Splitting of traffic to maximize the data transmission in mobile ad hoc network under different constraints

Sushil Chandra Dimri[1], Kamlesh Chandra Purohit[2] and Durgesh Pant[3]

[1]**Graphic Era University, Dehradun, Uttarakhand-India 248001**

[2]**Graphic Era University, Dehradun, Uttarakhand-India 248001**

[3]**Uttarakhand Open University, Dehradun, Uttarakhand-India 248001**

Abstract

Mobile ad hoc network (MANET) is a set of wireless mobile computer forming a temporary network with out any wired infrastructure, due to dynamic nature of topology and other constraints transmission routing is a challenging task in MANET. The splittable routing establishes multi paths between source nodes and destination nodes; this scheme provides better performance of the network under different constraints. This paper presents a L.P.P. model for the routing problem in MANET and generates the optimal solution in term of route identification for transmission and the amount of traffic per route to maximize the data transmission under various constraints.

Keywords: *MANET, Single path routing, Maximization of splittable traffic flow*

1. Introduction

Mobile ad hoc network consists of the nodes which change their position over time, the movement of the nodes is random and unpredictable, and nodes may leave and join the network at any point of time. The node works as a source, which generates data (traffic), destination and the router. Each node has limited memory, processing power and battery energy. The transmission and receiving range of a node is limited so multiple hops are required to transmit the data to the other distant nodes, which makes routing a crucial issue in mobile ad hoc network. There are many factors associated with MANET which makes routing a difficult issue in this mobile environment. [1, 2 and 3].

The main characteristics of the MANET are:

a) Temporary topology which changes over time
b) Limitation on resources
c) Wireless transmission
d) Network partitions
e) Limited bandwidths
f) Multi functionality of a node as source, destination router and rely transmitter Mobile ad hoc network is totally different from the wired network, in MANET, mobility of the nodes is the biggest issue; the mobility is absolutely random in term of time and direction. The mobility of nodes is mainly responsible for various problems associated with mobile ad hoc network.

The main challenges of mobile environment are:

a) Packet loss due to transmission error and limited processing power of a node
b) Variable capacities of links
c) Limited communication bandwidth
d) Broad cast nature of communication
e) battery life limited
f) Node mobility
g) Wireless medium

1.1 Single Path Routing:

In MANET single path routing is not an effective routing technique specially when there are many constraints. Single path routing sends entire traffic via a single route from source to destination. In MANET, the link capacity (bandwidth), the memory and processing power of the nodes are limited so that they can not handle high amount of traffic, which generally leads to congestion ,packet loss

, formation of hot spots in the network ,as a consequences the end to end delay and unreliability of the network increases. In single path routing, if a link breaks or a node fails it leads to the network failure, i.e. no transmission occurs between source S and destination T.

1.2 Splitting of Traffic to Multiple Routes in Manet:

Splitting the traffic to multiple routes can provide better load balancing, fault tolerance and higher aggregate bandwidth. Splitting of the traffic can be helpful in reduction of congestion and bottle necks; this also improves network resource utilization and bandwidth optimization [4, 5, 6 and 7].

Suppose if node S (source) has 3 routes to the destination T, If S sends data packets along all the three paths, as long as all the routes are not failed, node T will receive the data and the transmission survives. In single path routing failure of a link/node of the route will stop the entire transmission; thus this approach of splitting of traffic increases the strength of network survival.

