ENERGY EFFICIENT SUSTAINABLE ROUTING ARCHITECTURE FOR MANET

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Abstract
The Iternet of Things(IOT) is acknowledged as one of the most significant areas of upcoming technology and is gaining vast attention from a wide range of industries, Agriculture, Education, Telehealth, etc. IoT is a combination of various resource constrained networks like WSN and MANET where the limited battery power is a serious issue. In addition to this reliability and performance of the physical network topology is of major importance as they reflect the capability of the network to provide connectivity between the nodes in the ad hoc network at any instant. Maintaining connectivity is also a big challenge considering the self-organizing nature of the network topology and the dynamic change in the behaviour of nodes, such as frequent link and node failures, because of mobility, interference, battery limitation and radio channel effect. This work studies various energy efficient routing mechanisms/techniques to prolong network lifetime of resource constrained networks MANETand WSN and proposes an energy efficient sustainable routing architecture for MANET.
Key Words: Connectivity, Energy, Layered routing, MANET, Power Control, Routing protocol, Reliable communication, Sustainable Routing, Topology.

I. INTRODUCTION

In mobile ad-hoc network (MANETs) there is no fixed infrastructure of access points, the nodes are mobile and move independently in a random way, the physical topology of the network and its connectivity change dynamically, and at a given moment each node can act as a router. Self-organization is an inherent property of such networks, thus allowing a seamless interconnection within a specific range or zone. Such networks are being deployed for many diverse applications, such as vehicular communications, military applications, emergency, disaster operations, search and rescue operations, etc. [1]. The problem of network sustainability, load balancing and energy efficiency in MANETs is a topic of research since many years. A major issue related to sustainability in MANETs is the mobility of the nodes, their load, and energy deficiency. The result is a dynamic change of the topology of the network and the impossibility to predict accurately the network structure in time. A node ensuring the communication path between source and destination can become unavailable in the next time interval, because of movement out of the servicing area, a drop of power or traffic overload. Thus for such a dynamically changing environment a dynamic routing algorithm must be deployed to avoid link breakage and achieve the overall better performance of the ad-hoc network structure [2]. An efficient routing mechanism is required to maintain an acceptable service quality during communication between the nodes. Hence, the strength of a node regarding its available energy becomes an important issue for the period of the selection of an intermediate node to maintain stable transfer of data between nodes [3]. Keeping lifetime of a routing path in a network is a challenging task due to the power of the nodes which depends on the node size, the propagation model, the properties of the model, and the capacity of the battery [4]. Data traffic increases exponentially in today's MANETs and the energy requirements increase, while in response to this growth the energy available in the battery becomes insufficient, thus raising up the energy gap problem as shown in Fig. 1.

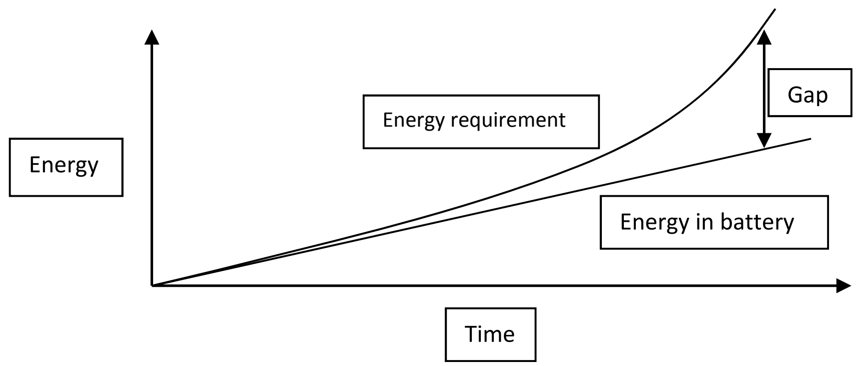

Fig.1 Energy gap

This work aims to make an overview of energy aware routing protocols to improve the lifetime of resource constrained ad-hoc communication networks like Mobile ad-hoc networks (MANET) and Wireless Sensor Networks. In Section II, related work in the fields of energy optimization through routing in MANET is described. Section III depicts performance parameters. Section IV proposes a Sustainable routing architecture for MANET. Finally, Section V concludes the work.

