Cooperative Multipath Admission Control Protocol: A Load Balanced Multipath Admission Policy

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Abstract
Bio-medical MANET helps in the growth of novel applications and services which enhance the quality of healthcare offered to the patients. In these contexts, the networks should be integrated within the already present network architecture and information system, while simultaneously guaranteeing high standards of Quality of Service (QoS). Good levels of reliability as well as confidence are to be fulfilled for their acceptance and usage in improving in-patient monitoring in hospitals To achieve QoS in Mobile ad Hoc Networks (MANET's), the admission control play an important role. To make a reliable communication between end system multi path routing provides enhanced service. However, when we enforce multipath routing in IEEE 802.11 based MANET, the bandwidth assurance is challenge one. Though Adhoc solves the MAC issues the biotechnology helps to overcome issues easily by reducing overhead. In this paper, a unique approach has been proposed for Multipath Routing and Admission Control (CMAC), which assured the bandwidth for multipath routing through by estimate analysis the available bandwidth and consumable bandwidth for through this we ensure the bandwidth assurance. Based on heuristic solution is to admit a session in two parallel paths. Through simulations, the performance of CMAC demonstrated.

Keywords: Multipath, Admission Control, Load Balancing, QoS, MANET.

Introduction

As wireless service becomes wide use in today's world, achieving hi-performance especially in multi-media communication become an obvious choice and we attempted to prove that it is supported in MANETS [1, 2]. Important patient data can be collected and analyzed through the deployment various kinds of bio-medical sensors (for instance, body temperature, heart beat, blood pressure, ECG, EEG, etc) for an extended duration, thereby decreasing health care cost. Bio-medical sensor nodes may either be placed on or within the body.

In recent years, there exists research interest in Quality of Service (QoS) [1]. There are several solutions that have been proposed to provide QoS, such as, Admission Control (AC) and QoS Aware Routing (QAR). One important issue to providing QoS in multi-hop MANET is to ensure whether a set of nodes between the source and destination pairs satisfy the bandwidth of the data session requirement [7, 11]. QoS can be achieved by admission control, where a new session gets admitted without disturbing already admitted sessions.

For multi- hop MANET there are several Admission Control algorithm have been proposed; such as Contention aware Admission Control (CACP), Adaptive Admission Control (AAC), and Perceptive Admission Control (PAC), etc.[6]. However, proposed protocol uses single path per data session. When protocols adopted with parallel multipath routing, these protocols will not work efficiently. Also, the multipath routing provides the reliable data communication and at the same time it improves the load balancing [3, 8].

Many researchers has been put on focus to multi-path routing protocol; such as Multi-path Source Routing (MSR), Bandwidth aware Multi-path routing, Multi-path Routing with Admission Control Protocol (MRAC) [12]. In wireless network, bandwidth is considered to be a most important resource. While considering the importance of network's bandwidth, multi-path with parallel routing approach becomes an interesting work to consider for. There is a challenge to estimate the available bandwidth in any IEEE 802.11 based wireless networks [4]; specifically when a session is admitted, there is ample difference between single path case and multiple parallel path case [5]. The traffic allocation among all parallel paths is critical portion in admission control when utilizing the multiple paths. Up to our knowledge, admission control protocols are mostly proposed single path and there are very few parallel multipath routing approach exist are coupled with admission control protocols. Hence proposed protocol focus on admission control and multipath routing with assured bandwidth for IEEE 802.11 based mobile ad hoc networks. In this paper, Cooperative Multipath Admission Control (CMAC) protocol is proposed for IEEE 802.11 based mobile ad hoc networks. In our design, first we described bandwidth estimation under multipath routing condition which also considers the bandwidth consumed by already admitted sessions. Then later, to improve our design the multi-path routing utilizes our proposed bandwidth estimation technique.