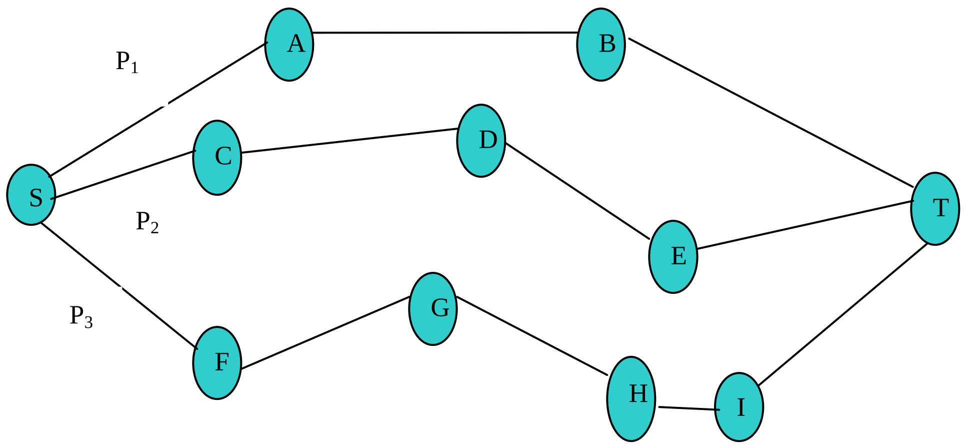

Fig. 1- Three disjointed routes between source S and destination T

There are 3 disjointed routes between source S and destination T, out of these paths P_1 is the shortest one containing merely two intermediate node and 3 links, let us suppose the probability of failure of link and nodes are 0.02 and 0.01 respectively, these probabilities are same for all nodes and links in the given network.(Figure-1). Then the probability of failure of path $P_1(S-A-B-T)$, $P\ (FP_1)$ is given by

$$P(FP_1)=3\times 0.02+2\times 0.01=0.08.$$

If we are applying splittable approach to send the data from S to T, and using routes P_1, P_2 and P_3 to send data then the probability that all the routes will fail simultaneously can be determined by the relation

$$P\ (FP_1 \cap FP_2 \cap FP_3\ )$$
$$= P(FP_1)\times P(FP_2)\times P(FP_3)$$

$$P(FP_2)=4\times 0.02+3\times 0.01=0.11$$
$$P(FP_3)=\ 5\times 0.02\ +4\times 0.01=0.14$$

Thus the probability of failure of all the routes is given by

$$P\ (FP_1 \cap FP_2 \cap FP_3\ )$$
$$= P(FP_1)\times P(FP_2)\times P(FP_3)$$
$$P\ (FP_1 \cap FP_2 \cap FP_3\ )$$
$$= 0.08\times 0.11\times 0.14 = 0.001232$$

Clearly the $P(FP_1 \cap FP_2 \cap FP_3) < P(FP_1)$

Thus splittable routing enhances the network reliability and survivability.

The bandwidth in mobile ad hoc network is limited and single path routing can not provide enough bandwidth to maximize the data transmission , since nodes are battery supported and have limited power, high traffic will reduce the energy level of a node very quickly, so in case of single path routing the consumption of energy is high. Splittable routing will be the best answer to all these problems, in this scheme the traffic will be splitted among the multiple paths. These paths may or may not be disjointed. The splittable routing scheme provides better load balancing, fault tolerance, as it distributes the traffic to multiple routes and increase the aggregate bandwidth, further this approach also decreases the intensity of traffic load per path, per nodes.

1.3 Route Establishment and Route Maintenance:

The process of establishing routes consists of finding multiple routes between a source node and the destination node [8 and 9]. (Fig. 2).

- In MANET a route between any two nodes is established sending a route request by the source node to the neighboring nodes, from where this request it reaches to the destination node if the routes exist.
- This mechanism discovers multiple routes in the network between source and destination node.
- The route request first to arrive is accepted by the target. The target then responds on that route and intimates the initiator what the source routes are.
- In this way routes are established and then used to send the data traffic.

1.3.1 Maintenance of Routes:

This process in ad hoc network is used to repair the broken routes or finding alternative routes in case of routes failure.

- When the links lies on the alive routes between source and destination breaks then the existing routes does not work.
- When a node detects a broken link while attempting to forward a packet to the next hop, it generates an error message that is sent to all the sources using the broken link. If a source receive an error message and route to the destination is still required, it initiates a new route discovery process. Routes are also deleted from the routing table if they are unused for a certain amount of time.
- With help of route discovery mechanism an alternative route has established.