II. Related Work

Routing, connectivity, and end-to-end communication are some essential services in MANETs. These services are likely to be continuously provided even in the occurrence of undesired events such as malicious attacks, natural disasters, or network failures [5]. Connectivity is treated as an essential requirement for survivability. The connectivity of MANETs is achieved via node degree, radio propagation, and node mobility. On the other hand, routing provides services at physical, network and data link layer to protect nodes from attackers [6].

Classification of the Routing Protocols based on the routing information update mechanism for Ad hoc wireless networks can be divided into three categories. They could be Proactive (Table-driven), Reactive (On-demand) or Hybrid [7]. Fig. 2. Depict the classification of MANET routing protocols.

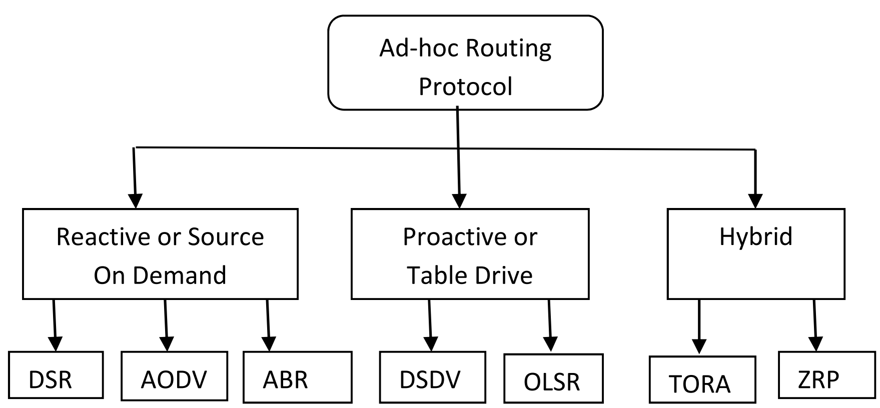

Fig. 2. Classification of MANET routing protocol

In reactive routing when the source node has data packets to send, a route discovery is carried by the source node to find the route to the destination node. Once a route is found, the route maintenance procedure is initiated to maintain this route until it is no longer required or the destination is not reachable. The advantage of these protocols is that overhead messaging is reduced. One of the drawbacks of these protocols is the delay in discovering a new route. Such protocolos for example are the Ad-hoc On Demand Distance Vector (AODV), Dynamic Source Routing (DSR), associativity Based Routing (ABR) [7]. In Proactive routing, the nodes maintain routing tables about nodes in the network. These routing protocols update the routing table information periodically or in response to a change in the network topology. The merit of these protocols is that a source node does not need route-discovery procedures to find a route to a destination node. On the other hand, the demerit of these protocols is that maintaining a regular and up-to-date routing table demands considerable messaging overhead, which consumes power and bandwidth and leads to a decrease in throughput, mostly in a large number of high mobility nodes. Table Driven Protocols are Wireless routing protocol (WRP), Fish eye State Routing Protocol (FSR), Destination Sequenced Distance Vector Routing (DSDV), Optimized Link State Routing Protocol (OLSR), Cluster Gateway Switch Routing Protocol (CGSR)[7]. Hybrid routing combines the features from both proactive and reactive routing protocols, typically attempting to exploit the reduced control traffic overhead from proactive systems while reducing the route discovery delays of reactive systems by maintaining some form of the routing table. A classification of ad hoc routing protocols is described in [8]. In [9] the authors propose a load balancing routing algorithm, called LBRA, to distribute the traffic load on gateways in MANET with Internet connectivity. To prevent the routing path becoming too long, a routing path increment threshold is introduced to restrict the routing path in a reasonable range.

In research work [10] an optimal energy scheme optimal routing algorithm called the Optimal Energy and Load Balance Routing (OELR) for mobile ad hoc net-works (MANETs) is proposed considering transmission power, interference, link lifetime, and load balance. A load balance approach is involved in distributing the traffic over available routes to address the well-known problem in energy efficient protocols of traffic congestion and nodes overused in minimal power path. Simulations demonstrate that OLER has high network performance.

In [11] Challenges to QoS routing mechanisms are discussed. One of these is the dynamic topology which may lead to considerable transmission overload due to the frequent exchanges of topology information, bandwidth congestion in wireless links, and possible depletion of the limited battery life of the nodes involved. Another challenge is the unreliable wireless channel with interference by other transmissions, multi-path fading effects, all of which affect the packet delivery ratio or link longevity guarantees or both. One more challenge is the node mobility as long as the velocity of state information broadcast is greater than the rate of the change of topology information, the network will be able to operate, and the routing information will not be stable. Node heterogeneity is also a critical factor for successful operation of MANETs.