In our CMAC protocol precisely estimates the bandwidth of each node and it does append with route request packet at the time of route discovery and then the destination node receives piggybacked the route request. The destination node ensures node disjoints condition of the paths. The heuristic algorithm finds the paths, which support the bandwidth of a session requirements. Through bandwidth estimation at each node in all parallel paths, the session may admit or rejected in route reply stage. Our newly designed protocol analyzed its performance with the help of extensively verified by simulation. Biotechnology concept in wireless network is used to improve the services and accuracy of network.

The rest of this paper organized as follows. A brief discussion about bandwidth analysis under multipath routing is explained in section 2. In section 3 we described our network model and Cooperative Multipath Routing Admission Control, a multipath algorithm is presented. In section 4, we analyzed the performance of CMAC and explained by simulation results.

Bandwidth Analysis under Multipath Routing

The basic input for an admission control to decide the admission is based on underlying network's bandwidth constrains. Here we analyze the bandwidth for following network model. The node set with IEEE 802.11 CSMA/CA with CTS/RTS mechanism [9]. And the carrier sensing range (CS-Range) is at least twice the transmission range [10]. The available bandwidth (B_{avail}) of a link in a certain direction is defined as the effective channel capacity on the available channel idle time over a given period. The available bandwidth is computed by:

$$B_{avail} = LTE \times CITR \quad (1)$$

Where, *LTE* is the transmission efficiency of the link which is calculated based on the maximum effective bits transmitted over the link per second, and Channel Idle Time Ratio (CITR) is the available channel idle time ratio during a given time period. *LTE* is the average time for successfully transmitting a packet S_{data}, and it's on a given link be T and is expressed by:

$$LTE = S_{data} / T \quad (2)$$

Where T, is the period from the beginning of the transmission when the medium becomes idle to Acknowledgement frame is received successfully. The CITR can be calculated by, the carrier sensing neighbors will also contend for the bandwidth in IEEE 802.11 based wireless networks. In our work, we use passive method to estimate bandwidth consumption of carrier sensing neighbors. The channel idle time T_{idle} is a certain period of Δt, and then CITR can be expressed by:

$$CITR = T_{idle} / \Delta t \quad (3)$$

The bandwidth estimation under single path differs from the multipath case. Assume BW_{req} is required bandwidth for a session and transfer to the multiple parallel paths. If path Pi the corresponding allocated traffic is T_{alloc}, then the bandwidth requirement should satisfy:

$$BW_{req} = T^{i}_{alloc} \quad (4)$$

Where $i = 1, 2, 3.., n$. Bandwidth consumption of a given node, when a session is admitted through n parallel path may depends on two factors: number of node contends bandwidth at the destination node and traffic of the each path. Bandwidth contender is generally reside within the carrier sensing range, then bandwidth consumption BC can be denoted as:

$$BC = \sum_{i=1}^{n} \left(\left| CS\text{-}Neighbor \cap \{Pi - D\} \right| * T^{i}alloc \right) \quad (5)$$

Where CS-Neighbor is the neighbors node of given node and $\{Pi - D\}$ is set of node except destination node. The important consideration of admission control is residual capacity mentioned as RC. It's defined as available bandwidth of a node after session admission. We calculate RC by:

$$RC = B_{avail} - BC \quad (6)$$

From our bandwidth estimation study, we made following equations to optimize the problem. The path residual capacity can be estimated by a collection of all nodes with minimum residual capacity in a path. It echoes remaining capacity of a path. We denote path residual capacity is RC_{path} and that can be expressed by:

$$RC_{path} = \min(RC1, RC2, \ldots, RCm) \quad (7)$$

Where, m is the number of node in a path. To achieve multipath data transmission we need multipath residual bandwidth, which can be denoted as $RC_{multipath}$. Assume there is n cooperative paths are used for the data session, and path residual capacity of each cooperative paths residual capacity can be evaluated by equation (8), then $RC_{multipath}$ can be expressed by:

$$RC_{multipath} = \min(RC_{path}1, RC_{path}2, \ldots, RC_{path}n) \quad (8)$$

The path's available capacity is related to the available bandwidth of every node in the path [8]. The nodes residual bandwidth and path residual bandwidth must be calculated separately for allowing node to admit a session in to multiple parallel paths.

