Abstract
Mobile Ad-hoc Network (MANET) is a category of wireless network that does not rely on any fixed infrastructure and adapts dynamically. Conventional ad-hoc routing protocols are aimed at finding optimum route from source to destination with no awareness of the current traffic in the network. Adapting to dynamic nature on addressing the challenges in utilizing the scarce resources such as bandwidth, battery power has become a key consideration in current research. Congestion during transmission is another major challenge faced by mobile ad hoc networks which affects the network traffic and thereby the performance directly. Though few congestion control mechanisms are proposed, they incur delay and thus deteriorate the performance of the network subsequently. Adaptation to current network traffic and congestion helps overcoming the delay incurred and thus improves the performance compared to conventional proactive and reactive routing mechanisms. This paper details a survey with an analysis on the existing congestion aware and congestion adaptive routing protocols to understand their impact in improving the performance of the network. The detailed survey presents an overview on the advantages and limitations of the existing congestion aware and congestion adaptive routing protocols.

Keywords: Congestion Aware routing, Congestion Adaptive routing, QoS, Traffic analysis.

I. Introduction
Mobile Ad hoc Network (MANET) is an infrastructure less network consisting of nodes which are dynamic. The main characteristics of MANETs are that they are independent and do not have any central controller or coordinator. Nodes organize and configure themselves to form a network dynamically [1]. Every node rely on their neighboring nodes in forwarding the data and hence all the intermediate nodes act as routers.
Moreover, the topology of the network in ad hoc mode cannot be predicted, as the nodes move randomly. The main challenges are localization of nodes, error rates due to the communication medium, security issues, network congestion and determining optimal routing strategies. Routing protocols in MANET are classified as:

A. Proactive or Table driven:
Every node maintains the routing table containing information about the global topology. These tables are updated periodically. Since every node has route information to reach every other node route discovery at the time of packet transfer is not required, which in turn reduces delay. Protocols like DSDV, CGSR, WRP, OLSR etc. come under this category. However, table maintenance and periodical updates cause overhead.

B. Reactive or On-demand:
Unlike proactive protocols, reactive protocols do not store information about routes prior to data transfer. Route discovery is initiated on-demand when a packet is to be transferred. Also, routing table is not required to be updated periodically. Overhead caused due to table maintenance in proactive routing is reduced. Protocols like AODV, DSR, ABR, SLR, LBR etc. fall under this category.

C. Hybrid routing protocols:
Hybrid routing protocols are a combination of both proactive and reactive protocols where they exploit the benefit of both. Within its proximity, a node maintains routing table and reactively finds route to different destinations. Examples for hybrid protocols are ZRP, FSR etc.

II. Congestion Based Routing Protocols:
Congestion based routing protocols used in wired networks cannot be extended directly to MANET due to their dynamic topology, support for mobility that leads to frequent path breaks and change in the topology of network. Bandwidth constraint experiences lesser data rates. Topology maintenance creates additional overhead due to exchange of more control messages.

Characteristics of an ideal routing protocol [2],[3] must be fully distributed and adaptive to frequent changes. Packet collision must be kept minimum by limiting the number of broadcasts made by each node. Congestion in MANET [4] occurs mainly due to limited bandwidth and unpredictable mobility pattern of the nodes, leading to delay in the packet transmission causing processing and communication overheads for re-routing with packet loss. These ultimately result in
throughput degradation. Recovering from congestion after it has occurred incurs huge expenses in terms of time, cost, etc, when it comes to large MANETs. Hence, there is a demand for protocols which can either predict congestion or react to congestion.

Congestion control protocols are classified as:

**A. Congestion Aware routing protocols:**

These protocols consider congestion only while establishing a new route. This route will not change until the intermediate nodes move towards a different location or when a link failure occurs resulting in disconnection of the nodes.

**B. Congestion Adaptive routing protocols:**

Routes can be changed adaptively based on the congestion status. The states of the nodes are continuously monitored to detect congestion. The paper is organized as follows: Section III discusses on various congestion control algorithms, section IV provides the comparative analysis of the various routing algorithms followed by section V with the conclusion.

