Qos Provisioning in Wireless ad-hoc Networks

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By

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CERTIFICATE

This is to certify that the thesis entitled "QOS provisioning Ad-hoc Network using Tubular Routing" is a Record of bona fide work carried out by Biswa Ranjan Barik , under my supervision and guidance for partial fulfillment of the requirement for the degree of Master of Technology in Electronic & Electrical Communication Engineering , Indian Institute of Technology, Kharagpur.

The thesis has fulfilled all the requirements as per the regulations of the institute and in our opinion has reached the standard needed for submission.

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DECLARATION **November 2012**

I certify that

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e. Whenever I have used materials (data, theoretical analysis , figures and text)from other sources, I have given due credit to them by citing them in the text of the thesis and giving their details in the references.

Biswa Ranjan Barik

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IIT Kharagpur, India Biswa Ranjan Barik

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Chapter 1

Ad-hoc Network information & Quality of service

1.1 Introduction

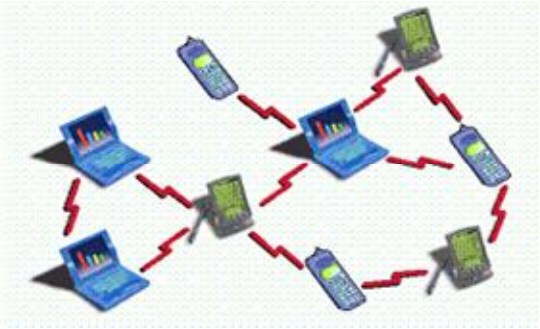


Figure 1 ad-hoc network

wireless ad-hoc network is a decentralized type of wireless network where the devices are PDAs, cell phones, sensors, laptop etc. The Network is ad-hoc because it does not rely on a preexisting infrastructure, such as routers in wired network or access points in managed (infrastructure)wireless networks. The node can transmit data to another node if it is within its frequency range. Each node participates in routing by forwarding data for other nodes, and so the determination of which nodes forward data is made dynamically based on the network connectivity.

In addition to the classic routing ,ad-hoc networks use flooding for forwarding the data. In flooding ,the source simply broadcasts the packet to its neighbor node via a MAC layer(Medium access control layer)

Ad hoc network refers to a mode of operation of IEEE 802.11 wireless networks, which is a set of standards for implementing wireless local area network(WLAN) computer communication in the 2,4,3.6 and 5 GHz frequency bands.

Ad-hoc network uses DCF(Distributed co-ordination function)to share the medium between multiple stations. DCF relies on csma/ca(carrier sense multiple access with collision avoidance technique) medium access control layer and optional 802.11 RTS/CTS(Request to send/Clear to send) to share the medium between stations. If Many stations want to communicate at the same time ,many collision will occur which will low the available band width and lead to congessive collapse.

For ad-hoc network OFDM technique is used to send data between nodes. A large number of closely spaced orthogonal sub-carrier signals are used to carry data. The data is divided into several parallel data streams or channels, one for each sub carrier .Each sub carrier is modulated with a conventional modulation scheme(such as quadrature amplitude modulation or phase shift keying) at a low symbol rate ,maintaining total data rates similar to conventional single carrier modulation schemes in the same band width. The primary advantage of OFDM over single –carrier schemes is its ability to cope with severe channel conditions without complex equalization filter.

The ad-hoc Network throughput is defined as the number of bytes (or number of packets) delivered per second. Intuitively the higher the transmission range, the higher the interference and the more likely the packets will get dropped and retransmitted. The network throughput is shown to be in some sense , inversely proportional to the transmission range of the nodes, and hence nodes should transmit at the lowest power possible. Selecting the optimal transmission range to maximize throughput.

The End-to-End latency is the delay encountered by all packets on their routes from source node to destination node .This delay can be attributed to

Queuing Delays:-Which denote the time spent by the packets in the queues of node

Transmission Delays:-Which denote the amount of time a network of band width "W" bps need to transmit a packet of length L bits. This is equal to L/W

Propagation Delays:-Which denote the time needed by the packet to propagate in the wireless medium for all the hops between the source and destination. This delay depends upon the distance between the source and destination for every hop.

Network life time of an ad-hoc network is defined as the number of message successfully routed before the first failure message.

In ad-hoc network a multi hop route from source to destination constituted by n_h links of length r_{link}^{i} ,i=1…….. n_h.The BER(Bit error rate) at the end of the i_{th} link is defined as

$$BER_{link}=Q(\sqrt{2SNR_{link}})$$

where $$Q(x) = \int_{x}^{\infty} \frac{1}{\sqrt{2\pi}} \left(e^{\frac{-u^2}{2}} \right) du$$

1.2 Why Ad-hoc:-

Figure-2 An examples of the Ad-hoc network usage area

Natural disasters like flooding,earthquake etc in military fight , rural areas and places where communication is a big challenge due to lack of existing infra structure , ad-hoc network is a problem solving technology. Because it doesnot require any pre-existing infrastructure such as base station,routers or accespoints for communication , if two nodes or stations are within the frequency range data transmission is possible.

The nodes are itself acting as routers and does all the work like forwarding and receiving of data, error detection and correction and finding the path from source to destination etc ad-hoc network are increasingly important because wireless communication is rapidly becoming ubiquitous and potential applications range from military and disaster response applications to more traditional urban problems such as finding desired products or services in a city ad-hoc networks are used.Hence researcher and scientist are continously in the process to provide quality of service in ad-hoc network .

1.3 QUALITY OF SERVICE:

Quality of service (QoS) is the performance level of a service offered by the network to the user. The goal of QoS provisioning is to achieve a more deterministic network behavior, so that information carried by the network can be better delivered and network resources can be better utilized. A network or a service provider can offer different kinds of services to the users. Here, a service can be characterized by a set of measurable prespecified service requirements such as minimum bandwidth, maximum delay, maximum delay variance (jitter), and maximum packet loss rate. After accepting a service request from the user, the network has to ensure that service requirements of the users flow are met, as per the agreement, throughout the duration of the flow (a packet stream from the source to the destination). In other words, the network has to provide a set of service guarantees while transporting a flow. After receiving a service request from the user, the first task is to find a suitable loop-free path from the source to the destination that will have the necessary resources available to meet the QoS requirements of the desired service. This process is known as QoS routing. After finding a suitable path, a resource reservation protocol is employed to reserve necessary resources along that path. QoS guarantees can be provided only with appropriate resource reservation techniques. For example, consider the network shown in where BW and D represent available bandwidth in Mbps and delay in milliseconds.

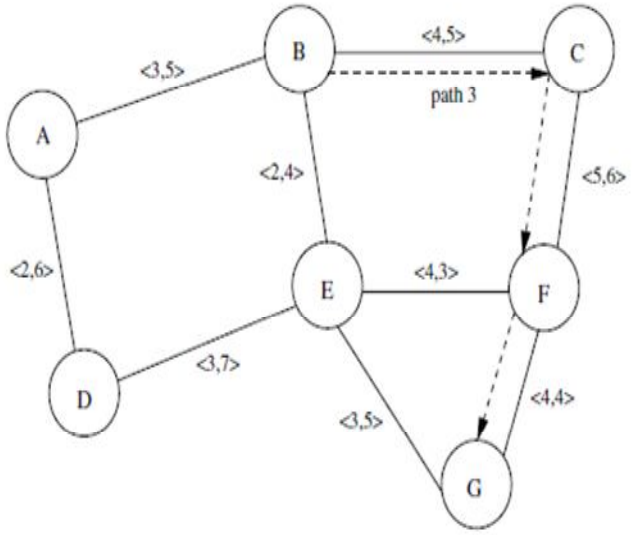


Figure-3:**An example of Qos routing in wireless ad-hoc network**

Table 1:-

Available paths from node *B* to node *G*

No.	Path	Hop count	BW (Mbps)	Delay (ms)
1	$B \rightarrow E \rightarrow G$	2	2	9
2	$B \rightarrow E \rightarrow F \rightarrow G$	3	2	11
3	$B \rightarrow C \rightarrow F \rightarrow G$	3	4	15
4	$B \rightarrow C \rightarrow F \rightarrow E \rightarrow G$	4	3	19
5	$B \rightarrow A \rightarrow D \rightarrow E \rightarrow G$	4	2	23
6	$B \rightarrow A \rightarrow D \rightarrow E \rightarrow F \rightarrow G$	5	2	25

suppose a packet-flow from node B to node G requires a bandwidth guarantee of 4 Mbps. QoS routing searches for a path that has sufficient bandwidth to meet the bandwidth requirement of the flow. Here, 6 paths are available between nodes B and G as shown in

Table 1. QoS routing selects path 3 (i.e., B-C-F-G) because, out of the available paths, path 3 alone meets the bandwidth constraint of 4 Mbps for the flow. The end-to-end bandwidth of a path is equal to the bandwidth of the bottleneck link (i.e., link having minimum bandwidth among all the links of a path). The end-to-end delay of a path is equal to the sum of delays of all the links of a path. clearly path 3 is not optimal in terms of hop count and/or end to-end delay parameters, while path 1 is optimal in terms of both hop count and end-to-end delay parameters. Hence, QoS routing has to select a suitable path that meets the QoS constraints specified in the service request made by the user .

1.3.1Qos parameters in wireless ad-hoc network:

As different applications have different requirements, the services required by them and the associated QoS parameters differ from application to application. For example, in case of multimedia applications, bandwidth, delay jitter, and delay are the key QoS parameters, whereas military applications have stringent security requirements. For applications such as emergency search and rescue operations, availability of network is the key QoS parameter.

Applications such as group communication in a conference hall require that the transmissions among nodes consume as minimum energy as possible. Hence battery life is the key QoS parameter here. Unlike traditional wired networks, where the QoS parameters are mainly characterized by the requirements of multimedia traffic, in AWNs the QoS requirements are more influenced by the resource constraints of the nodes.

1.3.2 Issues and challenges in providing QOS in ad-hoc wireless network:-

Providing QoS support in AWNs is an active research area. AWNs have certain unique characteristics that pose several difficulties in provisioning QoS .

Dynamically varying network topology:

Since the nodes in an ad hoc wireless network do not have any restriction on mobility, the network topology changes dynamically. Hence the admitted QoS sessions may suffer due to frequent path breaks, thereby requiring such sessions to be re-established over new paths. The delay incurred in re-establishing a QoS session may cause some of the packets belonging to that session to miss their delay targets/deadlines, which is not acceptable for applications that have stringent QoS requirements.

Imprecise state information:

In most cases, the nodes in an ad hoc wireless network maintain both the link-specific state information and flow-specific state information. The link-specific state information includes bandwidth, delay, jitter , loss rate, error rate, stability, cost, and distance values for each link.

The flow specific information includes session ID, source address, destination address, and QoS require-ments of the flow (such as maximum bandwidth requirement, minimum bandwidth requirement, maximum delay, and maximum delay jitter).The state information is inherently imprecise due to dynamic changes in network topology and channel characteristics. Hence routing decisions may not be accurate, resulting in some of

the real-time packets missing their deadline.

Lack of central coordination:-

Unlike wireless LANs and cellular networks, AWNs do not have central controllers to coordinate the activity of nodes. This further complicates QoS provisioning in AWNs.

Error prone shared radio channel:

The radio channel is a broadcast medium by nature. During propagation through the wireless medium the radio waves suffer from several impairments such as attenuation, multi-path propagation, and interference (from other wireless devices operating in the region).