Load Balanced Multipath Admission Policy

a) Problem Definition: In MANET, a node initiates a data session with required bandwidth is transferred to multiple parallel paths, then how total traffic disseminated to each path. In this problem, obviously the traffics assigned to all parallel paths are variable. As inspiring example, suppose that we have a communication network, in which certain pairs of nodes are linked by connections and connections has a limit to the rate at which data can be sent. Given two nodes on the network, what is the maximum transmission rate at which one can send data to the other?

b) Example: Consider the following network and assume that *a* needs to send data at a rate of 6 mbps to *e*.

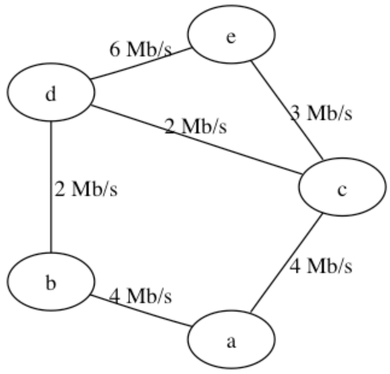

Figure 1: Network Graph

a can split its stream of data and send 4 mbps to *c* and 2 mbps to *b*. The node *b* relays the *2 mbps* stream of data that it receives from *a* to *d*, while node *c* splits the *4mbps* stream that it receives into two parts: it relays *3mbps* of data rate to *e*, and send the remaining 1 mbps to *d*. Overall, *d* receives 3 mbps of data, which it relays to *e*. But in case wants *a* send more data rate such as *7mbps* to *e*, but it is not possible. Consider the two links *(b,d)* and *(a,c)* in the fig.1 and suppose removed them from the network. Then there would be no way reaching *e* from *a*, and no communication would be possible. This means that all the data that *a* sends to *e* must go through one of those links. The two links *(b,d)* and *(a,c)* support at most the transmission of 6 mbps of data rate, and so that is the maximum transmission rate at which *a* can send data packet to *e*. The data packet has to go from one node to another node, subject to capacity constraints in links. In some such applications, it makes sense to consider in which the capacity of a link depends on the direction, thus that the capacity of the link $u \rightarrow v$ could be different from the capacity of the link $v \rightarrow u$. formally an instance of the maximum data rate is defined as follows.

c) Solution:

Assumption: We take up the nodes are identical and flows are follows independent uniform distribution. Nodes are having the same transmission range. We assume transmission and carrier sensing range of the nodes are same. The network graph we assume that $G = (V, E)$ where E is the edge and V is set of nodes. A network is a directed graph, in which, A vertex s $\in V$ and a vertex $d \in V$ are specified as being the source node and the sink node, respectively and all directed edge $(u, v) \in E$ has a positive capacity $c(u ,v) > 0$ associated to it. If both the edges (u, v) and (v, u) belong to E, we allow their capacities to be different. Sometimes capacities includes between pairs of vertices that are not connected by an edge. In such case the convention is that the capacity is zero. A session (flow) in a network is a specification of how to route data packets from *s* to *d* so that no link is used beyond its capacity and so that every link except the sender *s* and the receiver *d* and relays out data packets at exactly the same rate at which it receives from other vertices. In the given network graph, if nodes where sending out less data than they receive then there would be data loss and they cannot send more data packets than they receive, since they are simply forwarding data. Formally, we have the following definition.