### III. Congestion Control Algorithms

In a network, congestion can occur at any time. Every node or router has a buffer to keep the incoming packets where they wait for getting processed. Congestion happens whenever the number of incoming packets to a node exceeds the capacity of the buffer at that node which leads to loss of packets. Taking this factor into consideration, congestion can be detected in advance if the metric for congestion (say average queue length or packet drop etc.,) is used at the node.

**A. Congestion Aware Routing:**

i. Chen, X., et al, [5] have proposed a Congestion Aware Distance Vector (CADV) Routing Protocol which works based on DSDV routing algorithm. As congestion is related with packet delay, expected delay is calculated in CADV protocol to identify congestion at next hop. Expected delay is calculated at every node and is updated in routing table as follows:

\[
E[D]=\sum Di \times L/n \quad (i)
\]

where, \( n \) = number of packets sent; \( L \) = MAC layer packet queue length and \( D \) is the delay.

Routing decision in CADV is done by calculating the expected delay to the next hop and the distance to the destination node. Higher priority and low-expected delay routes are obtained using CADV. The three components of CADV protocol are as follows:
Traffic Monitor: Link layer traffic is monitored and average delay is tracked.

Traffic Control: Determines the packet to be dropped or sent and reschedules it. Drop tail FIFO queue is supported and queue packet functionalities are provided.

Route Maintenance: Exchange of information is performed with evaluation on maintaining the routes and neighbor nodes. The advantages of CADV are QoS support, real time performance and reduced end-to-end delay. The limitations are the overheads incurred in maintaining routing tables, delay estimation and reduced throughput in large networks.

ii. Tran, D. A., and Raghavendra, H have introduced a Congestion Aware Routing protocol (CARM) for MANET [6]. The metrics used in CARM are MAC overhead, data rates and buffer delay. The level of congestion is calculated using the parameter Weighted Channel Delay (WCD). Route Effective Link Data-rate Category (ELDC) is adopted to overcome Mismatched Data Rate Route (MDRR) problem.

WCD parameter is calculated by:

\[ WCD = a \cdot \Sigma \tau Q + (1+b) \cdot TMACALL + Tdata \quad (ii) \]

where, \( Q \) is the number of packets buffered for transmission, \( Tdata=Ldata/R \); where \( Ldata = \) data length, \( R = \) link data rate, \( TMACALL = \) MAC layer time spent.

Whenever a transmission of data is attempted to a particular destination, RREQ packets are broadcasted by source node along with WCD and ELDC. The weighted channel delay is estimated. The merit of CARM is that it eliminates congested links, avoids MDRR problem and determines the lesser congested routes first. The main disadvantage of CARM is that it suffers from high overhead.

iii. Jain. S et al. proposed a Congestion Aware routing plus Rate Adaptive (CARA) Routing Protocol [7] which involves rate adaptation. CARA modifies the DSR route discovery mechanism. The main aim of CARA is to determine the bypass route to congested nodes. RREQ packets are broadcasted whenever there is a need for data transmission from source to destination node. The level of congestion is checked by the intermediate nodes when it receives RREQ packet. RREQ is discarded when level of congestion is high. Destination node handles RREQ whenever it arrives at destination and it sends back RREP. Hence, established route do not contain congested nodes. Congestion information in CARA is measured using two metrics:

- Average MAC layer utilization
The advantages of CARA are the absence of conditional transmission burden in congested areas, and lesser overhead compared to CADV and CARM. The major limitation is that the route discovery mechanism takes considerable time.

iv. CARP, Congestion Aware Routing Protocol [8] is a reactive routing protocol based on AOMDV protocol. MAC layer information is gathered in order to find routes without congestion. To check the level of congestion a weight matrix with respect to its cost function is used. Route discovery process determines multiple paths. Node weight matrix (NM) is calculated for every network link and links with maximum throughput is selected as given below.

\[ \text{NM} = \frac{L_q \times D_{rate}}{O_{mac} \times D_{avg}} \]  

where, \( L_q \) = link quality and \( D_{rate} = \frac{D_{size}}{C_{delay}} \); \( D_{size} \) is data size and \( C_{delay} \) is channel delay; \( O_{mac} = \) MAC overhead.