Hidden terminal problem:-

The hidden terminal problem is inherent in AWNs. This problem occurs when packets originating from two or more sender nodes, which are not within the direct transmission range of each other, collide at a common receiver node. It necessitates retransmission of packets, which may not be acceptable for flows that have stringent QoS requirements.

Limited resource availability:

Resources such as bandwidth, battery life, storage space, and processing capability are limited in AWNs. Out of these, bandwidth and battery life are very critical resources, the availability of which significantly affects the performance of the QoS provisioning mechanism. Hence efficient resource management mechanisms are required for optimal utilization of these scarce resources.

Insecure medium:

Due to the broadcast nature of the wireless medium, communication through a wireless channel is highly insecure. Hence security is an important issue in AWNs, especially for military and tactical applications.

Chapter 2

ENERGY AND DELAY AWARE ONLINE ROUTING WITH MULTIRATE WIRELESS AD-HOC NETWORK

Energy efficiency is the major concern in the designing of routing protocols to increases the network life time .where network lifetime is defined as the number of successfully message transmitted before the first failure message. As the network nodes are operating in batteries hence energy minimization is very much importance. In many real time application how the end-to-end latency will minimized that is also taking into consideration. With the development of wireless- communication technology now mobile nodes are operating in multiple transmission rates. Assuming the power to be fixed, if the node operates in a lower transmission rate it can cover longer transmission distance otherwise it can travel shorter distance. Mean while a higher transmission rate leads to smaller transmission delay, while a lower transmission rate leads to a higher transmission delay**.** Under the multirate environment the primarily focused on optimizing the energy and minimizing the end-to-end latency constraint.

2.1 SYSTEM MODEL:-

Consider a multi-rate wireless ad-hoc network S(N,A), where N is the set of nodes with n=[N], A is the set of links with m=[A].

The nodes in N are Homogenous and each has M fixed transmission rate.

Assume that the transmission power Pt is fixed for node, then

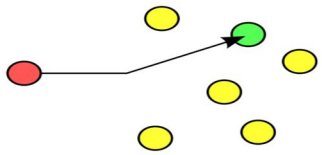
$$d_{i,l1} > d_{i,l2} \text{ if } r_{i,l1} < r_{i,l2}$$

Where r=Transmission rate and d=distance between two node

$r_{i,l} \varepsilon \{6,9,12,18,24,36,48,54\}$(Mbps) for IEEE 802.11a

ri,l ε {1,2,5.5,11}(Mbps) for IEEE 802.11b

2.1.1 PROBLEM DEFINATION:-



A unicast routing request is a quadruple q=(s,t,L, Γ) where s and t are source and destination nodes, L is the message length and Γ is the end to end latency constraint of q .A request q is implemented by the network if there is a routing path P in S from s to t such that the condition $\Sigma vi \varepsilon P, i \neq t\ L/ri,l \leq \Gamma$ is satisfied. where $r_{i,l}$ represents that node Vi chooses transmission rate $r_{i,l}$ for the message to transfer, otherwise we say that the request q is rejected. Given a multi-rate wireless ad-hoc network S(N,A), with M transmission rates and a sequence of unicast request Q=q(1),q(2)……..q(k') arrived one by one with out knowledge of future request arrival. The latency constrained network lifetime maximization problem (LCLM) is to maximize the number of request that can be implemented until the rejection of first request.

2.1.2 LATENCY-CONSTRAINED SHORTEST PATH PROBLEM

The latency-constrained shortest path problem is that to find a shortest path in a network between pair of nodes subject to the end –to-end latency constrained is

minimized. If the link latency is an integral and the end-to-end latency constraint is bounded by an integer η,the latency constraint shortest path problem can be solved in time by using Dijkstra's algorithm.

2.1.3 JOINT OPTIMIZATION FRAME WORK

For each incoming request the idea is to find an energy efficient routing path for it and to assign each node in the path with a specific transmission rate such that the total energy cost of the path is as small as possible, provided that end to end latency constraint is met too. The core challenge in designing online routing algorithm is how to deal with the right balance among energy, latency and node transmission rate. To achieve that ,we transform LClM in a wireless ad-hoc network into a latency-constrained shortest path problem in an auxiliary graph and solve the latter which corresponds to a solution of the original problem.

2.1.4 CONSTRUCTING THE AUXILIARY GRAPH:-

A multi-rate wireless ad-hoc networks S(N,A) with M multiple transmission rates and a unicast request $q=(s,t,L,\Gamma)$ and a weighted directed auxiliary graph (V,E,ω, τ) for q is constructed as follows. For each node vi in S let $_{i,1},r_{i,2},\ldots\ldots r_{i,M}$ be its transmission rates with $r_{i,l1}<r_{i,l2}$,where $1\leq l1<l2 \leq M.$,

a widget Wi=(Vi,Ei,ω,τ)for node vi is built .

where Vi={vi,Ri,1,Ri,2……..Ri,M}, Ei={(vi,Ri,l) I $1 \leq l \leq M$}

Vi represents vertices and Ei represents edges Ri,l namely the auxiliary vertices represents vi transmitting message using transmission rate $r_{i,l}$ .Assign edge (vi,Ri,l) with a pair of values (ω(Ri,l,vj),τ(Ri,l,vj)).

Where ω(Ri,l,vj) is the amount of transmission energy consumption of vi by transmitting an L-length message sequence of the request q using transmission rate $r_{i,l}$ .and τ(Ri,l,vj) is the corresponding latency.

It is obvious that τ(Ri,l,vj)=L/ri and ω(Ri,l,vj)=Pt.(Ri,l,vj).

For two nodes Vi and Vj in the S with $i \neq j$.if Vi transmits the message using ri,l and Vj is within its transmission distance di,l i(the maximum transmission distance of node Vi when it uses $r_{i,l}$) then there is a direct edge (Ri,l,Vj) in Ebridge with ω(Ri,l,vj)=0 and τ(Ri,l,vj)=0

2.1.5 FINDING LATENCY CONSTRAINED SHORTEST PATH:-

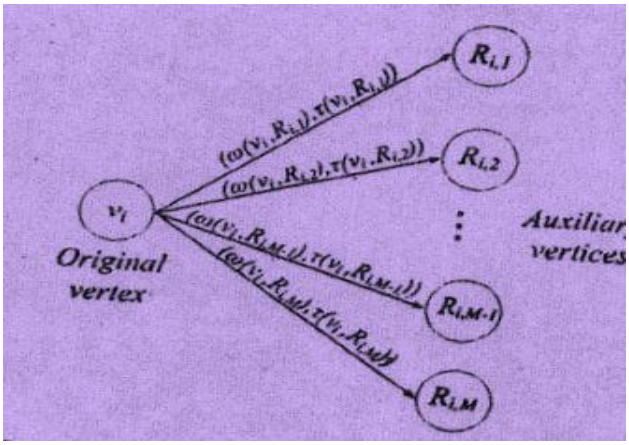


Figure-4:-Auxiliary graph[1]

For an auxillary graph G,we have to find a latency constrained shortest path in G for request q ,which corresponds to a routing path in S(N,A) for the request. Given a graph G=(V,E,ω, τ) and a unicast request q=(s,t,L, Γ)

Where Γ ε R+, let G'=(V,E,ω, τ') be the corresponding graph of G by assigning the transmission latency τ' (Ri,l,vi) = τ (Ri,l,vi).Δ=(L/ri,l). Δ=B/ri,l of edge (vi,Ri,l) in G' where B=LCM(ri,1,ri,2…….ri,M) is the least common multiple for all transmission rates.And Δ= B/L and q'=(s,t,L,Γ') is the corresponding request of q in G',where Γ'= [Γ. Δ]. Given a directed auxillary graph G=(V,E,ω, τ) and a unicast request q=(s,t,L, Γ)

where Γ ε R+ let G'=(V,E,ω, τ') and q'=(s,t,L, Γ') be the corresponding graph and request derived from G and q after performing the transformation . Hence an optimal path in G' for request q' corresponds to an optimal path in G for q

PROOF:-

Assume that P and P' are the optimal paths in G and G' for request q and q' respectively.

" We have to show that P' in G' corresponding to P in G exactly"

Let PS be the set of all the paths from s to t in G and G'

For any Pi ε PS\{P} let $\tau(Pi)$ and $\tau'(Pi)$ be the total transmission latency along path Pi in G and G' respectively.

For any Pi ε PS\{P} in G we distinguish it into two cases

1) $\tau(Pi) > \Gamma > \tau(P)$

or

2) $\tau(Pi) \leq \tau(P) \leq \Gamma$ with $\omega(Pi) \geq \omega(P)$

Case-1:

$\tau(Pi) > \Gamma > \tau(P)$ is equivalent to $\Sigma vj \varepsilon Pi, j \neq t (L/rj,l) > \Gamma > \Sigma vk \varepsilon P, k \neq t (L/rk,l')$

following the transformation we have

$\Sigma vj \varepsilon Pi, j \neq t (B/rj,l) > \Gamma > \Sigma vk \varepsilon P, k \neq t (B/rk,l')$ therefore $\tau'(Pi) > \Gamma' > \tau'(P)$

Case(ii)

$\tau(Pi) \leq \tau(P) \leq \Gamma$ with $\omega(Pi) \geq \omega(P)$ is equivalent to

$\Sigma vj \varepsilon Pi,j\neq t (L/rj,l) \leq \Sigma vk \varepsilon P,k\neq t (L/rk,l') \leq \Gamma$ then by following the transformation we

have $\Sigma vj \varepsilon Pi,j\neq t (B/rj,l) \leq \Sigma vk \varepsilon P,k\neq t (B/rk,l') \leq \Gamma'$ therfore $\tau'(Pi) \leq \tau'(P) \leq \Gamma'$

and $\omega (Pi) \geq \omega (P)$ it can be seen that the optimal path P'in G' for request q' correspond

to an optimal path P in G for q.

To find the latency constrained shortest path MRED algorithm is used.

2.1.6 **Algorithm MRED**:

Input:-The auxillary graph $G=(V,E,\omega, \tau)$ and a routing request $q=(s,t,L, \Gamma)$

Output:-A routing path P from s to t such that $\Sigma vj \varepsilon Pi\neq t \omega(Ri,l,vi)$

subject to $\Sigma vj \varepsilon Pi\neq t \tau (Ri,l,vi) \leq \Gamma$

Begin:-

1. $G'=(V,E,\omega, \tau)$ and $q'=(s,t,L, \Gamma')$be the resulting graph and request after performing the transformation in G and q

2.Find a path P' in G' for q', using the extended Dijkstra's algorithm

3.A corresponding path P in G for q is derived from P' in G' for q'.

end

2.2 ONLINE ROUTING ALGORITHM:-

Having MRED algorithm for finding an optimal routing path in S(N,A) for each individual request now deal with a sequence of request Q injected into the network, The main aim is to implement as many of them as possible such that network life time is maximized. For a request q(k),let REi(k) and IE be the residual energy and initial energy of node vj just before q(k) arrives.