T. K. Halder et.al.[12] describes energy aware on demand routing protocol based on AODV that takes care of an internal load of the individual nodes and its remaining power on other nodes in its neighborhood. Thus durability and lifetime of the network are increased by avoiding a node having lesser battery power at the time of path discovery. This helps a node to choose a stable route in which intermediate nodes have more residual power. Thus frequent invocation of route discovery due to frequent node failures can be avoided.

The proposed approach in [13] aims at increasing the network lifetime of a MANET, by distributing the routing load among all the nodes within the network. This is achieved by calculating the residual energy of all the nodes in the entire path between the source and the destination, for various paths available, and then comparing and selecting the path which is most optimal regarding energy efficiency. This approach follows a load balancing approach that avoids power/traffic congested paths and chooses paths that are lightly loaded. This helps in reducing the variance in energy consumption at various nodes due to load distribution and thus eventually increasing the overall network lifetime of the network. When a common node lies on several paths from different nodes, then the battery power of this node quickly runs into depletion. As a result this particular node may die of battery exhaustion very soon, eventually shortening the network lifetime. When choosing a path, the existing routing protocol implementation chooses the path with the minimum number of hops. However for an energy efficient approach, the residual energy is calculated for each node and then find the lowest residual energy of a node on a particular path. Then the selection is made by choosing the path with the maximum least residual energy.

In [14] the authors propose an Efficient Routing Protocol (ERP) scheme for communication in the MANET. In ERP, the possible routes are discovered and then a path that has less traffic for communication is selected. ERP decreases congestion and increases the packet delivery ratio which ultimately enhances the network performance. This is due to a reduction in redundant control routing overhead and increases the packet delivery ratio and will eventually minimize the delay in the network. arvind et.al. provides a novel solution to transfer server load from one server to another server. The proposed algorithm will divert the burden from low energy node to high energy node. The complete proposed solution can be applied for multipath routing, congestion control and load balancing for MANET [15]. Energy consumption can't be avoided but can be overcome by balancing the mobile node. Studies of the various routing algorithms find that a single route not only creates overwhelming traffic into the selected route but also decreases the energy resource capabilities for selected intermediate nodes. Thus multipath routing algorithms may be used to avoid load overhead on selected routes [15]. In single path routing algorithms various intermediate nodes are untouched and uninvolved in the communication. Unmanaged or single path routing may lead to certain serious problems which are:

- Over Load on intermediate nodes.
- Congestion and heavy traffic to selected Single route
- Heavy Energy draining on intermediate nodes
- Node failure and packet drop due to heavy use of same nodes.

Accordingly, routing algorithms for energy efficient communications are regarded as essential for MANET deployment and have been considered in many papers. In [16] the AOMDV_RR Range Routing protocol is proposed, which is a power and topology aware and ad hoc On-Demand Multipath Distance Vector routing protocol based on the maximum transmission range. The objective is to improve the performance of a MANET without increasing or decreasing multi-path routing protocol's default transmission range of the nodes. Whhich leads to control the routing process and only allow hops with maximum possible distances in a route based on the received signal strength at each node.

In [17] V.Lalita et.al. analyzed the positive and negative impact of an increase in transmission power of individual nodes on the performance of routing protocols. Here the transmission range of the node has more influence on the network connectivity. The nodes with sufficiently higher transmission range can maintain connectivity even at higher mobility. In a multi hop communication scenario, there may be frequent link failures because of rapid change in topology due to node mobility. If the power is increased and respectively the transmission range in order to increase the one hop distance of the nodes, then to some extent it will certainly avoid link failures due to mobility.

Mobile Ad hoc networks (MANETs) are power constrained since nodes are operated with a limited battery. A node not only sends it individual packets but also packets of other nodes. However, the energy consumption during routing remains a key challenge. In [18] a Power Aware QoS Multipath Routing Protocol (PAQMR) is proposed as an extension of AOMDV. This protocol avoids the loop formation in the network and selects less number of paths. Due to the discovery of fewer numbers of paths, it minimizes the routing overheads. An energy consumption model is proposed to evaluate the energy values at different times.

In [19] an attempt has been made to discuss issues and challenges of multipath routing in MANETs. The benefits obtained in multipath are higher energy efficiency, lower end-to-end delay, decrease congestion, good throughput, higher network lifetime, etc.

