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IMPROVEMENT OF PERFORMANCE OF MOBILE AD HOC NETWORK USING K- PATH SPLITTABLE TRAFFIC FLOW SCHEME

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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. k path splittable routing establish at most k paths between single source and single destination node, this scheme provides better load balancing and increase in reliability of data transmission. This paper presents a comparative study of single path routing and k path routing in mobile ad hoc network.

Keywords: Mobile adhoc network, Load balancing, System delay, Traffic distribution, Reliability,

1. Introduction

Mobile ad hoc network consists of a collection of wireless mobile nodes which dynamically exchange data among themselves without any dependency on a fixed base station. MANET nodes are typically distinguished by limited power, processing and memory resources as well as high degree of mobility. In such networks the wireless mobile node may dynamically enter in the network as well as leave the network. Due to limited transmission range of wireless network nodes, multiple hops are usually needed for the node to exchange information with other nodes in the network so routing is a crucial issue to the design of MANET [1, 2].

In single path routing there is only one path between source and destination. All the transmission between source and destination is through this path only. In this paper we propose, k- path splittable routing in MANET is discussed, k-path splittable routing allows at most k paths between source node and destination node. This scheme is typically proposed to increase the reliability of data transmission or load balancing. Load balancing is of great importance in MANET s because of the limited bandwidth between the nodes.

The paper compares both the scheme of single path routing and k path splittable routing in MANET. In MANETs communication between nodes is done through the wireless medium. Because nodes are mobile and may join or leave the network MANETs have a dynamic topology [1, 3]. Nodes that are in transmission range of each other are called neighbors. The Neighbors can send data directly to each other however when a node needs to send data to another non neighboring node the data is routed through a sequence of multiple hopes, with intermediate nodes acting as routers.

The main issues to consider when deploying MANET [1, 2], are

1. Unpredictability of environment:
2. Unreliability of wireless medium
3. Resources constraints nodes
4. Dynamic topology

As a result of these issues MANETs are prone to numerous types of faults which includes

1. Transmission error
2 Node failures
3 Link failures
4 Route breakages
5 Congested nodes

In single routing, only a single route is used between source and destination node. Two most widely used protocol are the Dynamic Source Routing (DSR) and Ad hoc on demand Distance Vector (AODV) protocols. Both AODV and DSR are on demand protocols [10, 12].

1.1. k-splittable routing in MANET

K path splittable routing can provide load balancing, fault tolerance and higher aggregate bandwidth. Load balancing can be achieved by splitting the traffic among at most k routes [4, 5, and 13]. This arrangement can alleviate congestion and bottlenecks. Suppose if node S (source) has 3 paths to destination D, If S sends same packet along all three paths as long all the paths are not failed, node D will receive the data.

Since band width may be limited in a wireless network, routing along a single path may not provide enough bandwidth for the connection. However if k path are used simultaneously to route the data the aggregate bandwidth of the paths may satisfy the bandwidth requirement of the application. Also since there is more bandwidth available, a smaller end to end system delay may be achieved.

1.2. Route discovery and maintenance

Route discovery and maintenance consists of finding at most k paths between a source and destination node. Route discovery is the process of finding a route between two nodes [3,10].

- A route between two nodes is found by sending an Route Request
- Route Request builds a source route on every path through the network
- First Route Request to arrive is accepted; target responds on that path and tells initiator what the source route is.
- Source route is used on subsequent data traffic

1.2.1. Route Maintenance

Route maintenance is the process of repairing a broken route or finding a new route in the presence of a route failure.

- When routing node/routing node link changes, existing source routes no longer work
- Routing nodes respond to source routes with a Route Error, triggering a new route discovery
- Routing nodes may attempt to change source route and re-forward on a cached route

1.3. Traffic allocation:

Once source node has been selected a set of paths to the destination it can begin sending data to the destination along the paths. The traffic allocation strategy used to deal with how the data is distributed amongst the paths. The choice of allocation granularity is important in traffic allocation [6].The allocation granularity specifies the smallest unit of information allocated to each path. For instance, a per-connection granularity would allocate traffic for one connection to a single path. A per packet granularity would distribute packets from multiple –connections amongst the paths. A per packet granularity result in the best performance, it allow the finer control over the network resources.