2.2.1 Algorithm LCLM-Basic :-

INPUT:- A request q(k)=(s(k),t(k),L(k), Γ(k))

OUTPUT:-A path enable to implement q(k),if existence

BEGIN:-

1.Construct an Auxiliary graph G=(V,E,ω,τ) for request q(k) as it arrives

2.A reduced subgraph G1=(V,E1,ω1, τ) of G is obtained by removing the edges (Vi,Ri,l) from G if ω(Vi,Ri,l) > REi(k)

3.Assign each edge of G1 a weight ω1(Vi,Ri,l)

4.Find the latency constrained shortest path for q(k) by algorithm MRED in G1

5.if no such path is found then reject the request otherwise implement q(k)

END

Step -1 construct a direct graph for each request q(k),in

step-2 any edge (Vi,Ri,l) in G if its weight ω(Vi,Ri,l) > REi(k) will be removed because otherwise Vi will runout of its energy to transmit this message by transmission rate $r_{i,l}$.

step-3 assigns a weight ω1(Vi,Ri,l) to each remaining edge (Vi,Ri,l) in G**.**

step-4 finds alatency constrained shortest path by using MRED algorithm

step-5 choose the path according to the condition satisfied, if condition is satisfied then implement the request otherwise reject the request.if only one path is there and bound to send the data then implement the path.We should fully consider node parameters such as transmission rate ,residual energy and transmission range to balance the energy consumption among the nodes to prolong the network life time.

The following three heuristic can be proposed for different cost matrices.

1 .Assign edge (Vi,Ri,l) in G1 a weight ω1(Ri,l,vi)= ω(Ri,l,vi) which means that the algorithm find latency constrained shortest path in terms of total energy consumption ,this algorithm is referred as LCLMT.

2. Assign edge (Vi,Ri,l) in G1 a weight ω1(Ri,l,vi)= ω(Ri,l,vi) /REi(k) indicating that algorithm makes use of nodes whose energy consumption for the request are as small as possible ,where as their residual energy is as large as

possible, this algorithm is referred as LCLMR

3.Assign edge (Vi,Ri,l) in G1 a weight $\omega 1(Ri,l,vi)= \omega(Ri,l,vi) (\lambda^{\alpha i(k)}-1)$

where $\lambda >1$ is a positive integer, $\alpha_i (k)=1-REi(k)/IE$ which is the energy utilization ratio of node Vi. This cost matrices considers not only the total energy consumption also it tries to avoid those nodes whose energy is relatively low or the energy utilization is relatively high.

Chapter-3

Analysis of BER in shortest path and flooding based routing

In order to provide quality of service (QOS) , routing protocol should be smart enough to pick a stable and good quality route in order to avoid any un-necessary packet loss. If the chosen communication path is error prone then the transmitted packets over consecutive links may get corrupted or even loss. This is undesirable in delay sensitive applications especially in ad-hoc networks where devices are power limited and topology is constantly changing... If the links are error prone, shortest path routing is not always the best option. Because if the selected path is error prone then re transmission of the packet increases delay which is against of providing quality of service . Hence We have to choose a route which guarantees the lowest BER(Bit error rate) at the ending node .

Assumption:-

1)Nodes are static
2)Data uses multihop transmission to reach at the destination**.**

3)The information generation at each node is packetized. And each packet is having same length.

4)Nodes are not initiate the session until the ongoing session is over.

3.1 Analysis of BER in Ad Hoc Wireless network

Consider a multi-hop route between source and destination, the BER at the end of link between two nodes is $BER_{link,}$ It depends on the signal to noise ratio(SNR) at receiving node. The Received power at the end of a link denoted as Pr can be written as

$$P_r = \frac{G_t G_r C^2}{(4\pi f_c)^2} \frac{P_t}{r_{LINK}^2} \quad \text{.....(1)}$$

Where Pt is the transmission power, Gt and Gr is the transmitted and received power gain. fc is the carrier frequency. C is the speed of light and r_{link} is the distance between the transmitter and receiver.

$$r_{range} = \sqrt{\frac{G_t G_r C^2}{(4\pi f_c)^2} \frac{P_t}{P_r^{\min}}} \quad \text{.....(2)}$$

in realistic scenario with inter node interference(INI) and for a binary modulation ,the link SNR can be written as

$$SNR_{link} = \frac{P_r}{P_{thermal} + P_{INI}} \quad \text{.....(3)}$$

Where $P_{thermal}$ is the thermal noise power and P_{INI} is the interference noise power

Where $P_{thermal}$ =FKTB,
F=noise figure
K=Boltzman's constant
T=Room temperature and it is equal to 300k
B=Transmission bandwidth and it is equal to the transmission bit rate R_b dimension (b/s)

P_{INI} = interference noise power and it is equal to 2* Transmission range.

The interference noise power depends upon Transmission data rate Rb ,

The packet length L and average packet generation rate λ.

This probability can be expressed as

$$\Pr\{\text{interference from a node}\} = 1 - e^{-\frac{\lambda L}{R_b}} \quad \text{.....(4)}$$

Considering Binary phase shift keying signaling and assuming that the noise

can be treated as Gaussian noise ,the link BER can be written as

$$\mathrm{BER_{link}} = Q\left(\sqrt{2\,\mathrm{SNR_{link}}}\right) \quad \text{.....(5)}$$

where

$$Q(x) \triangleq \int_x^\infty \frac{1}{\sqrt{2\pi}} e^{-u^2/2}\,\mathrm{d}u$$

Let a Multi hop route from a source(s) to destination(D) is constituted by n_h links of length $r_{\mathrm{link}}^{(i)}, i = 1, \ldots, n_{\mathrm{h}}$,Denoting by $BER^{(i)}_{link}$.

The BER at the end of the i-th link of the multi hop route (The SNR at the receiving node of this link depends upon the link length).

It is possible to show that the BER at the end of nh-th link can be written as

$$\mathrm{BER}^{(n_\mathrm{h})} \simeq 1 - \prod_{i=1}^{n_\mathrm{h}} [1 - \mathrm{BER_{link}}(i)] \quad \text{.....(6)}$$

3.2 NETWORK MODEL:-

let the nodes in ad-hoc network are placed in a random topology. Let (x,y) be the Cartesian co-ordinates of node in the network. Where X and Y are independent random variables, uniformly distributed in the interval(O,R). Nodes in a network can be represented by vertices or points in a graph. Given a fixed transmit power two nodes are neighbors if the displacement between them is equal or less than the transmission range.

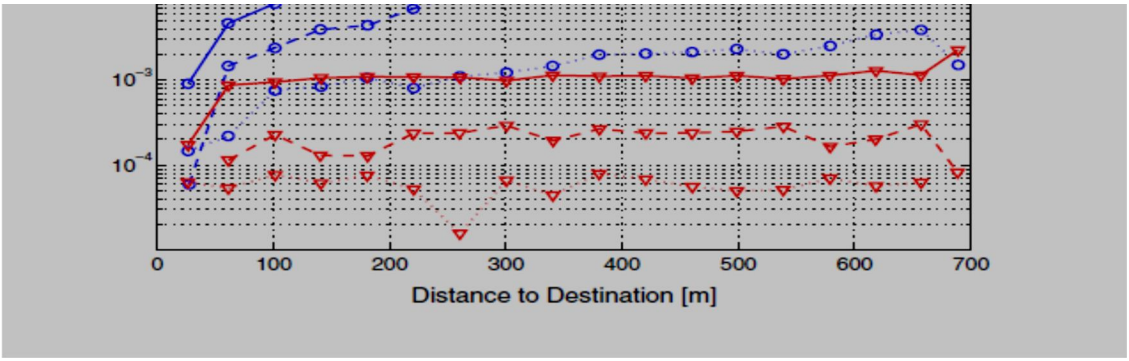


Figure 8: average route BER performance versus Distance to destination with SP and flooding based routing protocol, for various values of R_b

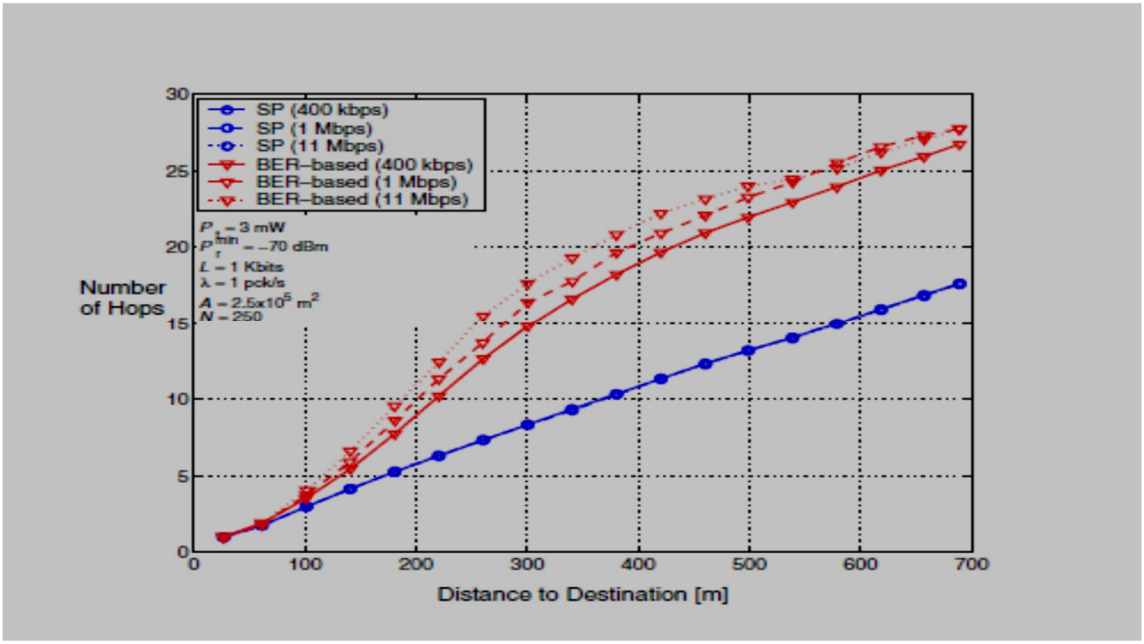


Figure:9 average route BER performance versus Distance to destination with SP and flooding based routing protocol, for various values of R_b

As expected, the higher the data rate the lower the route BER. This also implies that in all considered ad hoc wireless networking scenarios P_{INI}, rather than $P_{thermal}$, is the dominating source of noise. Since the transmission range does not depend on the data-rate, the average number of hops remains the same, for both routing strategies, regardless of the data transmission rate.

Chapter 4

QoS provisioning using TUBE Based Routing in Wireless Ad-hoc Network

Introduction:-

In the proposed circuit-switched multihop ad hoc wireless network communication scenario, i do not consider any *retransmission* mechanism, such as *automatic repeat request (ARQ)'*.Because retransmission does not represent an energy-conserving strategy, since a fundamental constraint in ad hoc wireless networks is limited energy available at each node. Since no retransmission is considered, each collision between packets has to be analyzed in terms of interference. To this end, i use a *bit-level* interference analysis for random access schemes . I consider a network communication scenario based on *circuit* switching with packetized transmission. The basic principle of operation is that, A multi-hop communication route between a source node and a destination node is initially created, through a route discovery mechanism based on *broadcast percolation* The nodes in the created route are *reserved* for this communication. only, so that this route can be visualized as a *communication tube,* which can bend (if the nodes are mobile) without breaking-provided that efficient *local route maintenance* is performed. The creation of a private path between source and destination resembles *circuit switching* At this point, the source simply "throws" its data packets into the tube, so that they are sent to the destination node. I named this novel routing method as" TUBULAR routing".

4.1 AN ANALYTICAL FR AMEWORK

On the basis of the communication-theoretic framework developed i consider a node distribution characterized by the presence of N nodes placed at the vertices of a square grid inside a circular area A. Denoting by $ps = N/A$ the node spatial density, it is easy to show that the minimum inter node distance, denoted by r_L, can be written as $r_L = 1/\sqrt{ps}$.