Availability of multiple paths is an advantage of CARP. But it poses weight calculation overhead for intermediate nodes.

v. Gulati, M. K., and Kumar, K present a routing mechanism for MANET which considers different metrics like end to end delay, length of queue, strength of signal and drain rate called Stable Energy efficient QoS based Congestion and Delay aware Routing (SEQCDR) Protocol [9]. Queue length helps in load balancing, drain rate prevents congestion and signal strength helps in estimating stable path to destination. SEQCDR is an on-demand routing protocol. Like most routing protocols, SEQCDR has a route discovery phase and route maintenance phase. During route discovery phase, source node checks if a route is available to the destination in its routing table. If route is available, transmission starts off, else source node prepares Route Request (RREQ) packet, assigns the Accumulated_delay value (A_delay) as 0 and broadcasts RREQ to the neighbors. If a reply (RREP) is obtained before the time out period and also the sequence number of RREP is greater, the route is updated and transmission happens; else the packet is dropped. If source does not get a RREP before the time out, it resends the RREQ packet. An intermediate node on receiving RREQ packet checks if the signal strength is above the predefined threshold value. If not, the packet is dropped. The drain rate is calculated as:

\[ DR(t_2) = \frac{E_m(t_1) \times E_m(t_2)}{(t_2 - t_1)} \]  

where, \( E_m(t_1) \) and \( E_m(t_2) \) are the energy levels at time \( t_1 \) and \( t_2 \).

The node also calculates the length of the queue at interface. If either the queue length or drain rate values are beyond the admitted threshold, that node is omitted from the route. Otherwise, admission control based on delay is performed by calculating the delay using \( A_{delay} = \text{total\_delay} + A_{delay} \), where, \( \text{total\_delay} \) is the sum of processing_delay,
queueing_delay, transmission_delay and propagation_delay. If the node passes all the above checks, it further checks whether if a route is available to destination. If yes, the path is provided to source through RREP and if no, it broadcasts the packet to its neighbors further.

If the packet had a route, the node updates the route provided the sequence number of the packet is greater. Destination node on receiving the RREQ performs same operations as intermediate node except that it creates a path to source in backward direction after all checks. Route maintenance in SEQCDR is similar to that of AODV wherein, in the occurrence of link failure, a local route repair is done. Alternate routes if available are used and otherwise, Route error message (RERR) is sent to all nodes which have this node details in their table. Source node on getting RERR packet will re-initiate route process. SEQCDR simulation results show that it provides better throughput, packet delivery ratio, less overhead and delay.

vi. Pingale.H et al.[20] proposed CARE, a Congestion Aware Scheduling Algorithm which is based on AODV protocol. The metric used to determine the congestion level is Load. Load is a congestion indicator which is calculated as the ratio of periodic arrival rate i.e., input and the service rate i.e., output. Load and priority information of flow is maintained in scheduling tables and the load information is added in RREQ and RREP packets. The advantage of CARE is that the arrival rate decreases at congested node and load in the network is balanced. The limitation is the increasing size of control packets and incurs maintenance of scheduling table for the flows.

vii. Congestion Isolation in Networks (ICARO) [24] is a method to isolate the congestion causing traffic into separate virtual networks while the traffic which does not cause congestion flows through the normal virtual network is proposed. ICARO has three phases:

Detection of congestion points at routers: Congested points are identified by calculating the number of messages going through a particular output port of each router. For each virtual network at the input port, the number of messages waiting for a particular output port is a measure of congestion at that port.

Notification of congestion: As soon as a congestion point is detected, all the sources are to be informed about this point and this communication is done through the congestion notification network.