2. Network model for k-splittable routing

The single-path model is considered as a multi-node M/M/1 tandem network, and the k-path model as a set of k- parallel path. The proposed framework allows us to investigate issues such as optimal load distribution, end-to-end delay and k- path routing reliability in ad hoc networks.

There are k node disjointed paths, which forms a sub graph in existing network, this sub graph is approximately a rectangular region ,its size depend on source destination separation and the node density.

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To model each multi-hop path, a multi node M/M/1 tandem network is considered

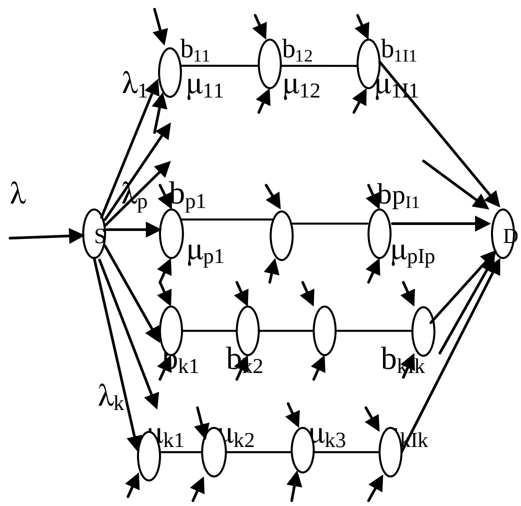

Figure: 1

Assuming a path p(p=1,2--k) consists of Ip intermediate relaying node .Then the pth path can be modeled as a network in which Ip queues are connected in tandem[7].

Suppose a traffic flow with average passion arrival rate λ exist between source and destination, this traffic is then splitted in k-node disjointed paths, the traffic along path p is λp ,(p=1,2,---,k) .the distribution of traffic λp ,(p=1,2,---,k) is Poisson distributed ,the

$$\sum_{p=1}^{k} \lambda_p = \lambda$$

Let μip be the average processing rate of the ith queue at the ith node on path p and bip is the average arrival of background traffic at the ith node on path p.

Let us assume that inter path traffic and sub flow traffic are independent and Pi.p is the probability that the node of interest remains available during observation..

Although we are studying the problem of adhoc network in static environment ,however it has been realized that node mobility pattern has significant impact on the connectivity graph which influences' the performance of the routing protocols in adhoc network.

2.1. k-path routing

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. [7, 16]

The load between any source destination pair is to be evenly divided among all available routes.

We know that the end to end path delay which consists of a large number of independent delays in the intermediate queues is approximately follows the Normal distribution.

The average end to end delay [9], for path p is given by

$$D_p(\lambda_p) = \sum_{i=1}^{I_p} \{1/(\mu_{ip} - \lambda_p - b_{ip})\}$$

The objective is to minimize the system delay with help of splitting the incoming traffic into k-paths. Thus the objective function can be defined as

$$D_{system} = \sum_{P=1}^{k} \{ D_p(\lambda_p) / \lambda + \sum_{p=1}^{k} b_p \}, \quad bp = \sum_{i=1}^{I_p} b_{i,p}$$

$$D_{system} = \sum_{P=1}^{k} \sum_{i=1}^{I_p} \{1/(\mu_{ip} - \lambda_p - b_{ip})\} / \lambda + \sum_{p=1}^{k} \sum_{i=1}^{I_p} b_{i,p} \quad ..(1)$$

Since $D_p(\lambda_p)$, p=1, 2, ---k. is non decreasing and convex so we can apply Lagrange multiplier approach to determine optimal traffic distribution for better load balancing.