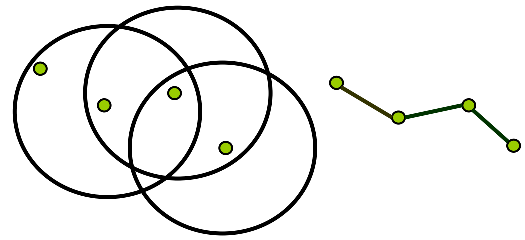

Fig. 2- The MANET and route establishment of routes in MANET

1.4 Distribution of Traffic:

Once source node establishes a set of paths to the destination, it can begin sending data to the destination along the paths. The distribution of traffic to different routes is based on the link capacity and cost of the routes. In case of equal capacity and equal cost routes ,the distribution of traffic will be same i.e. equally divided but when the cost of routes, capacity of the routes, energy consumption of the routes are different then the distribution of traffic among the different routes under various constraints is a difficult task. To solve this problem in this paper we present a L.P.P. model for distribution of traffic so as to maximize the data transmission between source and destination under various constraints. [7, 8, 9 and 10]

2. Network Model:

Assuming a path P_i (i =1, 2--p) consists of I_i intermediate relaying node. Suppose a traffic flow with average rate λ exist between source S and destination T, this traffic is then splitted in p routes, let the traffic along path P_i is $\lambda_i, (i=1,2,---,p)$, the distribution of traffic $\lambda_i, (i=1,2,---,p)$ is Poisson distributed.

$$\sum_{i \in (1, \dots, p)} \lambda_i = \lambda.$$

Let μ be the average processing rate of the each node which is sufficiently high and ignore the background traffic at any node on any path. Maintaining several routes for every source-destination pair would balance the traffic more evenly across the network and would alleviate the effect caused by congested link. The load between any source destination pair is to be evenly divided among all available routes. Although we are studying the problem of ad hoc network in static environment, however it has been realized that node mobility pattern has significant impact on the connectivity of the network.

3. Formulation of Problem:

Let S is the source and T is the target in the given MANET and the path under consideration for flow between S and T

are p, these paths are not necessarily all disjointed [2, 3 and 6].
Let P_1, P_2, P_3… P_p are the routes between S and T and traffic along these paths are $\lambda_1, \lambda_2, \lambda_3, \ldots\ldots\ldots \lambda_p$ respectively.

Under a fixed given cost B>0(Budget) for per unit of time, different link capacity, energy amount available per unit of time and with given cost of link (C_e) per unit of traffic, we have to maximize the (S, T) traffic flow. It is possible to transform this problem in to a linear programming problem with the objective of maximization of total traffic flow between S and T with the restriction of the link capacities and node energy availability and under a given cost (budget), that is the traffic flow value in a link cannot exceed the capacity of the link and the total flow cost cannot be higher than the given cost [11,124, and 13].
Let energy consumption per unit of flow per node is D_n mW and the energy limitation per unit of time is E unit (mW- Mili Watt).Clearly the energy consumption of a node is directly proportional the amount of traffic passing through that node per unit of time.

The problem as L.P.P. is

$$Max\ \lambda = \lambda_1 + \lambda_2 + \lambda_3 + \ldots\ldots\ldots + \lambda_p$$

Subject to

$$\sum_{i \in \{1, \ldots, p\},\ e \in Pi} \lambda_i \le U_e$$

U_e is capacity of link e. for all link e in the network

$$\sum_{i \in \{1, \ldots, p\}} \lambda_{i.} Cp_i \le B,$$

Cost $B > 0$

$$\sum_{i \in \{1, \ldots, p\}} \lambda_{i.} Ep_i \le E,$$

Energy available $E > 0$

$$\lambda_i \ge 0\ for\ all\ i \in \{1 \ldots p\}$$

Where cost of path P_i, $C_{p_i} = \sum_{e\ \varepsilon\ P_i} C_e$ C_e is the cost of the link where $e \in Pi$

$E_{pi} = I_{pi} \times D_n$ Where I_{pi} is the number of intermediate nodes on path P_i between S and T.