In [20] the authors analyze the routing performance as well as energy efficient behavior of AODV routing protocol in both homogeneous and heterogeneous MANETs (H-MANETs), using performance parameters like the ratio of delivered packets, throughput, average delay, average power consumption, the energy of alive nodes, etc. Heterogeneity has been introduced regarding different initial energy for all the nodes, unlike a scenario where the initial energy of all the nodes is equal. This work is helpful to get an insight of effects of heterogeneity on energy efficiency and other performance metrics of AODV and could motivate researchers to analyze more aspects of heterogeneous MANETs.

Devices in mobile ad hoc networks (MANETs) have limited energy resources and may be equipped with various transmission technology. These characteristics make MANET conventional routing protocols inconvenient in a heterogeneous environment. A put forward a power aware routing protocol for a MANET forming of heterogeneous nodes is considered in [21]. The proposed approach takes into consideration the battery status of nodes while building the routing table. It aims to avoid exhausting the nodes that are falling on best possible routes across the network thus providing better connectivity and extending the network lifetime. Practically this is a power aware heterogeneous AODV (PHAODV) routing protocol that uses efficiently the energy available in nodes when establishing and maintaining heterogeneous routes in the network. PHAODV routing protocol considers the node's residual energy and the power costs when developing different routes between nodes. Two thresholds are used by nodes to control further their energy consumption. The first threshold aims at keeping a node aware of the changes in its residual energy and enables it of invalidating routes using it as an intermediate node and thus establishing new routes using up to date information about nodes' energy status. The second threshold aims at preventing nodes from being exhausted over routes when it is possible to use alternative routes. The performance metrics taken into consideration were node reachability, routing overhead, energy consumption, and network lifetime [21].

The node selection process has been incorporated into many routing algorithms and techniques. However many suffer from certain shortcomings, especially during the route discovery process. These methods do not consider the available energy of a node as a parameter, so they may select a node with a low energy level as an intermediate node. The selection of a node with a low energy level reduces the stability of the communication path because that node may deplete its energy, causing the breakdown of the communication channel. In [22], the proposed system HTR-OLSR protocol uses a probability-based node selection method in which the residual energy level of a node is considered. It is an enhanced version of the OLSR protocol. This novel routing protocol includes energy aspects to OLSR protocol, leading to an increase in lifetime of nodes and network performance. The protocol minimized the inaccuracy in the energy level prediction of nodes.

Military and rescue operations are one of the highly sensitive applications of MANET. The aim of the research in [23] is to identify the networking gaps in MANET for military scenarios and enhance networks efficiency based on networks demand. Sharing the workload among the master nodes reduces its packet processing overheads and increases the lifetime of the request the availability of master node for its member master node. This approach also increases processing complexity.

Many modern network applications, such as transmission of multimedia data, real-time collaborative work, and interactive distributed applications, require QoS. In [24] a new Efficient Power-Aware QoS Routing (QEPAR) protocol implemented on existing DSR protocol with residual battery power and bandwidth (data rate) which are one of the main QoS factors in MANET is proposed. The designed protocol finds a better packet delivery ratio, end to end delay, throughput and battery lifetime of the mobile node. The simulation results show that such power-aware QoS routing protocol achieves better network lifetime with reduced energy consumption and end to end delay. The QEPAR considers cost metrics which include both a node specific parameter, i.e. the residual battery power, and a link specific parameter, i.e.

the packet transmission energy for communication across the link. The lifetime of the chosen path, defined by the maximum number of packets that may be potentially forwarded between Source Node and Destination Node using selected path, is determined by the weakest intermediate node.

In [25] Shabir et.al. Propose a new modified version of the Dynamic Source Routing (DSR) protocol to improve the lifetime of the MANET. When the energy of a node X that is forwarding data within a multi-hop path reaches a level less than or equal to a certain energy threshold percentage of the initial energy, the node will broadcast a special packet sent in DSR, or a "low energy" flag in the header, in which he tells his neighbours Y, implicitly asking not to continue to send packages to him, if there are other routes to the destination node. Neighbours will update his route cache by removing the previous link Y->X. If in the output queue of Y there are packages that have yet to be sent along the link Y-> X, they are still sent, to avoid destabilization of the network topology. Y will attempt 'to"save" package, or will generate' a Route Error to send broadcast, so that it reaches the source of this package, which will attempt 'to re-send the package using a different path, not containing the link Y-> X. If the node X, which is still active, is the only node "bridge" to a certain destination, it will 'still used to forward packets. This procedure could be thought as a sort of "survival instinct" of each node X when it reaches a low level of energy.