Let η be the Lagrangian multiplier then

$$L(\lambda_1, \lambda_2, \text{--}\ \lambda_p \text{---}\ \lambda_k, \eta) = D_{system} + \eta(\lambda - \sum_{p=1}^{k} \lambda_p) \quad ...(2)$$

Differentiating $L(\lambda_1, \lambda_2, \text{--}\ \lambda_p \text{---}\ \lambda_k, \eta)$ with respect to λ_p we get

$$d/d\lambda_p\{D_p(\lambda_p)\} = C\eta, \quad \forall\ p=1,2,\text{----}k.$$

$$d/d\lambda_q\{D_q(\lambda_q)\} = d/d\lambda_r\{D_r(\lambda_r)\}.$$

Further,

$$\sum_{i=1}^{Iq} \{1/(\mu_{iq} - \lambda_q - b_{iq})^2\} = \sum_{i=1}^{Ir} \{1/(\mu_{ir} - \lambda_r - b_{ir})^2\}$$

$$\forall\ q, r \in \{1,2,\text{--}k\} \text{ and } q \neq r.$$

In general the optimal traffic distribution with respect to path p must take all factors such as processing rate μip, inter path traffic rate bip and the route length Ip in to consideration

If we consider homogenous processing rate, then $\mu ip = \mu p\ \forall$ i and bip = bp $\forall$ i.

We can distribute the traffic among two paths according to the length and processing power of each path.

The processing delay per hop is

$D_p = 1/(\mu_p - b_p)$, before injecting traffic λ_p, we have

$$\sum_{i=1}^{I_q} \{1/(\mu_q - \lambda_q - b_q)^2\} = \sum_{i=1}^{I_r} \{1/(\mu_r - \lambda_r - b_r)^2\},\ q \neq r.$$

$$\{1/(\mu_q - \lambda_q - b_q)^2\} I_q = \{1/(\mu_r - \lambda_r - b_r)^2\} I_r$$

$$(\mu_q - \lambda_q - b_q)^2 / (\mu_r - \lambda_r - b_r)^2 = I_q / I_r$$

$$(\mu_q - \lambda_q - b_q) / (\mu_r - \lambda_r - b_r) = \sqrt{I_q} / \sqrt{I_r}.$$

$$(\lambda_q - 1/D_q) / (\lambda_r - 1/D_r) = \sqrt{I_q} / \sqrt{I_r}. \quad \text{... (3)}$$

When ignoring the path length difference the optimal traffic split will follow

$$(\lambda_q - \lambda_r) \propto (1/D_q - 1/D_r)\ \forall\ p, q \in \{1,2,\text{---}k\}, p \neq q$$

2.1.2. Delay Modeling for k- path routing:

Single path case:Since the transmission delay is smaller in comparison to queuing delay so it can be neglected. Considering the M/M/1/Q queuing model, the queue discipline is FIFO, for the ith queue with processing rate μ_i, and the arrival rate is λ_i the average waiting time[2, 8] (waiting + processing time) can be given by

$$E(W_i) = \{1-(Q+1)\rho_i + Q\rho Q+1\} / \{\mu_i (1-\rho_i)(1-\rho_i Q)\} \quad \text{...(4)}$$

where $\rho_i = \lambda_i / \mu_i$ and $\lambda_i = b_i + \lambda_i$ so, the sum of background inter -path relay traffic and self originated traffic respectively and Q is the queue capacity[7].

For a single path p the average packets delivery delay with Ip intermediate queues is given by

$$E_s(W_p) \geq \sum_{i=1}^{I_p} E(W_{i,p}) \quad \text{.... (5)}$$

For more accuracy in delay model, other factors such as packet loss, retransmission delay and link broken probability should be taken in to consideration.

k-path case:

The data packets will be delivered in order on each path respectively. Putting re-sequencing delay out of consideration then for k split path case the delivery delay will be

$$E_k(W) = E_s(W_p) \times \lambda_p$$

$$E_k(W_p) \geq \sum_{i=1}^{I_p} E(W_{i,p}) \times \lambda_p, \text{ for } p = 1, 2, \text{---}k. \quad \text{... (6)}$$

$$\lambda = \sum_{p=1}^{k} \lambda_p.$$

3. Delay performance measurement in two-path case

The system delay is given by

$$D\text{system} = \sum_{P=1}^{k} \sum_{i=1}^{I_p} \{1/(\mu_{ip} - \lambda_p - b_{ip})\} / \lambda + \sum_{p=1}^{k} \sum_{i=1}^{I_p} b_{i,p}$$

For simplicity let us consider the total traffic between source-destination pair is λ Є [0, 1], denoting λ1 and λ2 as the split of the traffic into two paths, let the processing power of all the nodes of the path and the background traffic for all nodes is same so μip= μp and bip = bp.