The constraints set contains constraints such that the sum of the traffic flow values on the paths containing the link e must be bounded by U_e (capacity of edge e), the cost of total transmission per unit of time remain less than B, and energy consumption per unit of time bounded above by E [14, 15 and 16].

3.1 Example: Maximization of Splittable Traffic Flow Under Above Mentioned Constraints for P=4, For Given Network:

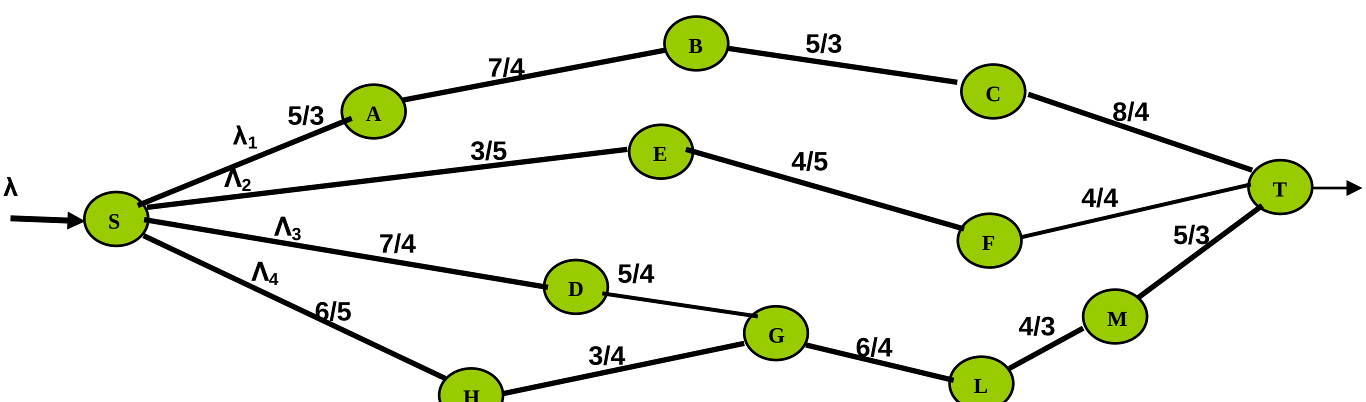

Fig.3 - The network with link capacity and cost

In Figure-3, a MANET is given with link capacity and cost to use that link per unit of traffic flow, S is the source node and T , is the destination, the objective is to maximize the traffic between S and T under cost, capacity and energy constraints.

Routes considered between S and T are:

$$P_1 \equiv S - A - B - C - T$$

$P_2 \equiv S - E - F - T$
$P_3 \equiv S - D - G - L - M - T$
$P_4 \equiv S - H - G - L - M - T$
λ_1 *traffic flow along* P_1
λ_2 *traffic flow along* P_2
λ_3 *traffic flow along* P_3
λ_4 *traffic flow along* P_4

The maximization of transmission with p = 4

Let the given cost (budget) B per unit of time is Rs200 and the available energy limit E is 50 unit (mw-mili-watt) the consumption of energy per unit of flow per node D_n =2 unit (mW-mili-Watt)

The different routes in the given network are
$P_1 \equiv S - A - B - C - T$
$P_2 \equiv S - E - F - T$
$P_3 \equiv S - D - G - L - M - T$
$P_4 \equiv S - H - G - L - M - T$

Also the cost of routes

$C_{P1} = 3+4+3+4=14$

$C_{P2} = 5+5+4=14$

$C_{P3} = 4+4+4+3+3=18$

$C_{P4} = 5+4+4+3+3=19$

The L.P.P for the problem.

$$Max\ Z = \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4$$

The transmission constraints

$\lambda_1 \le 5$
$\lambda_2 \le 3$
$\lambda_3 + \lambda_4 \le 4$
$\lambda_4 \le 3$
$\lambda_3 \le 5$
$14\lambda_1 + 14\lambda_2 + 18\lambda_3 + 19\lambda_4 \le 200$ // Cost constraints//
$6\lambda_1 + 4\lambda_2 + 8\lambda_3 + 8\lambda_4 \le 50$ // Energy constraints//