In [26] O. Souihli et.al. noted that in shortest-path routing protocols load-balancing is a critical deficiency in MANET, as nodes at the center of the network are much heavily-loaded than the others. In this work, load-balancing mechanisms are presented that push the traffic further from the center of the network. Novel routing metrics called nodes degree of centrality are taken into account for both proactive and reactive routing protocols. It helps to minimize the congestion and overload by identifying the nodes that are most likely to be surpassed.

K.Sumathia et.al. [27] noted that Limited battery power is one of the most important issues in mobile ad hoc networks as the mobile nodes operate on limited battery power. Also, there occurs a problem of broken links due to the lack of energy which causes disorder in the network system. Such problem occurs due to the lack of knowledge about the energy of mobile neighbor nodes. This paper presents the implementation of Adaptive HELLO messaging scheme to determine the local link connectivity information for monitoring the link status of nodes together with the integration of Dynamic On-Demand Routing Protocol to reduce the energy consumption of mobile nodes.

The paper [28] provides a survey of various protocols used for low-power and lossy networks and their advantages and limitations are compared. The comparison is based on the applied power control schemes and efficiency, but some limitations are related to the mobility of the nodes and the respective higher loss rates.

G.Varaprasad et.al. [29] propose a model called a power-aware routing algorithm for MANET using a gateway node. It aims to minimize the number of control message packets, the energy consumption and leads to an increase in throughput. The objective is the packets to use the gateway node whenever the source node request transmission to the destination, as the gateway node has enough battery power to route the packets. The proposed model is expected to deliver more than 95% of the packets with low end-to-end delay, but a major limitation is the lack of consideration of the packet loss.

In [30] a method for optimizing the performance of node discovery based on bio-inspired Lotka-Volterra (LV) population method is proposed. In the proposed model, LV is introduced in a cost optimization problem to allow for limiting the usage of energy resources in the node discovery process, during which the tree of a searching node may expand leading to larger delays, packet losses and energy consumption. This work uses hyper-graph representation enhanced with the LV population method to design a scalable and an energy-efficient model for the sensor node cooperation. It assigns a given node to a cluster, which is referred as hypergraph so that the node has a maximum access to other nodes while satisfying the constraints in the network. The proposed model covers well the dynamics of the compound sensor network, such as the one that may be employed in an Internet of Things (IoT) scenario, where nodes need to act autonomously during the communication process. The Lotka-

Voltera model is applied to increase the probability of the existence of the communication paths in the component while keeping the memory and thus the energy expenditure of the whole connected component under a threshold.

An energy-aware load-balanced routing (EALB) algorithm is proposed in [31]. This algorithm significantly increases the packet delivery ratio, reduces the delay and prolongs the network lifetime in heavy load networks. EALB can also provide better performance when nodes have very low energy levels. Most energy-aware routing algorithms in the power-limited network are designed to minimize the total energy consumption or maximize network lifetime mainly by selecting the forwarding nodes with most residual energy. However, heavy traffic load which leads to severe congestion and fast energy depletion at bottleneck nodes is not considered in the route selection. In this paper, the proposed EALB routing algorithm combines energy-aware and load-balancing mechanisms. In EALB, packets are forwarded to the nodes with more residual energy and less traffic load. Through the energy-critical nodes and load-critical nodes protection, the network lifetime can be prolonged. Simulation results show that EALB achieves higher PDR, lower delay and longer network lifetime than traditional AODV and DSR in the network with heavy traffic load.

For real-time streaming applications, important issues are the choice of the shortest path together with energy-efficient operation in order to maximize the lifetime of the mobile devices. In [32] an energy-aware and delay-aware routing approach for mobile ad hoc network (MANET) is proposed. It is based on Dynamic Source Routing (DSR) and labeled as DSR_ED. DSR_ED efficiently utilizes the network resources in order to balance traffic load. It ensures both timeliness and energy efficiency by avoiding low-power and busy intermediate nodes. Simulation results, compared with DSR, show an improvement of network lifetime and the end-to-end delay. DSR-ED is a flexible routing protocol, which makes the route selection decision according to the difference in the energy levels of the nodes and the route decision is made based on the residual energy and the total transmission power consumption.