Definition 1: A session in an network (G, s, d, c) is an assignment of a non-negative number $f(u, v)$ to every edge $(u, v) \in E$ such that
For every edge $(u, v) \in E$, $f(u, v) \leq$ c $f(u, v)$;

For every vertex $v \in V$, $\sum_{v \in V} f(u, v) = \sum_{w \in V} f(v, w)$;

Where we follow the convention that $\sum f(u, v) = 0$ if (u, v) not belonging to E. The *cost* of the session is $\sum v\, f(s, v)$. In this problem, given a network we want to find a session of maximum cost. Is the session optimal? In general, how do we reason about the optimality of a session? Because approximation algorithms for problems in each case able to reason about the approximation of an algorithm only because we had ways to prove lower bounds to the optimum. Here that we are dealing with a maximization problem, if we are going to motive about the quality of solutions provided by our algorithms, we require ways to prove upper limits to the optimum. When we considered the example, we noticed that if we look at any set of edges whose removal disconnects the receiver from the sender then all the session from the sender to the receiver must pass through those edges and so their total capacity is an upper bound to the cost of any session that including the optimal session. This motivates the following definition.

Definition 2: (Link Disconnection) A link disconnection in a network $G = (V, E), s, d, c)$, is partition $(A, V\text{-}A)$ of the set of vertices V into two sets, such that $s \in A$ and $d \in V\text{-} A$. We will usually identify a link disconnection with the set A that contains *s*. The capacity of a disconnected link is the quantity

$$c(A) = \sum_{u \in A,\, v \in A} c(u, v)$$

Let *A* be a disconnected link in a network, a set of vertices that contains *s* and does not contain *d*. If we eliminate those edges from the network, then it is impossible to go from any vertex in *A* to any vertex outside *A* and, in particular, it is impossible to go from *s* to *d*. This means that all the session from *s* to *d* must pass through those edges, and so the total capacity of those edges is an upper bound to the cost of any feasible session. Even though what we just said is rather self-evident, let us give a precise proof, since this will help make known ourselves with the techniques used to prove exact results about sessions.

Definition 3: (Residual Capacity) Let $N = (G, s, d, c)$ be a network, and *f* be a session. Then the residual capacity of *N* with respect to *f* is a network in which the edge (u, v) has capacity $c(u, v) - f(u, v) + f(v, u)$.

The idea is that, in the residual network, the capacity of an edge measures how much more flow can be pushed along that edge in addition to the session *f*, without violating the capacity constraints. The edge *(u, v)* starts with capacity c (*u, v*), and *f(u, v)* units of that capacity are taken by the current session; in addition, we have *f(v, u)* additional units of virtual capacity that come from the fact that we can reduce the session from *v* to *u*. The following CMAC algorithm is a simple greedy algorithm that starts from an empty session and as long as it can find an augmenting path improves the current solution using the path.

Algorithm: CMAC
Input: Network $G = (V, E), s, d, c$ *and* $f(u, v) = 0$
Compute the residual capacities of the network
While there is a path *P* from *s* to *d* such that all edges in the path have positive residual capacity

a. let c'_{min} be the smallest of the residual capacities of the edges of *P*
b. let *f'* be a session that pushes c'_{min} units of session along *P*, that is,

if $(u, v) \in P$
$f'(u, v) = c'_{min}$
else
$f'(u, v) = 0$

c. $f = f(u, v) + f'(u, v)$
d. **for each** (u, v) ; $f(u, v)$ *and* $f'(u, v)$ are both positive,

$f_{min} = \min \{ f(u, v), f(v, u)\}$
$f(u, v) = f(u, v) - f_{min}$
$f(v, u) = f(v, u) - f_{min}$

e. Recompute the residual capacities *c'* of the network according to the new session

Return *f*

At every step, the algorithm increases the current solution by a positive amount c'_{min} and, the algorithm converges in predetermined time to a solution that cannot be enhanced via an augmenting path. Note the step after the session is increased, which makes sure that session pushed along a virtual edge in the residual network is realized by reducing the actual session in the opposite direction. The CMAC algorithm is optimal and it proves the essential fact that whenever a link disconnection is optimal, its optimality can always be proved by exhibiting a disconnection whose capacity is equal to the cost of the session. An important three conditions are equivalent for a session *f* in a network that is, there is a link disconnection whose capacity is equal to the cost of *f*, the session *f* is optimal and there is no augmenting path for the session *f*.