Then from equation (3) we have

$(\lambda_1 - 1/D_1) / (\lambda_2 - 1/D_2) = \sqrt{I_1} / \sqrt{I_2}$

$\lambda = \lambda_1 + \lambda_2$

On simplification we get

$\lambda_1 = (\lambda\sqrt{I_1} + (\sqrt{I_2} / D_1) - (\sqrt{I_1}/ D_2)) / (\sqrt{I_1} + \sqrt{I_2})$.

$\lambda_2 = (\lambda\sqrt{I_2} + (\sqrt{I_1} / D_2) - (\sqrt{I_2}/ D_1)) / (\sqrt{I_1} + \sqrt{I_2})$.

If ignoring the path length

$\lambda_1 = (\lambda + (1 / D_1) - (1/ D_2)) / 2.$ ... (7)

$\lambda_2 = (\lambda + (1 / D_2) - (1/ D_1)) / 2.$ ... (8)

Consider the interval $[0, (1 / D_1) + (1/ D_2))]$ for traffic λ, then we have two cases

First when $0 \le \lambda \le ((1 / D_1) - (1/ D_2))$ we have from above equation $\lambda_2 \le 0$, but flow assignment can not be negative so in this range $\lambda_2=0$ and the entire traffic will assign to path first that is $\lambda 1 = \lambda$. it shows that if traffic is less than a certain limit then it would be better to send entire traffic through a single path only.

For the interval $((1 / D_1) - (1/ D_2)) \le \lambda < ((1 / D_1) + (1/ D_2))$ the k-path routing scheme is used, and the traffic is splitted among the k paths so as to minimize the total system delay and to optimize the network resources.

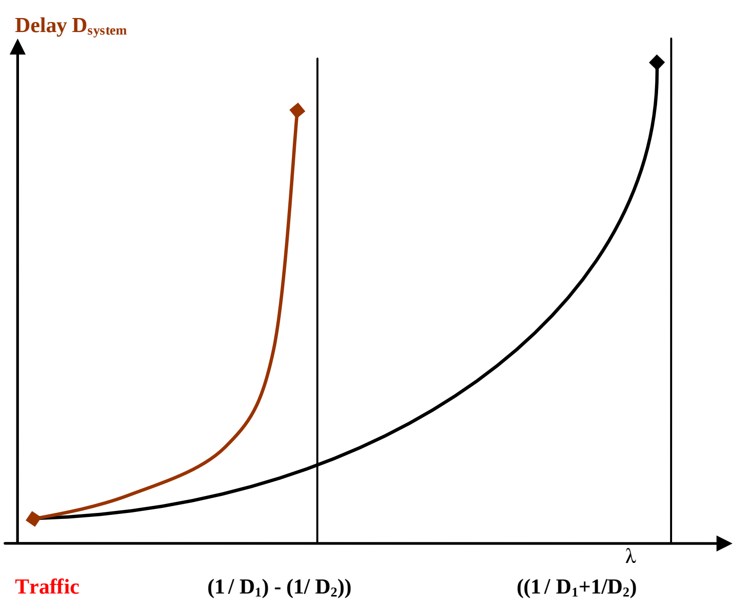

Figure: 2

4. Numerical simulation of (k=2) k path model

Consider the homogenous processing capabilities, let the average service rate for each node is 1.0 and the there is enough buffer size with each node, so no packet loss at any node in the system.