Congestion Isolation: Whenever a source node gets to know about a congestion causing flow, that particular flow is isolated through a different virtual network and all the other traffic is passed through the normal network.
B. Congestion Adaptive Routing

i. Alonso, M. G., and Flich, J[10] introduced a routing technique which improves overall performance by separating congested traffic from normal traffic in large networks termed End-Point Congestion (EPC) for Adaptive Routing with Congestion-Insensitive Performance. The separation of congestion is done using End-Point Congestion Filter (EPC) which blocks the congested packets from spreading into the network. The filter mechanism is deployed at the router. So, whenever a packet is to be forwarded by a router, the router checks if there is a possibility for congestion to occur in the network. Suppose the router has recently sent a packet p1 to destination node d, and another packet p2 arrives at the router to be forwarded to the same destination d, then the router forbids the adaptivity of packet p2 until packet p1 moves forward from the next router along the destination path. Thus, the router checks if packet p1 is moving without any delay which indicates there is no congestion and then packet p2 can be forwarded. Hence, the adaptivity of p2 is enabled again. EPC helps to prevent spreading of congestion within a network where adaptive routing is used. Router with EPC is proven to reduce the network latency and thus leads to higher throughput.

ii. Sankaranarayanan. V[11] presents EDAODV (Early Detection Congestion and Control Routing Protocol) protocol which provides an alternate path during congestion in a bi-directional manner i.e. both successor node and predecessor node of the congested node in the primary path (where congestion happened) are involved in finding alternate path. The predecessor node finds the alternate path and bypasses congestion to the successor node on the primary route. The three phases in EDAODV are route discovery, early congestion detection and bi-directional path discovery. Route discovery is similar to that in AODV. There are two routing tables maintained at each node, one Primary Routing Table (PRT) containing the primary routes to different destinations and one Alternate Routing Table (ART) containing alternate paths to destinations corresponding to an entry in the PRT. An entry in the PRT of node A for a destination B is denoted as PRT[A,B].

iii. In bi-directional path discovery, the primary path of a node, say ‘A’ can predict the congestion status of that node. This status is broadcasted through the primary path as Congestion Status Packet (CSP). So, a node ‘P’ in the primary path who is the predecessor of A will get to know the congestion status of A and also will have information about non congested nodes in the primary path. This information is updated in the PRT of predecessor and successor nodes which are in turn used to find alternate paths in case of congestion.
iv. Xia, L. et al., proposed an enhancement to AODV, as Improved Ad-hoc On-demand Distance Vector routing protocol (AODV-I) [12]. Conventional AODV does not address congestion control which is the main disadvantage. AODV-I is a congestion aware routing protocol based on route repair mechanism. In AODV-I, RREQ packet performs congestion processing while trying to find a route from source to destination. Congestion processing helps in avoiding nodes or paths which are already busy thereby reducing chance of congestion. There is route repair mechanism also in the RREQ which does not allow the initiation of new route discovery if the route is busy. These two enhancement mechanisms provide improved performance in terms of latency reduction, packet loss reduction, and fair utilization of resources available in the network.

v. Basavraju T.G et al. [13] proposed ECARP, an efficient congestion adaptive routing protocol for MANET. The main objective of ECARP scheme is to avoid routes which are stale. It also provides alternate routes and this is achieved by changing the various parameters of the basic AODV routing protocol. Every node will have congestion status ‘C’ which is set periodically by monitoring the buffer status. The number of packets in the buffer is the metric of calculating the congestion status. There are three states to indicate congestion viz. Go, Careful and Stop. Whenever the congestion status is indicated by three fourth of the buffer being filled, congestion control starts. The neighbor nodes are queried to find alternate routes to destination. After obtaining alternate routes, route with minimum hops is taken and data packets are transferred. In case if there are no alternate routes to destination, traffic is split into through routes which are less congested.

vi. A Dynamic Congestion Detection and Control Routing in Ad hoc Networks (DCDR) [14] [15], which reduces congestion by setting congestion free routes initially is introduced. Before route discovery, DCDR protocol configures a congestion free set of nodes called CFS which includes the one hop and two hop neighbors of the source. DCDR technique consists of the following 3 main components:

Estimating congestion dynamically: A queue management scheme called Dynamic Congestion, estimation (DC) estimates congestion based on few parameters like minimum and maximum buffer queue threshold, weight parameter, etc. The minimum threshold $TH_{\text{min}}$ is set as 35% of the queue size. Maximum threshold $TH_{\text{max}}$ is at least twice the value of $TH_{\text{min}}$. Based on these values average queue length is calculated which will capture the instantaneous lengths but react only to long term congestion.
The weight parameter ‘w’ is significant as it acts as a low-pass-filter which allows packets when the buffer size is within the permitted range i.e. $TH_{\text{min}}$ to $TH_{\text{max}}$.