In [2] a routing algorithm for MANETs is proposed, based on the formation of servicing zones and default gateways. The idea behind this approach is to gain power efficiency and sustainability of the network. The proposed approach reduces the overall number of broadcasts on the network and ensures a reliable and energy efficient connection, by balancing the load among the nodes. Authors apply a time slot based self-organizing and self-routing approach by the application of a network model with universal basic node properties, The algorithm has the logic of non-cooperative routing based on the evaluation of the defined fundamental properties of the nodes. The major advantages of the algorithm are related to the complexity and the reduced overall routing cost, especially in higher density networks.

An energy saving and survival DSR routing protocol which is based on DSR is developed in [33]. The authors incorporate an energy saving technique in every node and introduce a method like an energy survival technique which alerts its source and neighboring nodes about its little energy by broadcasting a special “low energy” packet. In this way are avoided low power nodes from overusing which may lead them to die soon. The proposed method has improved the individual node lifetime and as well as the whole network life span.

In [34] are proposed two novel energy-aware routing algorithms for wireless ad hoc networks, called reliable minimum energy cost routing (RMECR) and reliable minimum energy routing (RMER). RMECR addresses three critical requirements of ad hoc networks: energy-efficiency, reliability, and prolonging network lifetime. It considers the energy consumption and the residual battery energy of nodes as well as quality of links to find energy efficient and reliable routes that increase the operational lifetime of the network. RMER, on the other hand, is an energy-efficient routing algorithm which finds routes minimizing the total energy required for end-to-end packet traversal. RMER and RMECR are proposed for networks in which either hop-by-hop or end-to-end retransmissions ensure reliability.

Kavita and Vivek Sharma [35] projected an energy-efficient power control mechanism for a base station in mobile communication systems and an efficient sector power control based on the distance between the base station and the mobile node. He also proposed a sleep mode energy control mechanism. In the sleep mode energy-saving protocol, each sector monitors the number of users in a sector cell. Lee proposed that if the number of mobile nodes falls below a given threshold in a sector cell, the base station shuts down power. The key objective is to minimize power consumption and maximize the lifetime of the entire network.

Kwok and Ahmad [36] presented a comprehensive review and classification of deterministic scheduling algorithms. Among the most common methods is a class of methods called list scheduling techniques. List scheduling techniques are widely used in task scheduling problems.

The Autonomous Mobile Mesh Network (AMMNET) is the one that is a transformation of MANET [37]. It can adapt its topology dynamically so that it could be used in various applications where a dynamic topology is necessarily required. Autonomous Mobile Mesh Network uses a distributed client tracking algorithm to track mobile nodes and maintain connectivity between them. AMMNET considers a group mobility pattern and ensures good connectivity between the mobile nodes [37].

In MANETs, network survivability is an essential aspect of reliable communication by providing outstanding services to maintain network connectivity. It can be referred to the capability of a system to fulfill its mission promptly at the present of attacks, failures or accident [38]–[40].

However, in MANETs, sustainability depends on how well the ad hoc network meets the demands of the sustainability requirement. The essential requirement for sustainability is the capability of the network to provide connectivity between nodes in an ad hoc network at any instant [41]. Maintaining connectivity is a significant challenge to the self-organizing network. This is due to topology and the dynamic behavior of nodes such as the frequent happening of link and node failures because of mobility, interference, battery limitation and radio channel effect.

III.METRICS USED TO EVALUATE MANET ROUTING PROTOCOLS

To judge the merit of various routing protocols, both qualitative and quantitative measures are needed with which to measure their suitability and performance. Some of the major metrics are listed below [20].

Energy Consumption. The average of the total consumed energy of all the nodes of the network. It is measured in Joules.

Packet delivery ratio (PDR). Packet delivery ratio is defined as the ratio of data packets received by the destinations to those generated by the sources. [20].

Throughput. Throughput is the number of bytes or bits arriving at the sink over time. It is generally measured in bits per second.

Dropped Packets. It is the number of data packets that are not successfully sent or forwarded to the destination. The dropping of a packet can occur during a collision/error or another failure in the routing process.

Routing Load. It can be defied by the ratio of the number of routing messages propagated by every node in the network and the number of data packets successfully delivered to all destination nodes.[20].

Routing traffic received. This represents the amount of routing traffic received in bits/sec in the entire network. This traffic includes all the protocol's control overheads, such as Hello messages, route request/reply packets, route errors and maintenance packets, routing updates and acknowledgments.