The total traffic between source-destination pair is $\lambda \in [0, 1]$, denoting λ_1 and λ_2 as the split of the traffic into two paths, the length of paths are2 and 4 respectively, the processing power of all the nodes of the path is same μ =1.0 and the background traffic for all nodes is b= 0.15

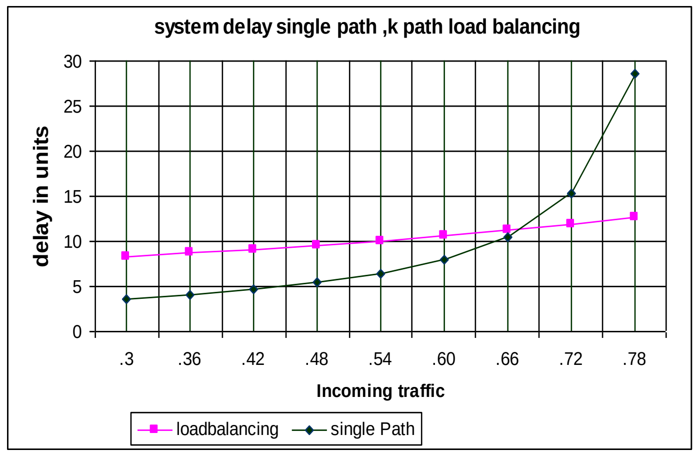

Figure: 3

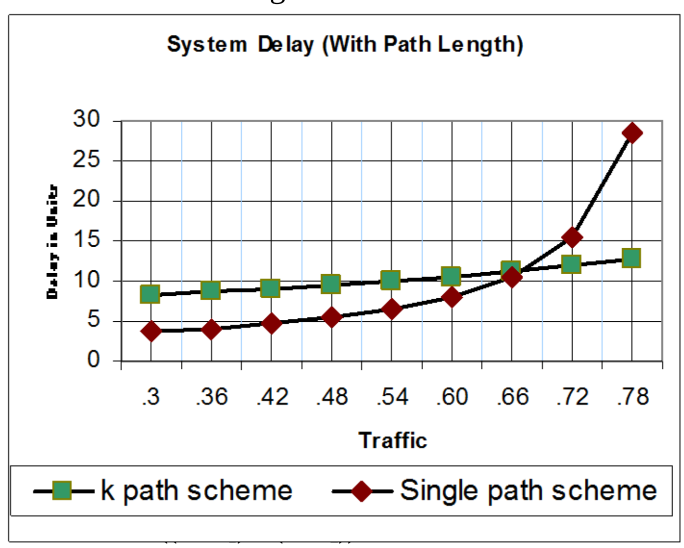

Figure: 4

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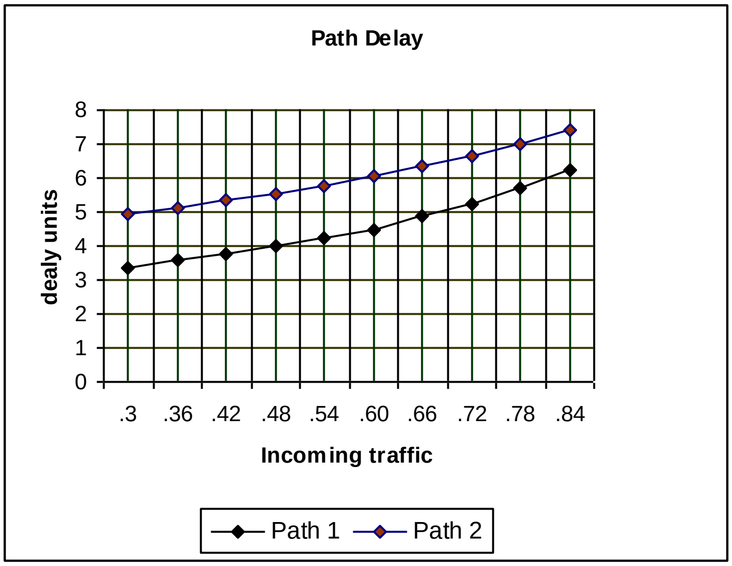

Figure: 5

5. Reliability modeling

In network design and modeling, the network reliability evaluation is very important. The network optimization is depends on its reliability measures. In our model there are k-node disjointed paths [12, 14, and 15]. The node disjointed paths means two paths must have no node in common except the source and destination node.