The BER at the end of a single link, assuming that

i) There is regeneration (i.e., detection and possibly error correction) at each intermediate node

ii) The uncorrected errors made in successive links accumulate.

It is possible to show that the BER at the end of the n-th link of a multi-hop route, indicated by P_L (Link BER), can be expressed as an expression for the average BER can he obtained by eqn (1)[3]

$$P_b^{(n)} \approx 1-(1-P_L)^n \quad \text{.....(1)}$$

evaluating for an average number of hops. Assuming that the number of hops is uniformly distributed between $n_h^{\max} = 2\sqrt{\frac{N}{\pi}}$ then the

average number of hops becomes $\bar{n}_h = E(n_h) = \sqrt{\frac{N}{\pi}}$

Hence $\bar{P}_b = P_b^{n\bar{h}} \approx 1 - (1 - P_L)^{\left[\sqrt{\frac{N}{\pi}}\right]}$ **……..(2)**

Hence Expression (2) shows the dependence of the BER, at the end of an average multi-hop route in an ad hoc wireless network, on the number of nodes N and the link BER P_L In particular, the link BER P_L depends, among other parameters, on the SNR at the ending node of the link, indicated by SNR_L. We assume that the transmitted signal is simply affected by free space loss.

Hence, according to Friis free space formula the received signal power at the end of a minimum length hop, indicated by $P_r^{(r_l)}$ can be expressed as follows in equation(3)[3]

$$P_r^{(r_l)} = \frac{\alpha P_t}{r_L^2} \approx \alpha p_s P_t = \frac{G_t G_r \lambda_c^2}{(4\pi)^2 f_l} p_s P_t \quad \text{……..(3)}$$

where Pt is the transmitted power from each node, G_t and G_r, are the transmitter

and receiver antenna gains, $\lambda_c = \frac{c}{f_c}$ is the wavelength corresponding to the carrier frequency fc , c is the speed of light and $f_l \geq 1$ is a loss factor.

Two distinct cases can be distinguished, based on the absence or presence of INI- the former represents an ideal case, while the latter represents a more realistic case.

4.1.2 Ideal case (no INI):-

The link SNR can be written as in eqn(4)[2] $$SNR_L^{noINI} = \frac{P_r^{(r_l)}}{P_{thermal}} \quad .....(4)$$

where $P_{thermal}$ is the thermal noise. one can write that $P_{thermal} = FkToB$, where K is the Boltzmann's constant ,B=band width and To is the room temperature.

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4.1.3 Realistic case:-

Since interfering signals come from other nodes, we make the preliminary simplifying assumption that the interfering signals can be treated as additive white noise independent from the thermal noise.

The SNR at the end of a minimum link length can be written as in eqn (5)[2]

$$SNR_L^{INI} = \frac{P_r^{(r_L)}}{P_{thermal} + P_{INI}} \quad \text{.....(5)}$$

We refer to *full connectivity,* in an average sense, when at the end of an average multi-hop communication route the BER is lower than a maximum tolerable value $P_b^{\max}$. Since the link BER ρ_L is a decreasing function of the link *SNR* .it is possible to conclude that, in order for P_b to be lower than $P_b^{\max}$, SNR_L. has to be larger than a minimum value, indicated by $SNR_L^{\min}$ ", which depends on $P_b^{\max}$ and *N*..

In the following, without loss of generality, numerical results will be presented in the case of un coded binary phase shift keying (BPSK) transmission over an additive white Gaussian noise with free space loss. In this case, the link BER can

be written as in eqn (6)[2]

$$P_L = Q\left(\sqrt{2SNR_L}\right) = \frac{1}{\sqrt{2\pi}} \int_{\sqrt{2SNR_L}}^{\infty} e^{-X^2/2} dx \quad \text{.....(6)}$$

And the minimum link SNR required to guarantee an end-to-end BER $P_b^{\max}$ is in the equation (7)[3]

$$SNR_L^{\min} = \frac{1}{2}\left\{ Q^{-1}\left[1-(1-P_b^{\max})^{\sqrt{\frac{\pi}{N}}} \right] \right\}^2 \quad \text{.....(7)}$$

The maximum sustainable number of hops $n_{sh}^{\max}$ corresponding to a final BER $P_b^{\max}$ i:e the maximum number of hops such that the final BER is lower than $P_b^{\max}$ can be written as in eqn(8)[3]

$$n_{sh}^{\max} = \left[\frac{\ln(1-P_b^{\max}}{\ln(1-P_L} \right] \quad \text{.....(8)}$$

Since, on average, a communication route is formed by a sequence of $\sqrt{\frac{N}{\pi}}$ hops.

The average sustainable number of hops can be defined as in equation(9)[3]

$$\bar{n}_{sh} \triangleq \min\left\{n_{sh}^{\max}, \left\lfloor\sqrt{N/\pi}\right\rfloor\right\} = \begin{cases} \left\lfloor\sqrt{N/\pi}\right\rfloor & , \text{ if } SNR_L \geq SNR_L^{\min} \\ \left\lfloor\frac{\ln(1-P_b^{\max})}{\ln(1-p_L)}\right\rfloor & , \text{ if } SNR_L < SNR_L^{\min} \end{cases} \quad \text{.....(9)}$$

In other words: (i) if the link SNR is larger than the minimum value $SNR_L^{\min}$, then the average number of hops is $\sqrt{\frac{N}{\pi}}$ (note that the maximum sustainable number of hops is larger)

(ii) if the link SNR is lower than $SNR_L^{\min}$ then the number of hops which can be sustained is lower than the average number of hops .This implies that in the latter case full connectivity (in an average sense) is lost.

4.2 Single Route Effective Transport Capacity:

The average sustainable communication path length $\bar{r}_{PATH}$ that a bit has to travel from a source node to its destination node is that given in equation (10)[3]

$$\bar{r}_{PATH} = \bar{n}_{SH} r_L \approx \bar{n}_{SH} \sqrt{\frac{A}{N}} \quad \text{.....(10)}$$

Where Sh=sustainable number of hops, A=area , N=total number of nodes

If only a single route at a time were active in the wireless network, the effective

transport capacity of the network would he given by the *single-route* effective transport capacity, i.e., by the rate-distance product carried by this single route. In particular, the single-route effective transport capacity can be written as

$$C_{T,e}^{(Sr)} = \lambda L \bar{r}_{PATH} \quad \text{.....(11)}$$

where λL represents the average data-rate at which the source node is transmitting , i.e., the traffic load per source node .A fundamental underlying assumption in equation (11) is that *only* the source node contributes actual information (the λLbits generated, on average, every second and considered in $C_{T,e}^{(Sr)}$ come from the source node).

In this sense, the intermediate nodes act as *relay nodes*, but they do not contribute to the effective transport capacity in terms of supplementary information bits. If only one route is active in the network, it *is* possible to assume that there is no INI. The single route effective transport capacity can then be further written as

$$C_{T,e}^{(Sr)} = \lambda L \bar{n}_{Sh}^{noINI} \sqrt{\frac{A}{N}} \quad \text{.....(12)}$$

Since $\bar{n}_{sh}^{noINI}$ does not depend on λL , it is immediate to conclude that the single-route transport capacity, defined as the maximum of the effective single-route transport capacity, can be written as follows

$$C_T^{(Sr)} = \max_{\lambda L, R_b : \lambda L \le R_b} C_{T,e}^{(Sr)} = \max_{R_b} R_b \bar{n}_{sh}^{noINI} \sqrt{\frac{A}{N}} \quad \text{.....(13)}$$

4.2.1 Aggregate Transport Capacity:-

Since the average number of hops per communication route is $\sqrt{\frac{N}{\pi}}$ there can be at most $\frac{N}{\sqrt{N/\pi}} \approx \sqrt{N\pi}$ *disjoint* active communication paths-it is possible to show that a network communication scenario with disjoint communication routes maximizes the effective transport capacity .It might happen that the maximum number of sustainable hops is lower than $\sqrt{\frac{N}{\pi}}$ .in this case, one might argue that

the number of disjoint routes could be larger than $\sqrt{N\pi}$ .However, in order to obtain a connectivity-based description of the effective transport capacity in the network, in the following we assume that there can be $N_{ar} \leq \left[\sqrt{N\pi}\right]$ disjoint – routes in the network, so that: (i) if there is full connectivity, then each route is formed by $\sqrt{\frac{N}{\pi}}$ successive hops (all the nodes in the network are used); (ii) if there is not full connectivity, then each route is formed by an average sustainable number of hops lower than $\sqrt{\frac{N}{\pi}}$. Based on these considerations, the effective transport capacity, indicated by C_{Te} , can be defined as follows

$$C_{T,e} \hat{=} \lambda L \bar{r}_{PATH} N_{ar} \quad \text{.....(14)}$$

Depending on the particular communication scenario, the average sustainable number of hops, number of active routes, and consequently, the transport capacity, can be determined.

4.2.2 Ideal case(no INI):-

The effective transport capacity is simply obtained by multiplying the single-route effective transport capacity (which assumes no INI) with the number of disjoint routes, given by $\sqrt{N\pi}$. In particular, the effective transport capacity can be written as a function of the number of nodes (for fixed data rate) or as a function of the data-rate (for fixed number of nodes), respectively, as follows:

$$C_{T,e}^{noINI} \approx \lambda L \bar{n}_{Sh}^{noINI} \sqrt{\pi A}$$

$$= \lambda L_{\min} \left\{ \sqrt{\frac{N}{\pi}}, \left[\frac{\ln(1-P_b^{\max}}{\ln(1-P_L} \right] \right\} \sqrt{\pi A}$$

. .. ……..(15)

As in the single-route case, in this case as well, since $\bar{n}_{Sh}^{noINI}$ does not depend on λ the transport capacity is simply obtained by substituting λL by R_b, and then by maximizing with respect to R_b.

The behavior of the effective aggregate transport capacity as a function of the data-rate is shown in fig 10 [3]

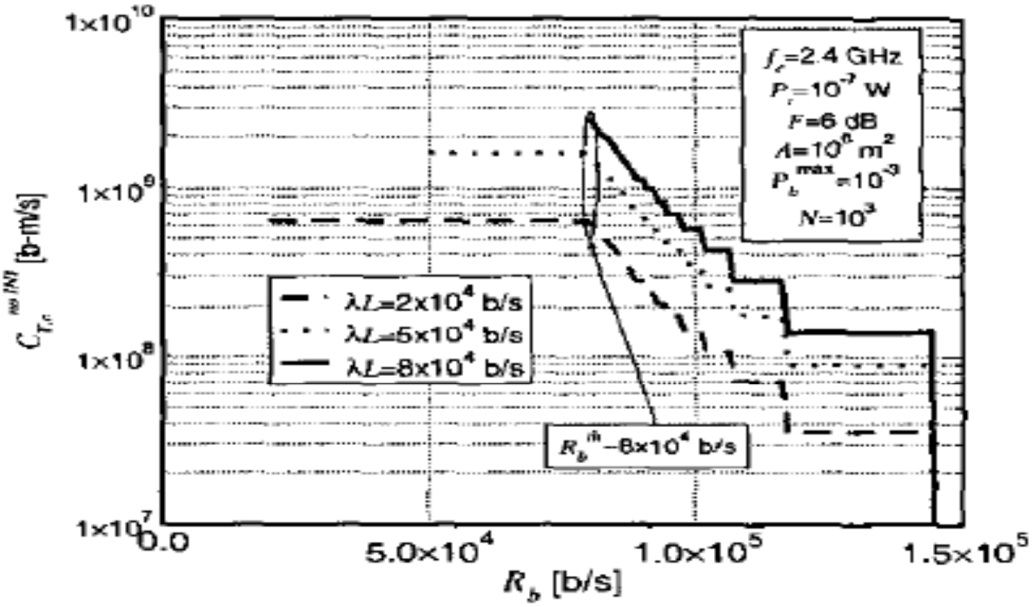

Figure:-10 Aggregate transport capacity versus data-rate in the ideal case(no INI) [3]

for various values of the traffic load λL-note that for each value of the product λL the valid data-rate range is given by $R_b \geq \lambda L$.It is immediate to notice that the effective transport capacity increases, for increasing λL, up to the maximizing value corresponding to $(\lambda L)^{noINI,max} = R_b^{noINI,max}$ =80 kb/s.