Constructing CFS: To construct CFS the congestion status of each node is calculated using the Dynamic Congestion Estimation method. The source node creates CFS by collecting the set of nodes from one hop neighbors corresponding to them and those nodes that form a congestion free zone.

Finding Congestion free Route: The source node checks the nodes in its CFS (two hop neighbors) to determine if the destination node mentioned is in the list of those neighbor nodes; else forwards RREQ packets to the nodes in CFS such that any intermediate or destination node would reply back with the RREP packet. DCDR method involves overhead of setting up CFS and monitoring the congestion status of the nodes, but the overall performance increases as it avoids congestion.

vii. Congestion Adaptive Routing Protocol (CRP) [16], avoids congestion at its first pace. Every node in a particular route sends a warning message to its preceding node when it is congestion prone. An additional “bypass” path is used to bypass packets over non-congested node which appears first in the primary route. CRP consists of following six components:

Congestion Monitoring: Monitors Congestion at every node and is maintained less than its capacity.

Primary Route Discovery: Congestion is avoided by using two strategies. If the congestion status a node is Red, RREQ to that node is dropped. Also, if a node already has the destination route, RREQ is dropped.

Bypass Discovery: A bypass route is discovered by broadcasting an update packet, UDT by a primary node.

Congestion Adaptability and Traffic Splitting: Traffic splitting is done to avoid congestion in the bypass path.

Multipath Minimization: CRP minimizes the number of multipath in order to reduce overhead of protocol.

Failure Recovery: CRP quickly recovers from breakage of link as it uses bypass routes.

CRP has the advantage of reduced packet delay with less packet loss rate and efficient power optimization. The main limitation is that an additional overhead is introduced due to the warning message and also by the requirement of bypass route knowledge.
viii. Shrivastava, L. et al., [18] proposed a protocol which reduces congestion in the network using two metrics: Traffic load density and Link cost. In Load Balanced Congestion Adaptive Routing (LBCAR), each node maintains a neighbour table which provides information about traffic load of its neighbour nodes. The congestion status about the route is determined by traffic load density metric. Route lifetime information is determined by link cost metric. In order to reduce congestion, a route is selected such that it has lesser traffic load and larger life time. By this, weakest nodes can be eliminated from data transmission process. The congestion status of a route is estimated based on the traffic-load-density metric. During route discovery, routes with minimum traffic density are chosen so as to avoid congestion.

\[
\text{TrafficLoad}(i) = \frac{\sum_{j=1}^{N} q_i(j)}{N} \quad \text{(vi)}
\]

where, \( q_i(j) \) = \( j \)th sample value, and \( N = \) Sample time over a particular period.

The traffic load values of all the nodes are collected and based on these values, the minimum loaded route is selected considering the residual energy and the retransmission energy of the node.

ix. Congestion Aware and Adaptive Dynamic Source Routing [23], a modified DSR to improve performance in terms of congestion, reduced jitter, improved throughput and efficient load balancing is introduced. For load balancing, resource utilization is monitored based on average queue length and the battery power consumption.

**Congestion Monitoring:** Queue length is taken as the metric for congestion. There is threshold level kept for buffer queue length to monitor congestion. When the queue length exceeds the threshold, multipath routing is invoked through DSR.

**Calculating resource utilization:** Calculation of the battery power is an efficient way to know about the resource utilization. It is considered that if a node initiates data transmission the battery power is decreased considerably.

**Load Balancing:** In the state of congestion, the protocol invokes multipath routing; paths with varying costs are selected from the cache. When queue length increases or the battery power level decreases beyond the threshold then RERR packet is transmitted to neighbors by the respective node. The neighbor nodes or nodes upstream will check their cache and find alternate routes via multipath routing. During this period, all RREQ packets are ignored for around 12 seconds (timer for route admission control). When the timer expires RREQ packets are treated normally.