To verify the correctness of the method, the proof has been given here. Let *f* be a session such that there is no augmenting path in the residual network. Take *A* to be the set of vertices reachable from *s* via edges that have positive capacity in the residual network. Then, $s \in A$ by definition and *d* does not belong to *A* Otherwise we would have an augmenting path. So, *A* is a disconnected link. Now observe that for every two vertices $a \in A$ and $b \notin A$, the capacity of the edge (a, b) in the residual network must be zero, otherwise we would be able to reach *b* from *s* in the residual network via positive-capacity edges, but $b \notin A$ means that no such path can exist. Recall that the residual capacity of the edge *(a,b)* is defined as $c(a, b) - f(a,b) + f(b,a)$ and that $f(a, b) \leq c(a, b)$ and that $f(b, a) \geq 0$, so that the only way for the residual capacity to be zero is to have, $f(a,b) = c(a,b)$; $f(b, a) = 0$;

Suppose that we had defined the residual network as a network in which the capacity of the edge *(u, v)* is $c(u, v) - f(u, v)$, without the extra capacity coming from the session from *v* to *u*, and suppose that we defined an augmenting path to be a path from *s* to *d* in which each capacity in the residual network is positive. Then we have seen before an example of a session that has no augmenting path according to this definition, but that is not optimal. Where does the proof of the maximum flow and minimum link disconnection break down if we use the $c(u, v) - f(u, v)$.

Simulation Evaluation

Simulation parameters are shown in Table.1. We used, traffic model as constant bit rate (CBR) and the CBR traffic size is 1024 bytes. Five data sessions were admitted to establish connections with random source and destination. In simulation, the IEEE 802.11 DCF (Distributed Coordination Function) are used as MAC protocol. We tested our protocol under a Mobile Ad Hoc Network with 100 nodes distributed randomly in 1000x1000. Radio transmission range set to 250m as and 550m as carrier sensing range respectively. The CMAC protocol compared with MSR and MRAC [12] protocol for performance evaluation purpose and the evaluation we made is based on traffic load given in table 2 and the table shows the starting time and the bandwidth requirement of the data sessions in the given scenarios, where the throughput of each session is randomly drawn between 10 and 200 kbps. The simulation runs for 200 seconds. We have collected end-to-end throughput and delay values of each session and used as the metrics to evaluate the performance.

Fig.1 and fig.2 shows the throughput of different load attained by CMAC respectively. In the results, the number of admitted session is more or less similar; in addition, the throughput of the admitted session is higher than other models during the simulation time. As shown, CMAC obtain higher throughput. However, when MSR and MRAC are used, only medium throughput is obtained.

From the results, it is clear that the proposed protocol is capable of reducing the number of unnecessary routing packets during route discovery, by making admission control decisions at every node in the network. Thus, MSR and MRAC can use more resources in the network than other models to transmit data packets. In addition, CMAC attains greater aggregated throughput than other models. The admission control protocols are primarily designed to realtime applications that have requirements on end-to-end delay, it is essential to make sure that the additional overhead do not comprise added delay that go over the delay bounds of the requests

Table 1
Simulation Parameters

Parameters	Values
Propagation Model	Two Ray Ground
MAC Protocol	IEEE 802.11
Reception range	250 m
Carrier Sensing Range	550m
Bit Rate	1 mbps
Data Rate	2 mbps
Network Area	1000m x 1000m
Mobility Model	Random Way Point
CW_{min}	32
CW_{max}	1024
DIFS	50 µs
SIFS	10 µs
Slot Time	20µs

Table 2
Bandwidth requirements of the session

Session	**1**	**2**	**3**	**4**	**5**
Starting Time	15	30	45	60	8 0
Load 1 (kbps)	49. 60	15 6.2	10 1.8	14 3.5	7 2
Load 2 (kbps)	18 0	15 6	10 2	11 5.5	8 3.