For larger values of the traffic load , the effective transport capacity is lower than the maximum value.

4.3 Tubular Routing:-

A multi-hop communication route between a source node and a destination node is initially created, through a route discovery mechanism based on Shortest path routing. The nodes in the created route are *reserved* for this communication only, so that this route can be visualized as a *communication tube,* which can bend (if the nodes are mobile) without breaking-provided that efficient *local route maintenance* is performed . The creation of a private path between source and destination resembles *circuit switching* .At this point, the source simply “throws” its data packets into the tube, so that they are sent to the destination node. A graphical example, with two communication tubes inside which packets are flowing .

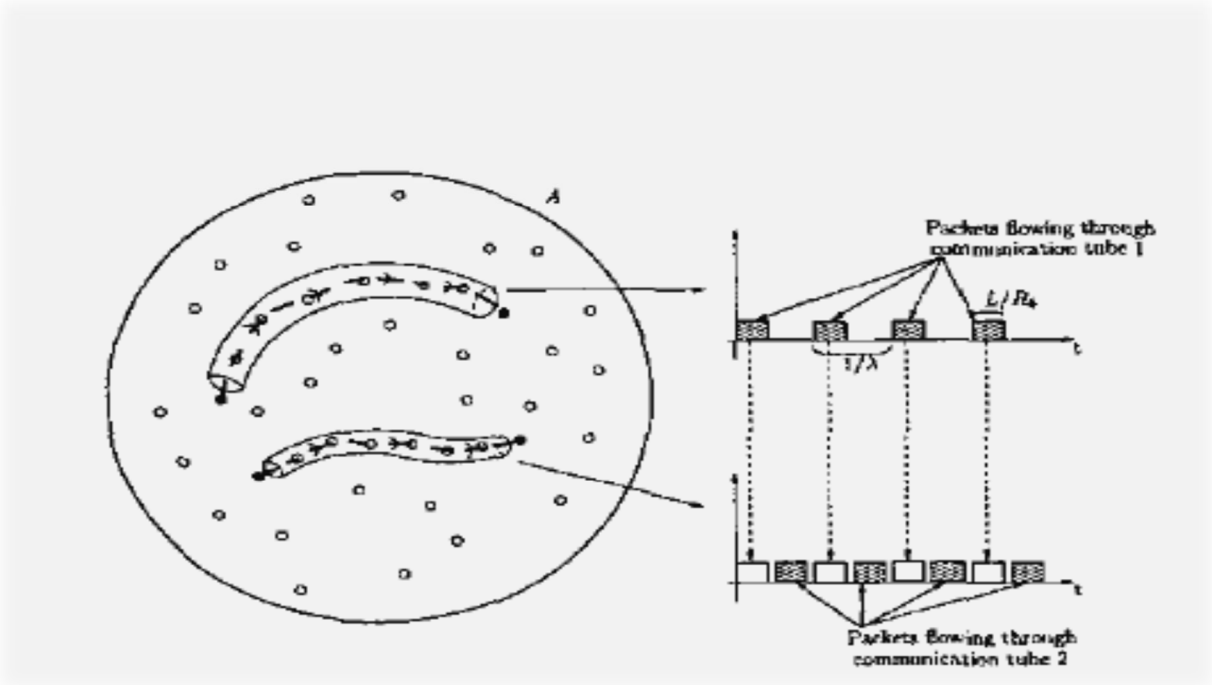

FIGURE:-11 Tubular Routing [3]

observe, from Fig 11 that in each tube there are “gaps” between consecutive packets. assuming that the packet transmission is Poisson distributed with parameter λ-(this implies that the average inter-arrival rate between two consecutive packets is1/λ). In other words, instead of considering “pure” circuit switching (where transmission in each tube is continuous) i propose a hybrid scheme, whereby data transmission is packetized. In fact, as shown in the timing diagrams if *L/Rb* (the packet duration) is sufficiently smaller than l / λ (the inter-arrival time), the packets transmitted in the two tubes may not overlap, reducing significantly the inter-route interference.

4.3.1 ALOHA with PR-CSMA Technique :-

The chosen route , completely eliminates the interference by activating almost always only one route (i.e., communication tube) at a time. This is due to the fact that, in the scheme "ALOHA with PR-CSMA", once a route is activated by a specific source node, all the other nodes which are not involved in this communication "sensing" the presence of an on-going transmission refrain from sending their packets. The under lying assumption is that communication route is created before the nodes are actually activated for transmission. Note that the condition $\lambda L \leq Rb$ has to be satisfied in order for the circuit-switched packetized transmission ad hoc wireless network to properly work.

After creating a path between source and destination connectivity is an important criteria. Hence the condition required to satisfy for connection between node is that given in equation (16) [3].

$$R_b \geq \frac{\lambda L}{\ln\left[\frac{\Delta_A(N) SNR_L^{\min}}{\Delta_A(N) SNR_L^{\min} - 1}\right]} \quad \ldots\ldots\ldots\ldots\ldots(16)$$

Where

$$\Delta_A(N) \hat{=} \left[\sum_{i=1}^{i_{\max}} \left(\frac{6}{i^2} + 8 \sum_{j=1}^{i-1} \frac{1}{i^2 + j^2} \right) - 1 \right] \text{.....(17)}$$

λL=Traffic load generally created by source node

$i_{\max} \approx \left[\sqrt{N/2} \right]$ is the maximum tier number in a square grid network. For example a square grid network consist of 64 nodes then it is having 4-tier architecture

If the equation (16) does not satisfied ,then regardless of transmitted power and node spatial density(number of nodes per unit area) the connectivity is lost.

In particular, for traffic load $\lambda L \leq 130$ b/s the maximum value (with respect to the data-rate) of the effective transport capacity is increasing for increasing traffic load, whereas for traffic load larger than 130 b/s, the maximum value of the effective transport capacity decreases. InFig.12, the effective transport capacity is shown, as a function of the traffic load λL, for various values of the transmitted power *Pt*. In particular, as one can see from Fig, increasing the transmitted power

beyond 10^{-4} W does not lead to any increase of the transport capacity. The highest possible value of the transport capacity is achieved for a critical value of the traffic load $(\lambda L)_c^{ALOHA}$ can be written as given in (18) [3].

$$(\lambda L)_c^{ALOHA} = R_b \ln\left[\frac{\Delta_A(N) SNR_L^{\min}}{\Delta_A(N) SNR_L^{\min} - 1}\right] \quad \text{.....(18)}$$

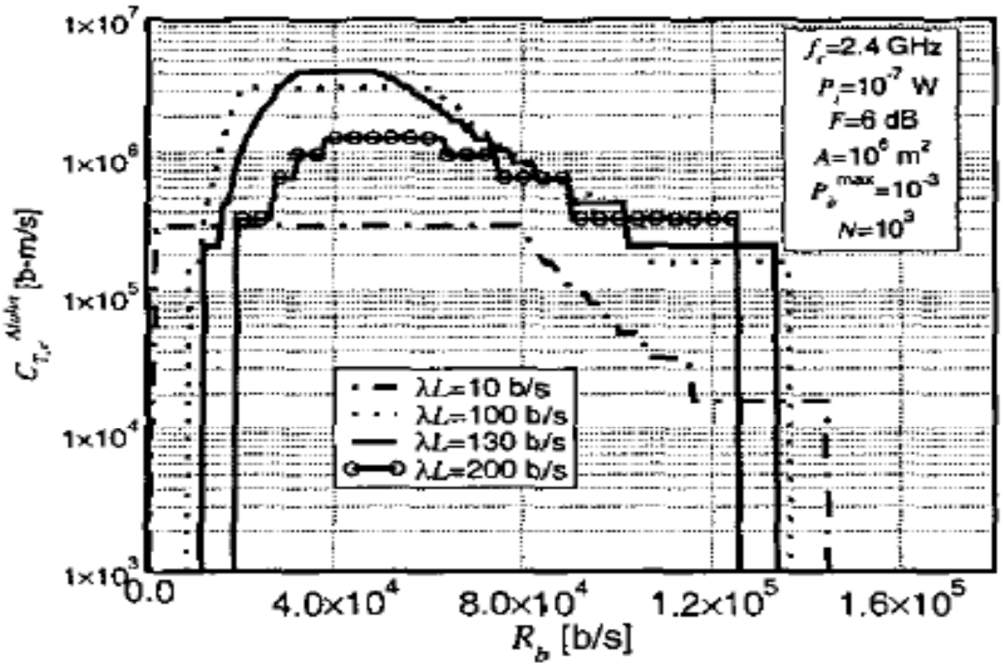

Figure:-12 Effective transport capacity versus data rate [3]

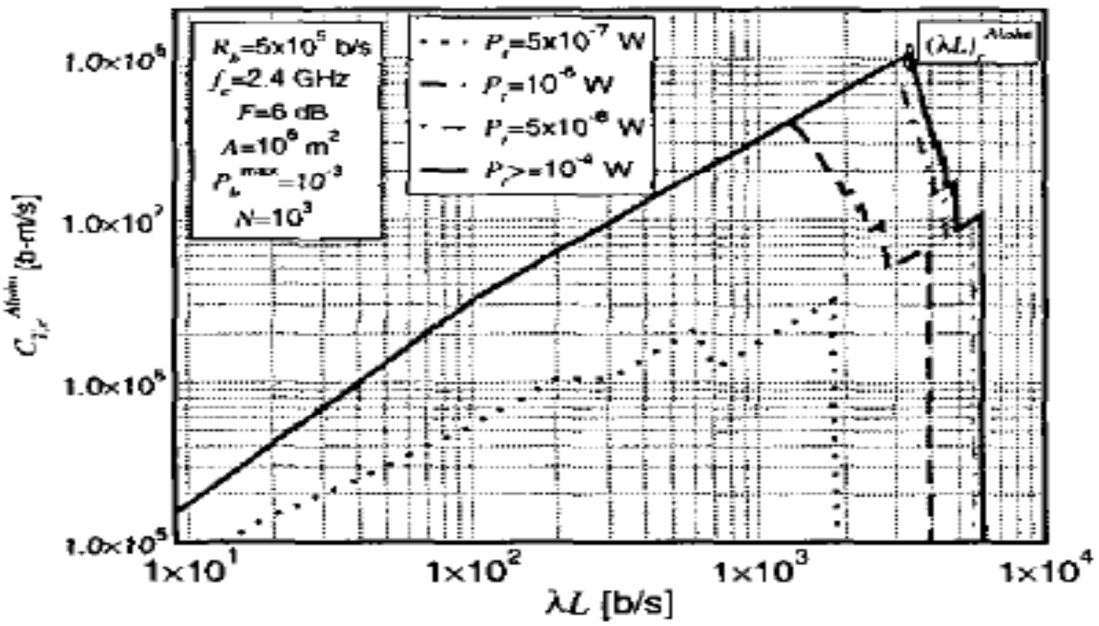

Figure:-13 Effective transport capacity versus traffic load [3]

4.3.2 Result Analysis of Tubular Routing:-

.The source node after searching for the shortest path by using Dijkstra's Algorithm between source to destination ,the equation (16) should satisfied for connectivity between the nodes. And by keeping consideration of data rate maximum of 80 kb/s (Result from fig 12) and traffic load of 130 b/s(Result from figure (13) the path will be created like a tube structure by using circuit switching with packetized transmission and Aloha with PR-CSMA technique.

