Routing Optimization of Mobile Network System

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Abstract

To send the packets from source to destination node on optimum route in mobile network, the router must find the path with minimum cost. If intermediate node has fialed, the routing table will be updated and the path should be changed depending on this failure.

In traditional protocols, the packet is sent on the path with minimum number of hops and this path is not always optimum, therefore the router selects the path depending on computing cost for each link and send the packets on path with minimum consumption energy, maximum capacity or minimum delay. If there is failure node in the path or no, computing the optimum path in minimum cost is more suitable and efficient than the path with minimum number of hops. Dijkastra's algorithm is used to find optimum path and depending on this algorithm, routing table will be built.

Key-Words: Routing optimization, Failure node, Cost, Energy consumption, Capacity of the link, Average delay.

التوجيه الامثل لنظام الشبكة المتنقلة

الخلاصة

لارسال الحزم من المصدر الى الهدف على احسن مسار في الشبكات المتنقلة يجب ايجاد المسار باقل كلفة.فاذا حدث اي عطل او فشل في عقدة وسطية ضمن المسار, فأن ذلك يؤدي الى تحديث جدول التوجيه وسيتغير المسار نتيجة لهذا الفشل حيث ان المسار الامثل يجب ان لا يحتوي على اي عقدة غير فعالة بالاضافة الى ان المسار الامثل هو المسار ذو اقل كلفة.

في الشبكات التي تعتمد على البروتكولات التقلدية والتي تعتمد على اقل عدد من القفزات فان المسار باقل عدد من القفزات لا يمثل المسار الامثل دائما, لذلك فان اختيار المسار بالاعتماد على حساب الكلفة لكل موصل بين عقدتين ويتم توجيه الحزم على المسار الذي يكون اقل استهلاكا للطاقة او المسار باكثر سعة واقل تاخير بدلا من المسار ذو اقل عدد من القفزات. لايجاد امثل مسار ان كانت هناك عقدة غير فعالة او لا توجد فان حساب المسار باقل كلفة يكون اكثر ملائمة وكفاة من حساب المسار على اساس اقل عدد من ا لقفزات حيث يأخذ بنظر الاعتبار الكلفة و لا يعتمد فقط على عدد القفزات. لقد استخدمت خوارزمية Dijkastra لايجاد امثل مسار وبناء جدول التوجيه على اساس هذه الخوارزمية لارسال الحزم باكثر موثوقية وبدون تاخير.

1. Introduction

The problem of routing is essentially how to find the minimum cost of the path from source to destination node. Each node in the network maintains for each destination a preferred neighbor, selection of the neighbor depends on minimum cost function [1].

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When the neighbor node fails it will be lost and all the nodes that are connected to it must now search to connect to other nodes and the source node will look up its routing table to see an alternate path to destination. The packets that are sent to node failure must be retransmitted, and the optimal path will be changed depending on this failure [2].

To find the optimal path in network scheme with intermediate node fails, it's supposed to use routing algorithm by computing the cost of each link between pair nodes and the path that is formed from active nodes and links, it's the route that the packets travel through a network from source to destination.

In traditional routing protocols that depend on minimum number of hops, there is no guarantee that the minimum hop path finds the optimal path, while the links with high bandwidth, low delay and minimum consume energy can be omitted.

2. How routing works

A router compares the destination address of each data packet it receives with table of addresses held in the router table. If it finds a match in the table, it forwards the packet to the address associated with that table entry, which may be the address of another network or of "next-hop" router that will pass the packet along towards its final destination.

Whenever a source node cannot send its packets directly to its destination node but has to rely on the assistance of intermediate nodes to forward these packets on its behalf, a multihop networks result. In such a network, an intermediate node (as well as the source node) has to decide to which neighboring node an incoming packet

should be passed on so that it eventually reaches the destination.

The basic idea is that each packet on a network has a source address, which means that any device that receives the packet can inspect its headers to determine where it came from and where it is going. If such device also has information about the network's design and implementation-for example, how long it takes packets to travel over a particular link-it can intelligently change the routing to minimize the total cost.

Normally, the costs are signs that reflect the preference for how the traffic to flow. A high priced, fast link would probably deserve a lower cost than a cheaper or slower link; by assigning most financially expensive links a high cost, they would not be used if there are more cost efficient links available [3].

Optimum routing seeks to spread traffic throughout a network in order to optimize a particular cost criterion [4].

Router exchange routing table information with neighbor routers periodically. The type of information exchanged is a function of the routing protocol used [5].

2.1 Building Router Tables

Routing table is a database that stores route information. The routing lists which routes exist between networks, so the router or host can look up the necessary information when it encounters a packet bound for a foreign network. Each entry in the routing table contains the following four pieces of information: [6]

1. The network address of the remote host or network.
2. The forwarding address to which traffic for the remote network should be sent.
3. The network interface that should be used to send the forwarding address
4. A cost, or metric, that indicates what relative priority should be assigned to this route.