Using the slack variable $\lambda_5, \lambda_6, \lambda_7, \lambda_8, \lambda_9, \lambda_{10}$ and λ_{11} to convert inequalities in to equalities

$$Max\lambda = \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 + 0\lambda_5 + 0\lambda_6 + 0\lambda_7 + 0\lambda_8 + 0\lambda_9 + 0\lambda_{10} + 0\lambda_{11}$$

$$\lambda_1 + 0\lambda_2 + 0\lambda_3 + 0\lambda_4 + 1\lambda_5 + 0\lambda_6 + 0\lambda_7 + 0\lambda_8 + 0\lambda_9 + 0\lambda_{10} + 0\lambda_{11} = 5$$

$$0\lambda_1 + 1\lambda_2 + 0\lambda_3 + 0\lambda_4 + 0\lambda_5 + 1\lambda_6 + 0\lambda_7 + 0\lambda_8 + 0\lambda_9 + 0\lambda_{10} + 0\lambda_{11} = 3$$

$$0\lambda_1 + 0\lambda_2 + \lambda_3 + \lambda_4 + 0\lambda_5 + 0\lambda_6 + \lambda_7 + 0\lambda_8 + 0\lambda_9 + 0\lambda_{10} + 0\lambda_{11} = 4$$

$$0\lambda_1 + 1\lambda_2 + 0\lambda_3 + \lambda_4 + 0\lambda_5 + 1\lambda_6 + 0\lambda_7 + \lambda_8 + 0\lambda_9 + 0\lambda_{10} + 0\lambda_{11} = 3$$

$$0\lambda_1 + 0\lambda_2 + 1\lambda_3 + 0\lambda_4 + 0\lambda_5 + 0\lambda_6 + 0\lambda_7 + 0\lambda_8 + 1\lambda_9 + 0\lambda_{10} + 0\lambda_{11} = 5$$

$$14\lambda_1 + 14\lambda_2 + 18\lambda_3 + 19\lambda_4 + 0\lambda_5 + 0\lambda_6 + 0\lambda_7 + 0\lambda_8 + 0\lambda_9 + 1\lambda_{10} + 0\lambda_{11} = 200$$

$$6\lambda_1 + 4\lambda_2 + 8\lambda_3 + 8\lambda_4 + 0\lambda_5 + 0\lambda_6 + 0\lambda_7 + 0\lambda_8 + 0\lambda_9 + 0\lambda_{10} + 1\lambda_{11} = 50$$

$$\lambda_1, \lambda_2, \lambda_3, \lambda_4, \lambda_5, \lambda_6, \lambda_7, \lambda_8, \lambda_9, \lambda_{10}, \lambda_{11} \ge 0$$

FORMING THE SIMPLEX TABLE

Table 1: The initial Simplex Table

		C_J	1	1	1	1	0	0	0	0	0	0	0
C_B	X_B	B	λ_1	λ_2	λ_3	λ_4	λ_5	λ_6	λ_7	λ_8	λ_9	λ_{10}	λ_{11}
0	λ_5	5	1	0	0	0	1	0	0	0	0	0	0
0	λ_6	3	0	1	0	0	0	1	0	0	0	0	0
0	λ_7	4	0	0	1	1	0	0	1	0	0	0	0
0	λ_8	3	0	0	0	1	0	0	0	1	0	0	0
0	λ_9	5	0	0	1	0	0	0	0	0	1	0	0
0	λ_{10}	200	14	14	18	19	0	0	0	0	0	1	0
0	λ_{11}	50	6	4	8	8	0	0	0	0	0	0	1