Network throughput. Routing traffic has a high impact on the network throughput, which is the average rate of successful message delivery over a communication channel. Usually, the larger the routing traffic used by a routing protocol, the less throughput is available for actual data traffic good put.

Reachability. This is defined as the fraction of possible reachable routes to all possible routes between some/all different sources to some/all different destinations. This statistic is collected to measure the percentage of the successful routing discovery attempts that managed to discover at least a single route to every requested destination using the various discovery mechanisms out of the total number of routing discovery attempts during a simulation run.

Route discovery delay. It can be defied as the time delay needed to discover a route to particular destination nodes. This can be calculated from the moment when a route request is sent out by a source node to discover a route to the desired destination, until the time a route reply is received at the source node with a route to that destination.

End-to-End Delay. This the average time interval between the generation of a packet in a source node and the successfully delivery of the packet to the destination node. [20]

Aggregate throughput. This is the average of successful packets delivery via a communication link.

Drop packet. This occurs when there is a loss of a packet during travelling from source to destination.

Efficiency of routing protocol, = (Number of acknowledged packets / Number of transmitted packets) * 100

IV. Sustainable routing architecture for MANET

The essential key factor of any survivable network should be able to deliver essential services even in occurrences of failures, attacks, interruption. In MANETs, to maintain network connectivity, network survivability is an essential aspect of reliable communication by providing outstanding services. Network survivability in MANETs is most likely affected by either dynamic topology of the networks, node and link Fault or Security attacks. The survivable resource-constrained wireless network architecture is depicted in Fig. 3.

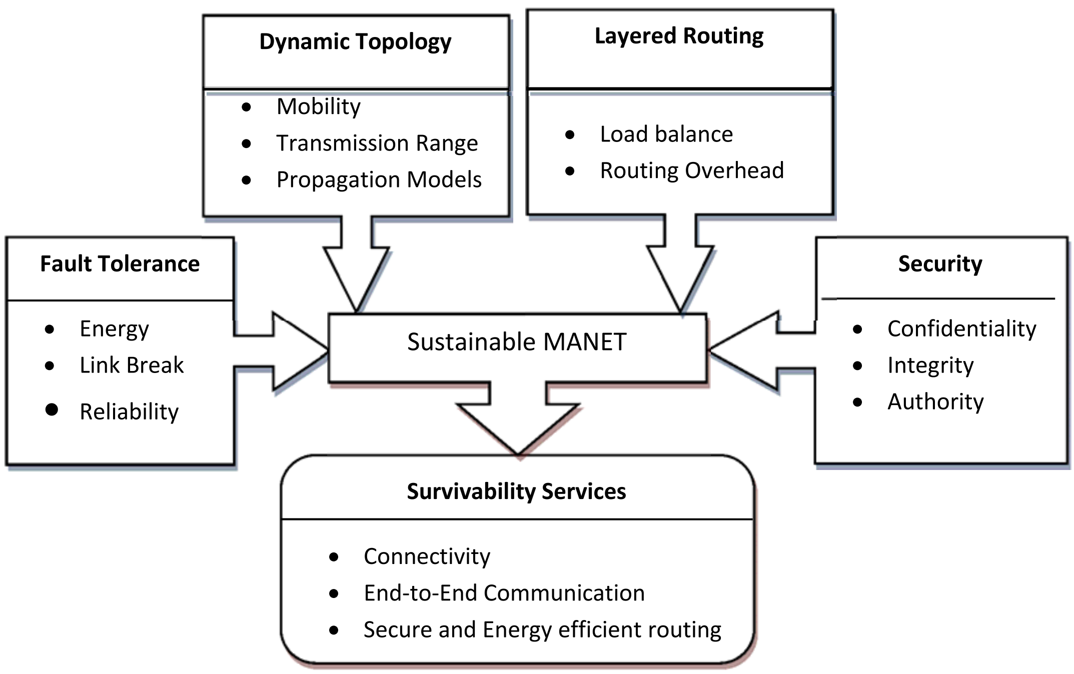

Fig. 3. The architecture of sustainable MANET.

The essential components of the proposed Sustainable routing architecture for MANET is illustrated in Fig. 3. They are dynamic topology, connectivity, fault tolerance, energy, security and layered routing. It can be observed that many routing algorithms developed until now consider and focus on a single or combination of few particular parameters to be optimized. Such an approach will not fulfill the complete requirement of sustainability.