2 .2 Node Failure

Figure (1) shows a simple network that the optimal path is $S \rightarrow i \rightarrow D$, where node i is active as in Figure 1(a). If node i fails as a consequence of any drawback, the source node searches in routing table for other nodes that lead it to destination node in minimum cost and does not contain the node failure. This is shown in Figure 1(b). F is assigning to the node failure and the optimal path changes depending on this failure.

2.3 Dijkastra Shortest Path First Algorithm

The algorithm works by setting, for each node (n), the cost $C(n)$ of the shortest path found so far between source node (S) and n. Initially, this value is zero for the source S, ($C(S)=0$) and infinity for other nodes, representing the fact that it does not know any path leading to those nodes, $C(n)=\infty$ for every n in N, where N is number of nodes, except S [7].

3. Assigning Link Costs

Paths are the number of links between routers the traffic must traverse in its way from a source to a destination. Each link is assigned a value, called cost or weight. Routers use routing protocol to exchange link weights. Each router computes shortest paths (as the sum of link weights) and creates a table that controls the forwarding packet to the next hop in its route. Network operators assign weights to links. The lower the weight, the greater the chance that traffic will be routed on that link [8].

From the basics of radio communication and the inherent power limitation of radio communication follows a limitation on the feasible distance between a sender and a receiver. Because of this limited distance, the simple, direct communication between source and sink is not always possible [9]. Also, to set up connection, a node does not necessarily establish a direct link, even when the power of its transmitter is sufficient to achieve a one-hop path. Rather, it might select a multihop path for the connection, in order to reduce emitted power.

The fundamental problem then is the selection of relevant parameters and the construction of an associated cost function to compare and select paths, and solve the routing problem. The cost function should incorporate power constraints, as well as other factors, such as delay [10]. The flowchart for Dijkastra algorithm is given in Figure (2).

3.1 Energy Cost Analysis

The mobile nodes modify their path to come within communication range and are considered moving the mobile nodes along a route so that the distances between the nodes are changing and different energy is used to transmit over a shorter range [11].

There is operating models type like Hop-by-Hop Retransmissions (HHR) where each individual link provides reliable forwarding to the next hop using localized packet retransmission.

In the HHR model a transmission error on a specific link implies the need for retransmission on that link alone. In this case, the link layer retransmissions on a specific link essentially ensure that the transmission energy spent on the other links in the path is independent of the error rate of that link.

Since the number of transmissions on each link is now independent of the other links the energy cost for the link is: [12]

$$e_{i,j} = a \ d^{K}{}_{i,j} \qquad \text{... (1)}$$

Where α is a proportionality constant, k is a constant that depends on propagation medium, and $d_{i,j}$ is a distance between node i and j. The routing algorithm's job is to compute the shortest path from source to the destination that minimizes the sum of transmission energy costs over each

constituent link. The error rate of individual links affects the overall number of transmissions needed to ensure reliable packet delivery. So the cost for link $l_{i,j}$ denoted by *C(energy)* is given by: [12].

$$C(energy) = \frac{e_{i,j}}{1 - r_{link}} \quad \ldots (2)$$

Where $e_{i,j}$ is the energy cost between the node *i* and *j*, and ρ_{link} is the packet error rate associated with the link.

3.2 Capacity Analysis

In wireless communication it is important to determine the capacity limits of the channels. These capacity limits dictate the maximum data rate that can be transmitted over wireless channels. The capacity of the single wireless channel embodied by link *l* can be modeled as a function of Signal to Noise Ratio (*SNR*), the received signal power (P_r), in Additive White Gaussian Noise (AWGN) with noise power N_o. Based on the stated assumptions, the *SNR* is given in decibel as: [9]

$$SNR = 10 \log_{10} \frac{P_r}{N_o} \quad \ldots (3)$$

Shannon's capacity formula is used to model the capacity of an AWGN channel of bandwidth *W* and *SNR*. The achievable transmission rate for link *l* is defined as: [13][14]

$$capacity = W \; Log_2(1 + SNR) \quad \ldots (4)$$

Major router, by default assigns in some protocols weight as inverse of the link capacity, and then the shortest paths will be the links of the higher bandwidths. However, this type of assigning weights does not guarantee that the network will run efficiently [15]. Therefore the cost on link *l* is determined by the capacity (*cap*) and the total flow rate *Flow* on link *l*: [16]

$$C(capacity, Flow) = \frac{Flow_{i,j}}{cap_{i,j} - Flow_{i,j}}$$

,for $0 \le Flow_{i,j} < cap_i$ ... (5)

The link cost function is dependent on the link capacity, as well as the total flow rate. Cost function tries to send flows over links with small utilization. Since increasing link capacity reduces link costs. *C(capacity, Flow)* is also equal to the expected number of packets in the queue of the link [16][8].

3.3 Average Delay Analysis

A quantity that is widely used for measure of performance in network is message delay, which is defined as the time interval between the arrival of a message to the network from external source and it final departure from the network [4].