We know that bit error rate of the path depends upon number of hops according to the relation

$$\mathrm{BER}_{\mathrm{route}}^{(n_h)} = 1 - (1 - \mathrm{BER}_{\mathrm{link}})^{n_h} \quad \text{.....(19)}$$

Note:-We can reduce the total BER by reducing total number of hops

Hence the presented structure gives the exact result for latency and Energy minimization what we have got by using shortest path algorithm and we will get quite well result in the case of BER because we will reduce the total BER by decreasing total number of hops and making zero interference caused by other nodes which are not participating in communication by using Tubular Routing method.

Latency and Energy loss Analysis :-

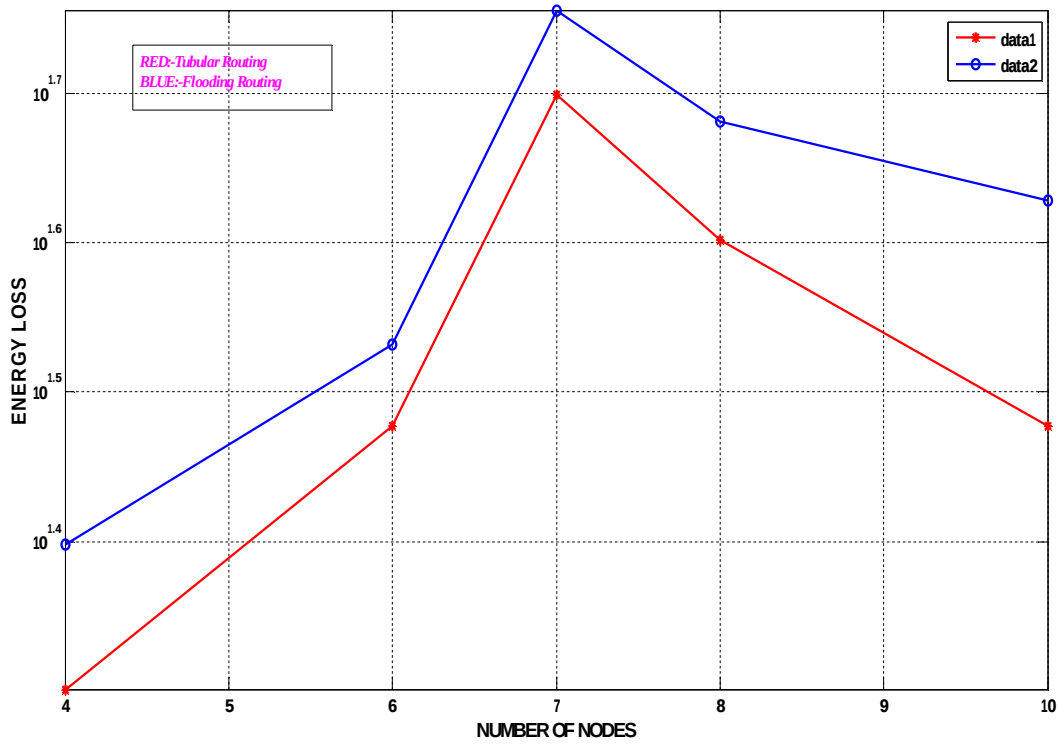

Figure 14:-Energy loss in Tubular Routing & Flooding Routing

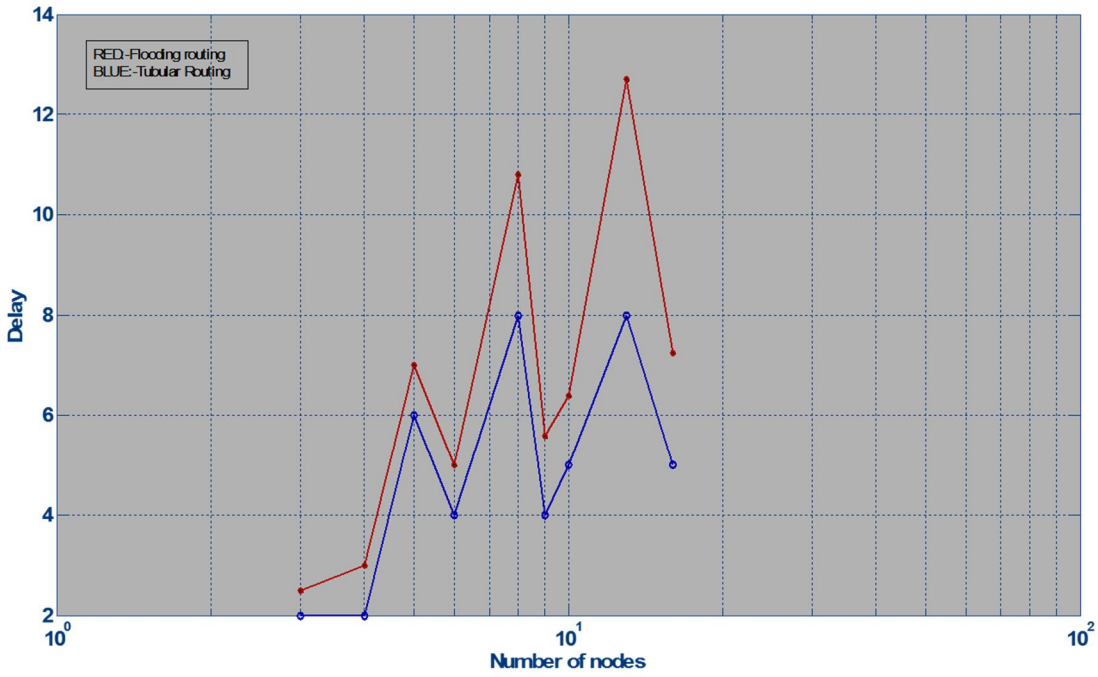

Figure:-15 End-to-end latency in Tubular Routing and Flooding Routing

BER Analysis:-

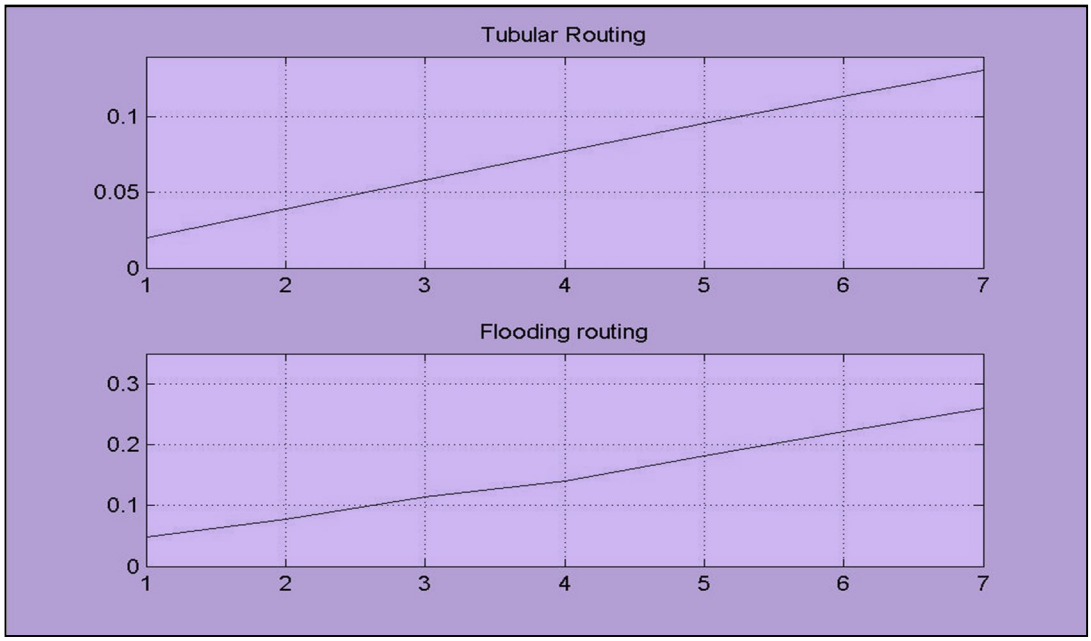

Figure16 :-BER in Tubular and Flooding Routing

Appendix

Result analysis of Flooding and Dijkstra's Algorithm

The network is ad-hoc because it does not rely on a preexisting infrastructure, such as routers in wired network or access point in managed (infrastructure) wireless networks. Instead each node is participates in routing by forwarding data for other nodes and so the determination of which nodes forward data is made dynamically based on network connectivity. In Addition to classic routing ad-hoc networks use flooding algorithm for forwarding the data .Flooding is an important communication primitive in mobile ad-hoc networks and also serves as a building block for more complex protocols such as routing protocols. In this chapter I am comparing with the basic flooding algorithm principle with a shortest path routing algorithm(Digkstra's algorithm) and proved that we can decrease latency and total energy utilization of nodes by using shortest path routing.

Here I want to show that end-to-end latency and total energy utilization of node following shortest path routing is less compared to flooding algorithm. I am not concentrate on other facts such as Transmission rate, channel conditions etc

I have taken the help of C-programming and Mat-lab for result analysis

Assumption:-

1)All nodes are fixed nodes

2)Transmission rate of all nodes is same or constant

3)The channel is treated as only a path through which data is flowing

4)Channel is error free and channel condition does not affect data

5)There is no interference caused by other nodes

1.1 FLOODING ALGORITHM:-

It is the simplest way to deliver data from a node to another node in the network. In flooding the source simply broad casts the packet to its neighboring nodes via MAC layer .The ad-hoc network uses csma/ca(carrier sense multiple access with collision avoidance) principle for sending data frames from sender to receiver.