C. Fault tolerant based Congestion Aware Routing protocol

i. Rajkumar, G., and Duraiswamy, K [17] have designed a routing protocol that overcomes the problem of breakage of routes and packet losses due to congestion (Fault Tolerant Congestion Aware Routing Protocol). This scheme consists of
more nodes which salvage a packet that was lost. Hence, a distributed packet salvage process is maintained. Multiple routes are determined by the nodes using the protocol AOMDV, taking into consideration the wasted energy and battery power, to all destinations which are active. Based on the strength of the received signal, fault-tolerant method invokes warning packets to its preceding node. When forwarding error is encountered by a downstream node, the corresponding upstream node retransmits data through an alternative route. The advantage of this scheme is that better throughput is achieved with reduced delay, packet drop probability and less energy loss. Congestion control is performed by considering both link and node level congestion. Congestion Control based on Bird Flock Behaviour [21], a congestion control mechanism for wireless networks uses the behavior of birds for routing packets by voiding area with congestion. The packets in the network are considered as birds; the algorithm demands the packets to move in flock like bird flock and divert the path whenever an obstacle comes (in case of congestion).

This approach is mainly based on the following conditions:

- A packet is repelled from neighbor nodes which are at a distance of one hop and containing packets which are within the field of visibility.
- A packet is attracted to two hop neighbor nodes having packets which are within the field of visibility.
- Destination is the attractor to which all packets are attracted.
- Packets pick route randomly when required

ii. Sharma.V.K and Bhadauria.S.S [22] have proposed a congestion control mechanism using mobile agents. The network consists of a number of mobile agents whose responsibility is to collect congestion status of the nodes. As the mobile agents move through the network, they collect congestion status of all the nodes and distribute to other nodes. As they progress along the network, the mobile agent’s look for lightly loaded neighbor as the next hop node and the details are updated in the routing table.

iii. The information collected about the entire network is then dissipated throughout the network so that a source node can be aware of congestion free paths in the network.

D. QoS based Routing Schemes

i. Ravichandran.S and Umamaheswari.M [19] have proposed a backbone based routing scheme called QoS Mobile Routing Backbone (QMRB). Quality of service approach is presented over AODV protocol by QMRB in order to include
QoS in MANETs. The distribution of traffic in the network is done by Mobile Routing Backbone (MRB) and the route with best and efficient QoS between source and destination is selected. Nodes in the network are classified as QoS Routing Nodes (QRN), Transceiver Nodes (TN) and Simple Routing Nodes (SRN). QoS is guaranteed by QRNs, whereas packet routing within a network is performed by SRNs and sending or receiving packets are done by TNs. These nodes form MRB, but it is not mandatory that MRB should consist of all these nodes.

The computation of MRB node classification is performed by the following QoS metrics:

- Static Resource Capacity (SRC)
- Dynamic Resource Availability (DRA)
- Neighborhood quality (NQ)
- Link Quality and Stability (LQS)

The aptitude of node is calculated by:

\[ MN \text{ aptitude} = \mu \text{SRC} + \eta \text{DRA} + \delta \text{NQ} + \omega \text{LQS} + \Phi \text{BW} \]  

where, \( \mu, \eta, \delta, \omega \) and \( \Phi \) are coefficients, BW is the available bandwidth. The main advantage of QMRB is its efficient bandwidth utilization through traffic distribution and reduced number of control messages for route establishment. However, identification of QRN is a limitation.

ii. Gawas M. A et al. proposed a Cross Layer Best Effort QoS Aware Routing Protocol for Ad hoc Network (CLBQ) [25] for improving the performance. The main essence of this methodology is the involvement of multiple layers to provide optimized routing.

iii. A relationship between congestion metric (delay in the MAC layer) and the data rate is determined. The data rates are varied according to the variations in queue length which is also the congestion metric. This method provides improved throughput and fairness as it dynamically changes the data rates as required by changing the contention window at MAC layer.

