packet again leads to maximize the energy usage. Those techniques necessitate intricate node timing and organization that can be tricky for implementing for applications of MANET.

4.7. Limitations of energy consumption optimization solutions based on multicast algorithms

The intermediate node in those techniques has more power consumption. Because the intermediate node is in charge of more duties than other nodes, it can shut down earlier any others and leads to minimize the network's lifespan and separate the network into more than two parts. Current power-conscious multicast mechanisms frequently cause the network to increase controlling overhead which lead to more power usage.

5. CONCLUSION

In this paper we presented an in-depth survey of state-of-the-art energy optimization routing protocols for MANET networks, particularly from Optimizing energy consumption perspective. The surveyed routing protocols have been reviewed based on a set of metrics which constitute the elementary feature of energy efficient consumption routing protocols for MANET'S. Additionally, the methodology of each routing protocol is explained briefly for better understanding of the readers. The surveyed routing protocols are categorized into seven classes based on their basic operation i.e., schemes based on adaptation of the state of radio algorithms, methods based on load balancing adaptation, schemes based on multicast algorithms, position-based routing protocols, schemes based on proactive algorithms, protocols based on energy efficient reactive algorithms, and techniques based on control of transmission energy algorithms. Finally, we presented our view on the limitations in the area of Energy efficient consumption for MANET networks. In the future, we intend to utilize the knowledge gleaned from this survey to pursue new solutions for the evident limitations highlighted in this survey.

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