The essential services in MANETs are routing, connectivity, and end-to-end communication. These services are likely to be continuously provided even in the occurrence of undesired events such as malicious attacks, natural disasters, or network failures. So to fulfill these requirements researchers of the algorithm should try to incorporate maximum features along with security options as depicted in Fig. 3.

The connectivity of MANETs is achieved via proper node degree, selecting proper radio propagation, and node mobility. On the other hand, to protect nodes from attackers routing should provide services at physical medium and data link layer. The majority of existing MANET routing protocols use the minimum hop approach to finding the route. They broadcast route discovery packets to find a new route with a minimum hop count. If the selected path contains weak links, then the route is prone to failure. Repeated failure of the route may increase the number of route discovery, which will in turn increase the routing overhead of the network. There is a need to consider a parameter other than minimum hops to improve the stability of the route.

Energy can be saved using efficient routing techniques. It can be observed from the approaches for energy efficient routing described in section II, as for example the layered or cluster routing which, is one of the efficient routing techniques to minimize routing overheads in MANET. Layered routing has been identified as one of the approaches to improve the routing protocols' scalability and can prove to be useful in the reduction of routing overheads by neglecting the additional overheads incurred by the layered routing management. Merits of layered routing algorithm are using gateways in a cluster that are assumed to be more stable than the rest of the nodes and allocation of noninterfering channels between adjacent clusters. Channel allocation algorithms are easily deployed in layered or clustered networks. The routing information kept by a node in a cluster is limited to the configuration of that cluster. Inter-cluster routing information can be managed by cluster heads and gateways. A clusterhead has the additional responsibility of coordination and synchronization for cooperative tasks.

Due to the wide online use of mobile devices in various applications in IOT scenario, the data must be secure. There is a need to develop robust routing mechanism for sustainable MANET which should resist the attacks. There are an ample variety of attacks which target the weakness of MANETs. Malicious routing attacks can target the routing discovery or maintenance phase by not following the specifications of the routing protocols. Due to the lack of security measures an attacker can try overloading the network by injecting junk packets into the route. It will affect energy depletion of nodes, connectivity and topology. So there should be simultaneous provision to add security features in MANET.

In addition the system should be fault tolerant. Faults may happen in nodes or links. Due to node faults the state of the nodes may change. A cooperative node may change to the different state of behavior. It may as selfish or state of fail due to battery depletion. Once at selfish state, the node may not forward data packets for the sake of saving its own energy. Which degrades the throughput and the node at this state will create a broken link between connecting neighbors. On the other hand, a link fault may cause by signal fading effect, which influences the transmission range of the node.

Due to node mobility, the node may change its position and may go beyond the transmission range of its neighbor. It may cause a link break. If that particular node is gateway then it may cause network partition. In such cases, alternate node should take over the role of the outgoing mobile node.

V. CONCLUSION AND FUTURE WORK

This work studies the various energy efficient routing mechanisms related to resource constrained networks like MANET. Different techniques are evolved to save energy in MANET. The essential services in MANETs are routing, connectivity, and end-to-end communication. These services are likely to be continuously provided even in the occurrence of undesired events such as malicious attacks, natural disasters, or network failures. In this work a sustainable routing architecture for MANET is proposed. Towards sustainable network approach, addition of features simultaneously like dynamic topology control, layered routing, fault tolerance, energy and security in routing mechanism of MANET may help to improve the performance and robustness. This approach may help to gain power efficiency and sustainability of the network. This also will reduce the overall number of broadcasts on the network and ensures a reliable and energy efficient connection, by balancing the load among the nodes. It was also found that layered routing is one of the efficient techniques to minimize the routing overheads. Layered routing has been identified as one of the approaches to improve routing protocols' scalability. Finally, it may be concluded that there is a need to develop robust routing mechanism for sustainable resource constrained communication networks (MANET and WSN) which should consider the connectivity, security, dynamic topology and connectivity while designing the routing mechanism. The aim should be better Connectivity, reliable End-to-End Communication, Secure and energy efficient routing to improve network lifetime in homogeneous as well as heterogeneous MANETs.

Future work could be related to the implementation of proposed architecture of sustainable MANET including an analysis of performance parameters in response to variation in different topology, density, mobility. Although extensive research has been carried out in clustering since the last decade, there is still room for further contributions within MANETs, WSNs and VANETs.

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