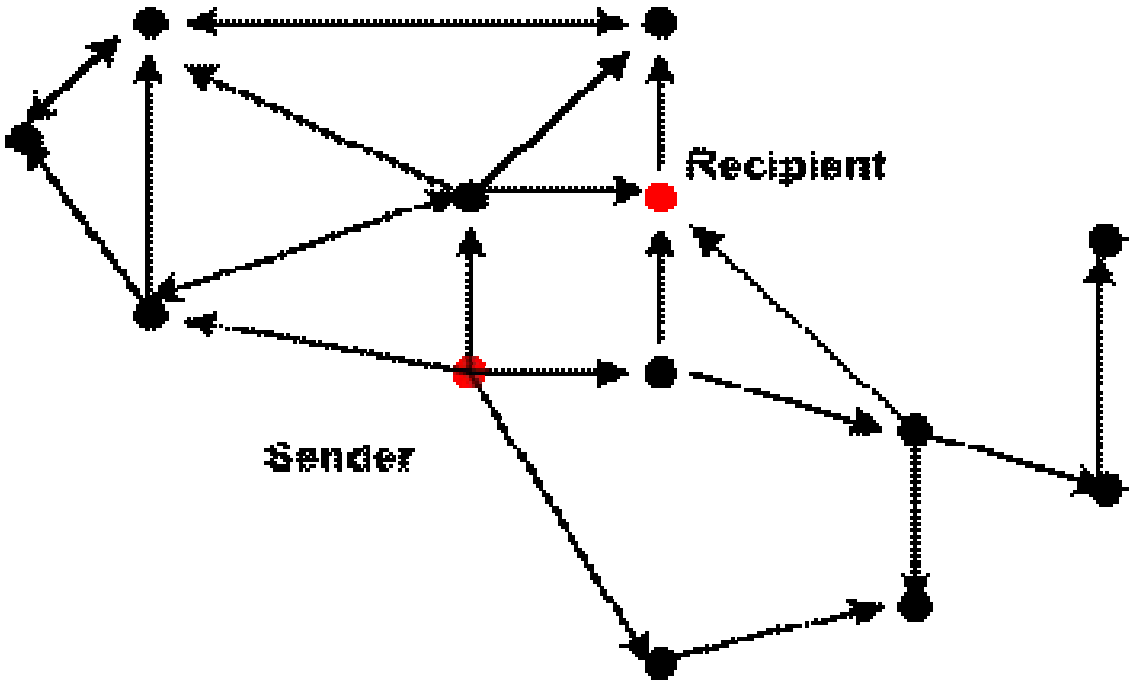

Figure:-17 flooding routing

1.1.1 C-programming for Flooding Algorithm:-

```
#include<iostream.h>

#include<conio.h>

//using namespace_std

/*hop Count function will decide the life time for frame to live in network

*/static int hopCount(int m[][30],int n)

{

int h=0;

for(int i=1;i<=n;i++)
{
        for( int j=1;j<=n;j+)
        {
```

```
                h+=m[i][j];
            }
        }
            h-=n;
            h=((h%2)==0)?(h/2):(h/2+1);
            return h;
}

/*this function show the network in matrix form which you  entered*/

static void showNetworkMatrix(int m[][30],int n)
{
        cout<<"\n\nNetwork Matrix 1st row and colomn showing nodes(or hops) id\n\n";
        for(int i=0;i<=n;i++)
        {
            for(int j=0;j<=n;j+)
            {
                if(i==0&&j==0)
                    cout<<"nodes-   ";
                else if(j==0)
                    cout<<m[i][j]<<"      ";
                else
```

```
                    cout<<m[i][j]<<"    ";
            }
                    cout<<"\n";
        }
}
```

//m-network matrix ; n-number of nodes ; ps - denoted previous node; s-new source node ; d- destination node; h- time remain to live in network

```
static void check(int m[][30],int n,int ps,int s,int d,int h)
{
        int i=s;
        if(h==0||s==d)return;
        for(int j=1;j<=n;j++)
        {

        cout<<"\n\n";
        for(  j=1;j<=n;j++)
        {
                if(m[i][j]==1&&j!=i&&j!=ps)
                check(m,n,s,j,d,(h-1));
        }
}
```

//check function search the next node and repeat till it not got the destination address or hopcount will become zero;

```
static void FloodAlgo(int m[][30],int n,int s,int d,int h)
{
	cout<<"\n\n"<<s<<"\n\n";
	check(m,n,0,s,d,h);
}
int main()
{
	int n;
	clrscr();
	cout<<"\n enter number of nodes in network";
	cin>>n;
	//int n=6;
	/*1 stands for a connection and 0 stands for not connection between two nodes */
	cout<<"Enter the network Matrix	with(0 and 1):";
	int network[30][30];
			/*first row and colmn contains nodes(hops) number starting from 1 to n */
	for(int i=1;i<=n;i++)
	{
		network[0][i]=i;
		network[i][0]=i;
	}
```

```
/*this is matrix containing the information about connection between hops*/
        for(i=1;i<=n;i++)
        {
                cout<<"Row no: "<<i;
                for(int j=1;j<=n;j++)
                {
                        cout<<j<<":   ";
                        int c;
                        cin>>c;
                        if(c==0||c==1)
                                network[i][j]=c;
                        else
                        {
                                cout<<"You entered Other than 0 or 1.\n Enter again.";
                                j-=1;
                        }
                }
        }
        showNetworkMatrix(network,n);
        int h=hopCount(network,n);//h used to count maximum time to live frame
        cout<<"Maxium Life of frame :  "<<h;
        int c;//just a variable used to determine error
```

```
        do
        {
                cout<<"Enter the source node id : ";
                cin>>c;
                if(c==0||c>n)
                        cout<<"Entered wrong id number not available in network.try
again.\n Re";
        }while(c==0||c>n);
        int s=c;//source node id variable
        do{
                cout<<" Enter the  destination node id  :  ";
                cin>>c;
                if(c==0||c>n)
                cout<<"Entered wrong id number not available in network.try again.\n
Re";
        }while(c==0||c>n);
                int d=c;//destination node id variable
                FloodAlgo(network,n,s,d,h);
                getch();
            return 0;
}
```

Here we are getting an output of data flow diagram in flooding algorithm

enter number of nodes in network4
Enter the network Matrix with(0 and 1):Row no: 11: 1
2: 1
3: 1
4: 0
Row no: 21: 1
2: 1
3: 0
4: 1
Row no: 31: 1
2: 0
3: 1
4: 0
Row no: 41: 0
2: 1
3: 0
4: 1

Network Matrix 1st row and colomn showing nodes(or hops) id

nodes- 1 2 3 4
1 1 1 1 0
2 1 1 0 1
3 1 0 1 0
4 0 1 0 1
Maxium Life of frame : 3Enter the source node id : 1
Enter the destination node id : 4

1

2 3

4

1.2 DIJKSTRA'S ALGORITHM:-

Dijkstra's shortest path algorithm is a routing algorithm which select the shortest path from source node to destination node, As number of nodes decreased the End-to-End latency will be minimized simultaneously the interference that is occurring due to more number of nodes will be reduced which will help for energy minimization. Here I am trying to represent Dijkstra's Algorithm in Mat-lab format

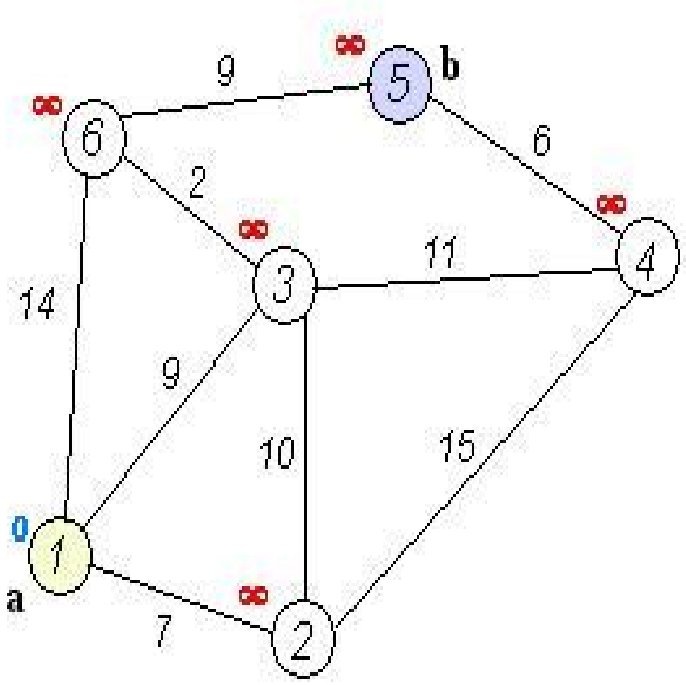

Figure:-18 Dijkstra' algorithm

1.2.1 NODE INFORMATION:-

All the nodes which are participating in data communication are having certain Information here I am representing it through mat-lab**.**

```
classdef Node
    %UNTITLED3 Summary of this class goes here
    %   Detailed explanation goes here

    properties
        TrRate;
        Energy;
        Radio;
    end

    methods
        function obj = Node(TrRate,Energy,Radio)
           % class constructor
               if(nargin > 0)
                 obj.TrRate = TrRate;
                 obj.Energy = Energy;
                 obj.Radio = Radio;
               end
           end
    end

end
```

The out put of the following program

```
ans =

  Node

  Properties:
    TrRate: []
    Energy: []
     Radio: []
```

1.2.2 LINK OR EDGE INFORMATION :-

```
classdef Link
    %UNTITLED4 Summary of this class goes here
    %   Detailed explanation goes here

    properties
        DataRate;
        Delay;
        Length;
        N1;
        N2;
    end

    methods
        function obj =
Link(DataRate,Delay,Length,N1,N2)
           % class constructor
               if(nargin > 0)
                 obj.DataRate = DataRate;
                 obj.Delay    = Delay;
                 obj.Length   = Length;
                 obj.N1       = N1;
                 obj.N2       = N2;
               end
        end
    end
end
```

The output of the following program is

```
Link

  Properties:
    DataRate: []
       Delay: []
      Length: []
          N1: []
```

```
          N2: []
```

1.2.3 Digkstra's Algorithm:-

```
function Adhoc(m,n)

%UNTITLED2 Summary of this function goes here

%   Detailed explanation goes here


%d1=Node(100,200,300,400,500)

%d2=Node(20,30,40,50,60)

%x=[d1 d2];

%x(1,1)

Graph=randsrc(m,n);

count=1;

for i=1:1:m

    for j=1:1:n

        if(Graph(i,j)==1)

            Node_X(count)=i;

            Node_Y(count)=j;

            Node_ID=count;

            count=count+1;

            disp_node(i,j)=Node_ID;
```

```
        else
            disp_node(i,j)=Graph(i,j);
    end
end
fprintf( 'Total Number of nodes: %d\n ', count-1);
fprintf('Nodes with their ID number and Position:');
disp_node
%Node_X
%Node_Y
%Node_ID
count=count-1;
for i=1:1:count
    x1=Node_X(i);
    y1=Node_Y(i);
    for j=1:1:count
        x2=Node_X(j);
        y2=Node_Y(j);
        distance(i,j)=sqrt((x2-x1)^2+(y2-y1)^2);
    end
end
```

```
fprintf('Distan from each node to other:');
distance

yes=input('Do u want to give the node information

individually(type 1) or common to all (type 0)?');

if(yes==1)

    for i=1:1:count

       fprintf('Node %d information:',i);

       TxRt=input('enter the information of
TxRate');

       Energy=input('enter the information of
Energy');

       RadioRange=input('enter the information of
RadioRange');

       node=Node(TxRt,Energy,RadioRange);

       NodeInfo(i)=node;

    end

elseif(yes==0)

       fprintf('Node information:');

       TxRt=input('enter the information TxRate of
Node');


       RadioRange=input('enter the information
RadioRange of Node');
       node=Node(TxRt,Energy,RadioRange);
```

```
        for i=1:1:count

        NodeInfo(i)=node;

        end

else fprintf('Wrong option');

end

num_link=input('Please enter the number of links');

for i=1:1:num_link

        fprintf('Link %d information:',i);

        DataRate=input('enter the information of
DataRate');

        Delay=input('enter the information of
Delay');

        Length=input('enter the information of
Length');

        node1=input('enter the ID of node1');

        node2=input('enter the ID of node2');

       link=Link(DataRate,Delay,Length,node1,node2);

 LinkInfo(i)=link;

end

Q=1;

while Q~=0
s = input('Please enter a source node:');
```

```
d = input('Please enter a destination node:');

%sdist=dijkstras1(v,(count-
1),num_link,LinkInfo,NodeInfo);



%LinkInfo

for i=1:1:(count-1)

    for j=1:1:(count-1)

        adj(i,j)=0;

    end

end


for k=1:1:num_link


adj(LinkInfo(k).N1,LinkInfo(k).N2)=LinkInfo(k).Delay;

adj(LinkInfo(k).N2,LinkInfo(k).N1)=LinkInfo(k).Delay;

end

%adj

[sdist,path]=dijk(s,d,count,num_link,adj,NodeInfo);


%[dist,path]=dijk(s,d,(count-
1),num_link,LinkInfo,NodeInfo);

%for i=1:1:(count-1)

fprintf('\nTotal cost from source node to
```

```
destination node is %d:',sdist);

fprintf('\nPath followed from source node to
destination node is:');

for i=length(path):-1:2

fprintf('%d->',path(i));

end



Q=input('\n Do you want to check for another path?
(Enter 0 for Quit)');

 end

 %end

%NodeInfo(1)

%NodeInfo(2)

%x = input('Please enter a value for x:');



end
```