		Δ_J	−1	−1	−1	−1	0	0	0	0	0	0	0

Table 2: λ_6 is outgoing and λ_2 is incoming vector

		C_J	1	1	1	1	0	0	0	0	0	0	0
C_B	X_B	B	λ_1	λ_2	λ_3	λ_4	λ_5	λ_6	λ_7	λ_8	λ_9	λ_{10}	λ_{11}
0	λ_5	5	1	0	0	0	1	0	0	0	0	0	0
1	λ_2	3	0	1	0	0	0	1	0	0	0	0	0
0	λ_7	4	0	0	1	1	0	0	1	0	0	0	0
0	λ_8	3	0	0	0	1	0	0	0	1	0	0	0
0	λ_9	5	0	0	1	0	0	0	0	0	1	0	0
0	λ_{10}	158	14	0	18	19	0	−14	0	0	0	1	0
0	λ_{11}	38	6	0	8	8	0	−4	0	0	0	0	1
		Δ_J	−1	0	−1	−1	0	1	0	0	0	0	0

Table 3:- λ_7 is outgoing and λ_3 is incoming vector

		C_J	1	1	1	1	0	0	0	0	0	0	0
C_B	X_B	B	λ_1	λ_2	λ_3	λ_4	λ_5	λ_6	λ_7	λ_8	λ_9	λ_{10}	λ_{11}
0	λ_5	5	1	0	0	0	1	0	0	0	0	0	0
1	λ_2	3	0	1	0	0	0	1	0	0	0	0	0
0	λ_7	1	0	0	1	0	0	0	1	−1	0	0	0
1	λ_4	3	0	0	0	1	0	0	0	1	0	0	0
0	λ_9	5	0	0	1	0	0	0	0	0	1	0	0
0	λ_{10}	101	14	0	18	0	0	−14	0	−19	0	1	0
0	λ_{11}	14	6	0	8	0	0	−4	0	−8	0	0	1
		Δ_J	−1	0	−1	0	0	1	0	1	0	0	0

Table 4:- λ_{11} is outgoing and λ_1 is incoming vector

		C_J	1	1	1	1	0	0	0	0	0	0	0
C_B	X_B	B	λ_1	λ_2	λ_3	λ_4	λ_5	λ_6	λ_7	λ_8	λ_9	λ_{10}	λ_{11}
0	λ_5	5	1	0	0	0	1	0	0	0	0	0	0
1	λ_2	3	0	1	0	0	0	1	0	0	0	0	0
0	λ_3	1	0	0	1	0	0	0	1	−1	0	0	0
1	λ_4	3	0	0	0	1	0	0	0	1	0	0	0
0	λ_9	5	0	0	0	0	0	0	−1	1	1	0	0
0	λ_{10}	83	14	0	0	0	0	−14	−18	−1	0	1	0
0	λ_{11}	6	6	0	0	0	0	−4	−8	0	0	0	1
		Δ_J	−1	0	0	0	0	1	1	0	0	0	0

Table 5:- λ_3 is outgoing and λ_7 is incoming vector

		C_J	1	1	1	1	0	0	0	0	0	0	0
C_B	X_B	B	λ_1	λ_2	λ_3	λ_4	λ_5	λ_6	λ_7	λ_8	λ_9	λ_{10}	λ_{11}
0	λ_5	4	0	0	0	0	1	2/3	4/3	0	0	0	−1/6
1	λ_2	3	0	1	0	0	0	1	0	0	0	0	0
1	λ_3	1	0	0	1	0	0	0	1	−1	0	0	0
1	λ_4	3	0	0	0	1	0	0	0	1	0	0	0
0	λ_9	4	0	0	0	0	0	0	−1	1	1	0	0

0	λ_{10}	69	0	0	0	0	0	$-14/3$	2/3	-1	0	1	$-14/6$
1	λ_1	1	1	0	0	0	0	$-2/3$	$-4/3$	0	0	0	1/6
		Δ_J	0	0	0	0	0	1/3	$-1/3$	0	0	0	1/6