IV. Comparative Analysis On Existing Congestion Aware And Adaptive Routing Protocols

This section presents an exhaustive analysis on the congestion aware and congestion adaptive routing protocols (Table 1). The table highlights the methodology proposed, algorithms used, various advantages and the limitations of each work presented in existing literature.
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| 1     | CADV  | Xiaoqin Chen, Haley M. Jones and Jayalath | • Based on DSDV routing protocol  
• Expected delay calculated at every node and updated in routing table  
• Function of distance and expected delay used as routing metric | • QoS support  
• Good real time performance  
• Reduced end to end Delay | • Overhead of maintaining routing tables and delay estimation in large networks  
• Reduced throughput in large networks |
| 2     | CARM  | D.A. Tran and H. Raghavendra | • Weighted Channel Delay (WCD) to measure congestion level  
• Adopts Efficient Link Data-rate Category (ELDC) to avoid Mismatched Data Rate Route (MDRR) problem  
• Source node broadcasts RREQ packets with WCD and ELDC information | • Lesser congested route discovered first  
• Congested links are eliminated  
• Avoids MDRR problem | • High overhead |
| 3     | CARA  | Shitalkumar Jain, Shrikant Kokate, Pranita Thakur, Shubhangi Takalkar | • Modification of DSR  
• RREQ is forwarded or discarded based on congestion level at an intermediate node  
• Two congestion metrics: average MAC layer utilization and instantaneous transmission queue length | • No conditional transmission burden generated in the congested areas  
• Less overhead compared to CADV and CARM | • Route discovery mechanism is slower |
| 4     | CARP  | Laxmi Shrivastava, G.S. Tomar and Sarita S. Bhadauria | • Based on AOMDV  
• MAC layer information used to detect multiple congestion free paths  
• Calculates Node Weight metric(NW) for each link based on data rate, MAC overhead and link quality | • Availability of multiple paths | • Weight calculation overhead at intermediate nodes |
| 5     | QMRB  | S. Ravichandran and M. Umamaheswari | • Added QoS support in AODV  
• Best QoS route selection  
• Formation of Mobile Routing Backbone(MRB) where nodes classified as QRN,SRN or TN | • Efficient bandwidth utilization through traffic distribution  
• Reduces number of control messages for route establishment | • Identification of QRN |
| 6     | CARE  | Harshada Pingale, Ashwini Rakshe, S.A. Jain, S.R. Kokate | • Based on AODV  
• Load of flow is congestion metric  
• Load and priority information of flow maintained in scheduling | • Decreases arrival rate at congested node  
• Balances load among the network | • Maintenance of scheduling table for flows  
• Control packet size increased |

Table 1: Comparative analysis of existing Congestion Aware and Congestion Adaptive routing protocols.
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<td>Load balancing through queue length</td>
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<td>Congestion control through drain rate</td>
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<td>Stable route through signal strength</td>
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<td>Filter at router which separates congested traffic from non-congested traffic</td>
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<td>Monitors packet flow downstream for incoming packet admission</td>
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<td>Alternate path found during congestion by the involvement of both successor and predecessor nodes</td>
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<td>Early congestion detection possible</td>
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<td>Involvement of both upstream and downstream nodes</td>
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<td>RREQ packets involved in congestion processing</td>
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<td>RREQ not routed through routes which are busy</td>
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<td>Reduced latency</td>
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<td>Fair utilization of resources</td>
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<td>Average queue length is congestion metric</td>
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<td>Uses CFS</td>
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<td>Establishes congestion free routes</td>
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<td>Avoids congestion by Early detection</td>
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<td>Efficiency depends on parameters</td>
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<td>Multipath routing</td>
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<td>Lost packet retained by distributed packet salvation</td>
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<td>Reduces packet drop</td>
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<td>Increases throughput</td>
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<td>Have to monitor both link level and node level congestion</td>
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V. Conclusion

Analysis carried out on various congestion adaptive and congestion aware routing protocols for MANET indicates that more than one parameter such as QoS along with congestion or load balancing as a metric is essential in protocol design. Routing algorithms in a mobile ad hoc environment should be adaptive to the dynamic nature of the network topology. Various metrics and characteristics to be considered while designing a routing protocol are illustrated. The success rate and efficiency of congestion control algorithms lie in the fact that they adapt to the changes or congestion rather than eliminating it from the network in order to achieve improved performance. The perspective of this survey is to enable...
researchers’ with a summary of the advantages and limitations of the existing literature so as to further explore the limitations to define their further research.

References


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