The output of the following program is

Adhoc(3,3)

Total Number of nodes: 6

Nodes with their ID number and Position:

disp_node =

```
 1    2   -1
 3    4    5
-1   -1    6
```

Distan from each node to other:
distance =

```
    0    1.0000    1.0000    1.4142    2.2361    2.8284
1.0000         0    1.4142    1.0000    1.4142    2.2361
1.0000    1.4142         0    1.0000    2.0000    2.2361
1.4142    1.0000    1.0000         0    1.0000    1.4142
2.2361    1.4142    2.0000    1.0000         0    1.0000
2.8284    2.2361    2.2361    1.4142    1.0000         0
```

Do u want to give the node information individually(type 1) or common to all (type 0)?0

Node information:enter the information TxRate of Node10

enter the information Energy of Node20

enter the information RadioRange of Node20

Please enter the number of links5

Link 1 information:enter the information of DataRate10

enter the information of Delay5

enter the information of Length10

enter the ID of node11

enter the ID of node22

Link 2 information:enter the information of DataRate10

enter the information of Delay10

enter the information of Length10

enter the ID of node1,1

enter the ID of node2,3

Link 3 information:enter the information of DataRate10

enter the information of Delay5

enter the information of Length10

enter the ID of node1, 3

enter the ID of node2 ,4

Link 4 information:enter the information of DataRate10

enter the information of Delay5

enter the information of Length10

enter the ID of node1 ,4

enter the ID of node2 ,5

Link 5 information:enter the information of DataRate10

enter the information of Delay10

enter the information of Length10

enter the ID of node1,5

enter the ID of node2,6

Please enter a source node:1

Please enter a destination node:6

source =1
desti = 6
n = 6
num_link = 5
adj =

0	5	10	0	0	0
5	0	0	0	0	0
10	0	0	5	0	0
0	0	5	0	5	0
0	0	0	5	0	10
0	0	0	0	10	0

path =

0	6	5	4	3	1

sdist = 30
Total cost from source node to destination node is 30:

Path followed from source node to destination node is:1->3->4->5->6->

Do you want to check for another path? (Enter 0 for Quit)

1.3 Result analysis:-

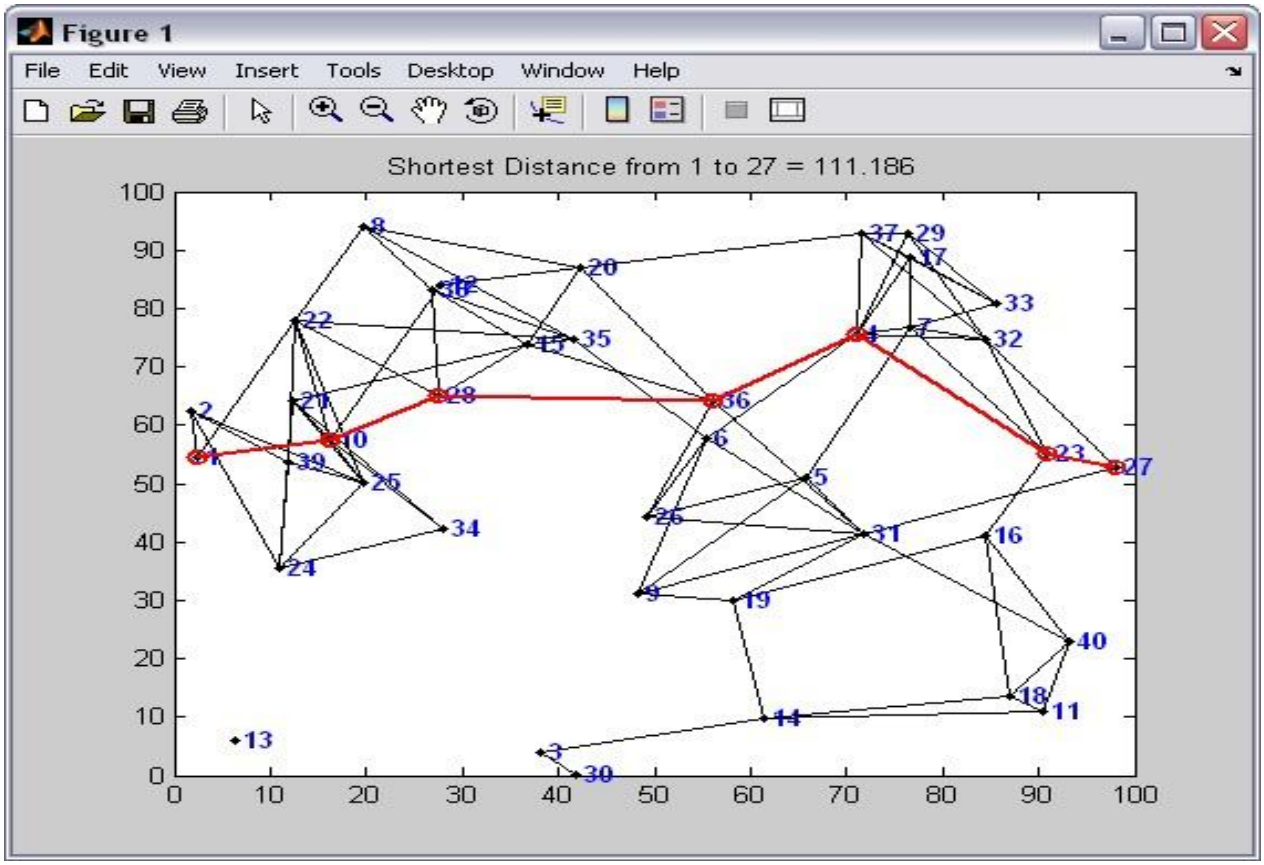

Figure:-19 shortest path from source to destination

Here forty nodes are placed in random manner and each node can transmit data to another node if it is within its frequency range.

The communication between all nodes is duplex

From node 1 to 27 there are number of paths but the shortest route between the two node is "1-10-28-36-4-23-27" and the path cost is 111.86 .

1.3.1 Latency and Energy loss analysis:-

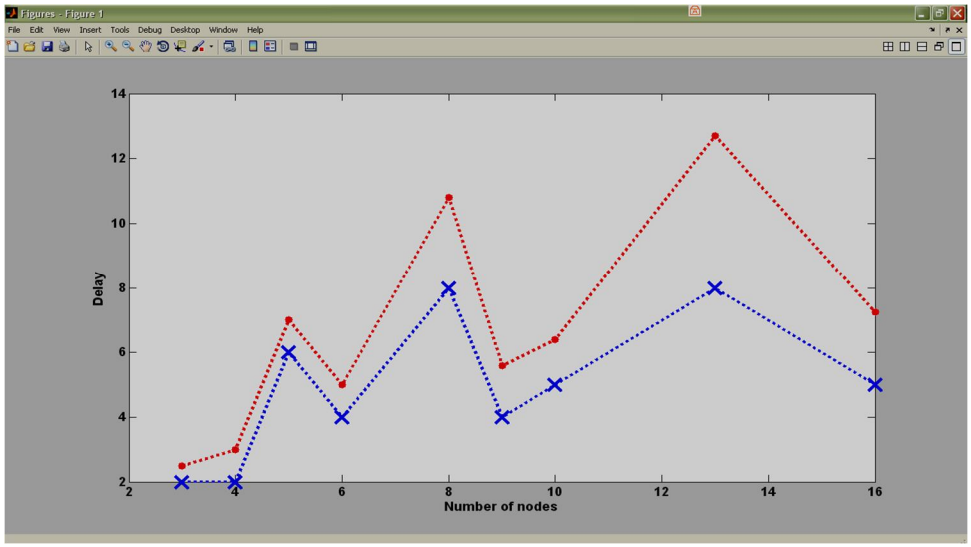

Figure:-20 Delay variation in Shortest path routing and flooding algorithm

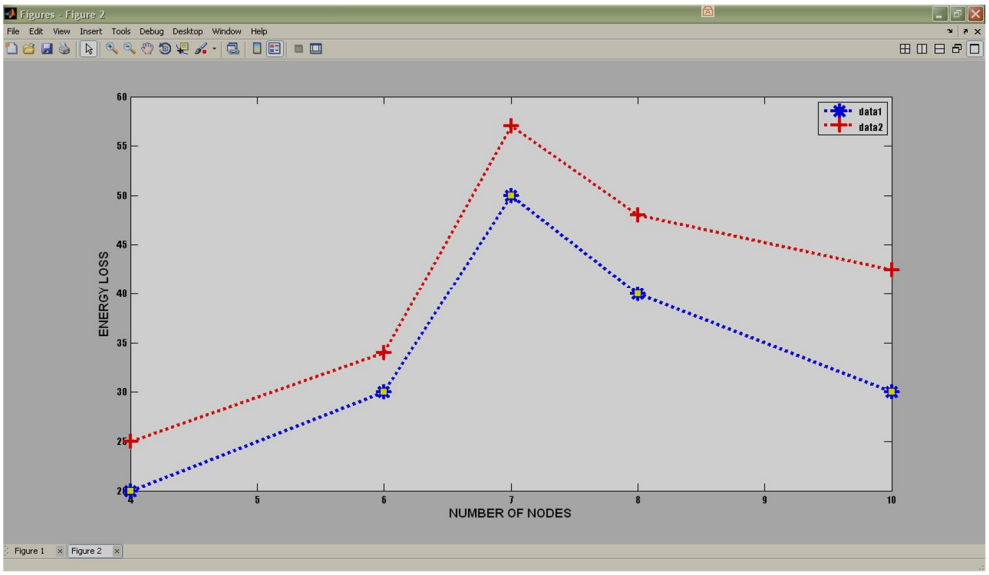

Figure :-21 Total energy utilization in shortest path routing and flooding algorithm

Conclusion:-

From the above result we concluded that by using shortest path routing by using

Dijkstra's algorithm the end-to-end latency and total energy loss of the nodes participating in communication is so less compared to that of using flooding algorithm i:e we can say that by using shortest path routing we can provide quality of service in terms of latency and total energy utilization of nodes .

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