Table 6:- λ_5 is outgoing and λ_8 is incoming vector

		C_J	1	1	1	1	0	0	0	0	0	0	0
C_B	X_B	B	λ_1	λ_2	λ_3	λ_4	λ_5	λ_6	λ_7	λ_8	λ_9	λ_{10}	λ_{11}
0	λ_5	8/3	0	0	$-4/3$	0	1	2/3	0	4/3	0	0	$-1/6$
1	λ_2	3	0	1	0	0	0	1	0	0	0	0	0
0	λ_7	1	0	0	1	0	0	0	1	-1	0	0	0
1	λ_4	3	0	0	0	1	0	0	0	1	0	0	0
0	λ_9	5	0	0	1	0	0	0	0	0	1	0	0
0	λ_{10}	205/2	0	0	$-2/3$	0	0	$-14/3$	0	$-1/3$	0	1	$-14/6$
1	λ_1	7/3	1	0	4/3	0	0	$-2/3$	0	$-4/3$	0	0	1/6
		Δ_J	0	0	4/3	0	0	1/3	0	$-1/3$	0	0	1/6

able 7:- all $\Delta_J \geq 0$ Optimal solution Table

		C_J	1	1	1	1	0	0	0	0	0	0	0
C_B	X_B	B	λ_1	λ_2	λ_3	λ_4	λ_5	λ_6	λ_7	λ_8	λ_9	λ_{10}	λ_{11}
0	λ_8	2	0	0	-1	0	3/4	1/2	0	1	0	0	$-1/8$
1	λ_2	3	0	1	0	0	0	1	0	0	0	0	0
0	λ_7	3	0	0	0	0	3/4	1/2	1	0	0	0	$-1/8$
1	λ_4	1	0	0	1	1	$-3/4$	$-1/2$	0	0	0	0	1/8
0	λ_9	5	0	0	1	0	0	0	0	0	1	0	0
0	λ_{10}	619/6	0	0	-1	0	1/4	$-9/2$	0	0	0	1	$-57/24$
1	λ_1	5	1	0	0	0	1	0	0	0	0	0	0
		Δ_J	0	0	0	0	1/4	1/2	0	0	0	0	1/8

Solving these equations with help of Simplex method we get the optimal traffic flow as

$\lambda_1 = 5,\ \lambda_2 = 3,\ \lambda_3 = 0$ and $\lambda_4 = 1$.

The maximum amount of traffic that can be routed per unit of time between source and destination under the constraints is given by $\lambda_{max} = 9.$ unit, also the selected paths to route the data are P_1, P_2 and P_4 only.

4. CONCLUSION:

It is found that the traffic between source S and destination T with given link capacity, cost constraints and energy constraints need not use all available paths but selects few specific paths so as to maximize the transmission under the constraints. In MANET, the nodes are having limited powers so it is very important to route the traffic along the different paths so that the energy consumption remains minimum and network survives for long time. There are several set of source and destination pair in MANET and the splittable routing definitely increase the performance of the network by improving the load balancing, end to end delay and optimization of bandwidth and by minimization the of energy consumption. The L.P.P. formulation of the routing problem in MANET certainly solves the problem of selection of routes and distribution of traffic under constraints. This study of MANET is in static environment but in actual mobility play a great role in MANET.

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Sushil Chandra Dimri

He is Professor of the Department of Computer Applications in the Graphic Era University. He received his Ph.D. in Computer Science from the Kumaun University, India, a Master's degree in Computer Science from the ISM, Dhanbad, India, His main research areas are network services in mobile networks, cyberspace and cyber security, Analysis and Designing of Algorithms , and so on.

Kamlesh Chandra Purohit

He is an Assistant Professor of the Department of Computer Applications in the Graphic Era University. He received his Master's in Computer Science from the Graphic Era University, India. His main research areas are network Security in mobile networks, cyber security and so on.

Durgesh Pant

He is Professor of the Department of Computer Applications in the Uttarakhand Open University. He has more than 20 Years Experience in Academics. His main research areas are network services in mobile networks, Software Engineering and Network resource optimization.