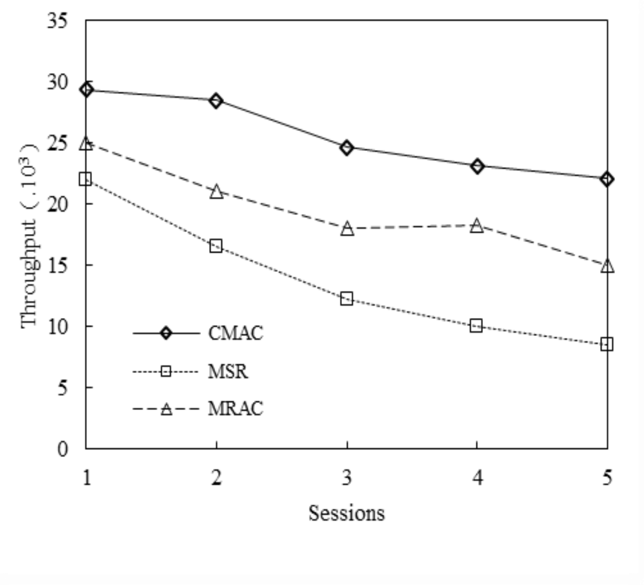

Figure 2: Throughput on Load 1

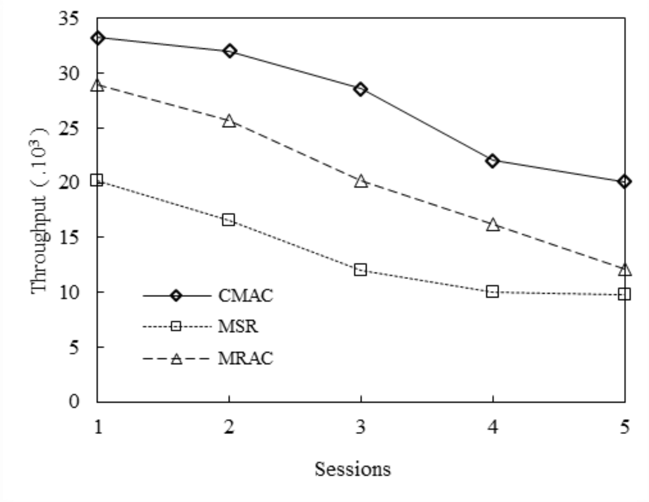

Figure 3: Throughput on load 2

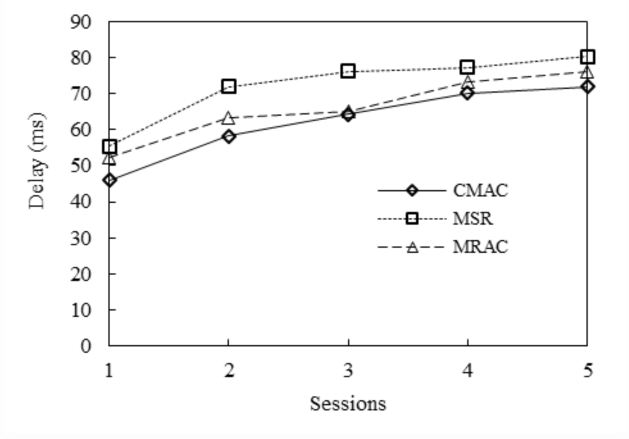

Figure 4: Delay on load 1

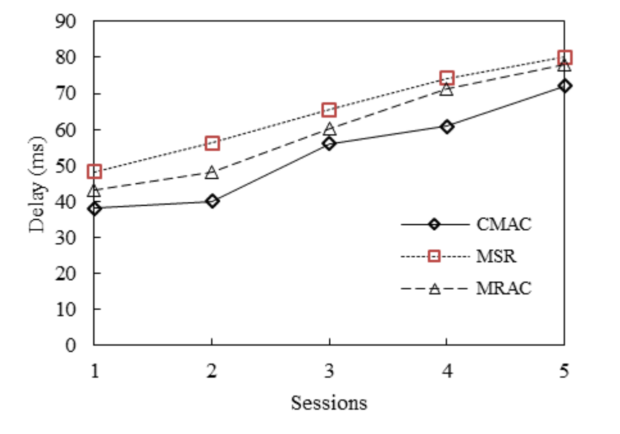

Figure 5: Delay on load 2

The end-to-end delay for the different load can be seen in fig.3 and fig.4 respectively. From these figures, CMAC is capable of providing an increase in data packet delivery and minimize the end-to-end delay. Since there is no admission control performed in MSR and MRAC, the network becomes congested as new sessions are added to the network, resulting in decreased throughput and dramatically increasing the delay of the sessions. The throughput of the sessions shows significant degradation; also the delay rises as the numbers of sessions increases. The average end to end delay in the simulations that is achieved for all other two protocols is much higher than CMAC, indicating CMAC's ability to balance the network load.

Conclusion

This paper analyses the available bandwidth and bandwidth consumption under single path routing and multipath routing. Then CMAC model that identifies the optimal parallel path and with combined admission control algorithm where proposed for IEEE 802.11 based MANET. It found that two parallel paths could significantly improve the throughput. Finally the simulation result shows that CMAC achieves a better performance in improving throughput, end to end delay.

References

1. Hanzo L. and Tafazolli R., A Survey of QoS Routing Solutions for Mobile Ad Hoc Networks, *IEEE Communications Surveys & Tutorials*, **9 (2)**, 50-70 **(2009)**

2. Ronghui Hou, King-Shan Lui, Hon-Sun Chiu, Yeung Kwan L. and Fred Baker, Routing in multi-hop wireless mesh networks with bandwidth guarantees, *ACM Mobihoc*, **09**, 353-354 **(2009)**