Let us consider k path scenarios, denoting N_1 ,N_2,---,N_k as the path lengths of first , second and so on up to k-path respectively .Let Pip is link broken probability of the i th link in path p . The path broken probability PB in single path case and k- path case has been analyzed as

The Single path case:

A single path route p is said to be alive until none of the link in the path is broken, if at least one link is broken then the path is broken. Let $P_{B,S}$ denotes the single path broken probability [4, 7], then

$$P_{B,S} = 1-\prod_{i=1}^{N_1}(1-P_{ip}). \quad \dots (9)$$

The k path scheme:

Let PB, k denotes the path broken probability of k-path model, where all the paths are node disjointed, each path can be considered as a single path carrying a fraction of traffic λ, and then we have

$$P_{B,k} = \{(1-\prod_{i=1}^{N_1}(1-P_{i1})).\ (1-\prod_{i=1}^{N_2}(1-P_{i2}))\dots(1-\prod_{i=k}^{N_k}(1-\backslash P_{ip}))\}\dots (10)$$

For more accurate assessment of breaking probability we also need to consider the influence of mobility and transmission quality.

Numerical results for reliability modeling:

For k=2.

Let us consider the two path scenario; the first is single shortest path and the second is next shortest path, both are node disjointed. The breaking probabilities for all links are P, then in single shortest path case, the path breaking probability is given by

$$P_{B,S} = 1-\prod_{i=1}^{N_1}(1-P) = (1-(1-P)^{N_1})$$

k=2 path case

$$P_{B,k}=\{(1-\prod_{i=1}^{N_1}(1-P)).(1-\prod_{i=1}^{N_2}(1-P))\}=(1-(1-P)^{N_1}).(1-(1-P)^{N_2}).$$

$$P_{B,k} = (P_{B,S}).\ (1-(1-P)^{N_2}).$$

Clearly

$P_{B,k} < (P_{B,S})$, because $(1-(1-P)^{N_2}) < 1$.

This shows that the reliability of k- path system is more than single shortest path.

Assume for numerical simulation, the probability of link failure is 0.1, that is P=0.1 then (1- P) =0.9

The graph for path breaking probability, single path and k-path (k=2), case:

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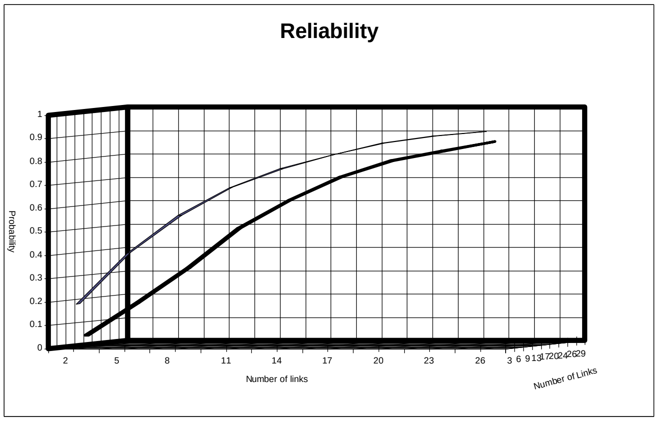

Figure: 6

N_1:Number of links Path1	2	5	8	11	14	17	20	23	26
N_2:Number of links Path2	3	6	9	13	17	20	24	26	29
single path	0.19	0.41	0.57	0.69	0.77	0.83	0.88	0.91	0.93
k=2,k path	0.05	0.19	0.34	0.51	0.63	0.73	0.8	0.84	0.88

6. Conclusion

In this paper we have established a network model in order to study the load balancing and it has been shown that with load balancing we can improve the end to end delay. We have discussed the need of k splitting of traffic compared with single shortest path routing. This paper investigates three aspect of modeling k path routing in adhoc network, load balancing, delay and reliability. It has been established that the reliability of k path scheme is higher than the single path case.

The entire model is discussed in static environment the future work might include the study of the load balancing scheme in dynamic environment.

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