3. Lei Wang, Lianfang Zhang, Yantai Shu and Miao Dong, Multi-path source routing in wireless MANETs networks, Canadian Conference on Electrical and Computer Engineering, **1(7-10)**, 479-483 **(2000)**

4. Xie G. et al, Joint Optimal Multi-path Routing and Rate Control for Multi description Coded Video Streaming in MANETs Networks, *IEEE Transactions on Multimedia*, **10**, 1687-1697 **(2008)**

5. Meghanathan Natarajan, Stability and Hop Count of Node-Disjoint and Link-Disjoint Multi-Path Routes in MANETs Networks, Third IEEE International Conference on Wireless and Mobile Computing, *Networking and Communications*, WiMOB **8-10**, 42-49 **(2007)**

6. Yaling Yang and Kravets R., Contention-aware admission control for MANETs networks, *IEEE Transactions on Mobile Computing*, **4**, 363-377 **(2005)**

7. Ng P. and Liew S., Throughput Analysis of IEEE 802.11 Multi-hop MANETs Networks, *IEEE/ACM Transaction on Networking* **(2007)**

8. Banner R. and Orda A., Multi-path Routing Algorithms for Congestion Minimization, *IEEE/ACM Transactions on Networking*, **15(2)**, 413-424 **(2007)**

9. Sarr C., Chaudet C., Chelius G. and Lassous I.G., Bandwidth estimation for IEEE 802.11-based ad hoc networks, *IEEE Transactions on Mobile Computing*, **7(10)**, 1228-41 **(2008)**

10. Suresh K.C., Prakash S., Priya A.E. and Kathirvel A., Primary path reservation using enhanced slot assignment in TDMA for session admission, *The Scientific World Journal* **(2015)**

11. Suresh K.C. and Prakash S., MAC and Routing Layer Supports for QoS in MANET: A Survey, *International Journal of Computer Applications*, **60(8)**, 41-46 **(2012)**

12. Peng Z., Xinyu Y. and Anhua Y., Joint Multipath Routing and Admission Control with Bandwidth Assurance for 802.11-based WMNs, WCNC **(2011)**.