By Little's formula the average number of messages in the network at node *i* is given by $\lambda_i T_i$. Summing over *i* gives the total average number. Where T_i is the average delay of message entering at node *i*, λ is the average arrival rate. Then the average delay of a message entering the network at any node can be calculated by: [4]

$$T = \frac{1}{g} \sum_{i=1}^{N} \frac{Flow_i}{cap_i - Flow_i} \quad \ldots (6)$$

Where $Flow_i = b\,\lambda_i$ is the flow in link in bits per second [4]. This equation is very effective for design calculation. However, it ignores certain realities, which become important when one wishes to give amore precise predication of network delay. This would account for processing at the nodes and the propagation delay between nodes. The cost of the link is the sum of the

average delay, in this case can be written as: [4][17]

$$C(delay) = \frac{1}{g}\left(\frac{Flow_i}{cap_i - Flow_i} + l\ \ (g + p)\right) \quad .... (7)$$

Where g_i is the propagation delay and p is the processing delay on link l. The propagation delay is: [17]

$$g=d/v$$

Where d is the distance between any pairs of router and v is the speed of the light.

The processing delay, p is also called nodal processing time and the processing delay of a message is constant delay at each node, and is estimated by: [17]

$$p=1/\mu cap$$

The objective is to allocate the capacities of the links so as to minimize average message delay with a constraint on the total capacity [4]. Hence the link with maximum capacity is the minimum delay.

4. Specification of the Type of Network

The network that is suggested is point to point network, assuming the topology of a network is determined by set of active nodes and set of active links along which direct communication can occur. Instead of using all links in the network, some links can be disregarded to purpose study of the effect path selection.

Formally, takes a graph $G= (N, L)$ represents the network. Where N = {node i, node j, node k, ….}, is the set of all nodes in the network and L is the set of the links if and only if pair of nodes can directly communicate with each other [9], in other words, a link is assumed to exist between pair (i,j) as long as node j lies within the transmission range of node i.

The route in this work is determined in hop by hop routing; this means the next hop is determined at each hop. Each node maintains a routing table which allows it to route the packet for other destinations in the network. To find the path it will find the connected pair node and hop by hop to get a complete, connected route from source to destination. In order to determine the optimal path, the links that have the minimum cost from source to destination node must be determined. Selection of optimal cost path is calculated using the shortest path algorithm (Dijkasra's algorithm), if more than one links have the same cost it will consider the minimum hops.

Assume that:

- Each node has the same functionality.
- All the nodes have information about the exact position to each other.
- All the nodes have the same transmission range.

4.1 Computing the Cost of the Link

The link cost is determined by computing the energy consumption, capacity of the link and average delay to get the optimal path and compare those paths with the path that has minimum number of hops.

The parameters given in Table (1) are needed to specify and compute the cost of the link.

4.2 Network Scheme

The network is suggested to be distributed in a random way, with 25 nodes that are located in area of 100units*100units. In Figure (2), the circles and lines represent nodes and links between those nodes, respectively.

To observe the effect of node failure on selecting the optimal path and how it changes according to this failure, consider node 4 failures which are the most effective on the overall scheme of the network due to its intermediate position. Also assume node 1 as a source node which sends packets to node 8 as a

destination node. First determine the cost for each link and select the minimum cost, and then compare the path before and after failure of the intermediate node (node 4). Figure (3) shows the connection scheme of the network after node 4 failures and according to this failure the number of hops and the cost in terms of energy consumption, capacity of the link and average delay will be recalculated

4.2.1 Optimum Path with Number of Hops

The source node sends the packet to the neighbor nodes which collectively have minimum number of hops, if the neighbor node fails, the source node looks to anther node that is active with minimum number of hops and sends packets to it. The routing table for the source node (node 1) is given in Table (2), attached with it is the path with minimum number of hops before and after the node 4 failure. The cost for this path is given in terms of energy spending, the capacity of the link, and the average delay.

4.2.2 Optimum Path with Energy Consumption

Node failure enforces the network scheme to change. This change includes connection links and paths consequence energy for new links must be recalculated. This tends to acquire an optimal path with high energy, compared with the one before node 4 failure.

Figure (4) shows the path from source to destination node. In this figure the path with bold line is the path from source to destination node before node 4 fail, the second path with stared line represents the optimal path after node 4 failures.

Table (3) clarifies the path from source node to destination node and the C(energy) for the path before and after node 4 failure.

4.2.3 Optimum Path with Capacity of the Link

When intermediate node fails, the cost of the capacity is affected and the optimal path will be changed. This failure effect is to turn the packets from the route that has node failure to new route.

Figure (5) shows two different paths from source (node 1) to destination (node 8), the first path with bold line is acting the optimal path before node 4 fails, while the path with stared line configures the optimal path from source to destination after node 4 failure.

Table (4) shows the optimal path from source to destination node before and after node 4 failure.

4.2.4 Optimum Path with Average Delay

The optimum path is changed depending on the intermediate node failure. Figure (6) shows the path from source to destination node across node 4. This path is the same with the path in term of capacity.

The routing table for source node is given in Table (5), list the optimum path and the cost for this path before and after node 4 failures.

5. Conclusions

Node failure effect on the source node retransmission of packets and the routing table will be updated to achieve the optimum path with all nodes active. Intermediate node has big role in mobile network and effect on transmitting the packets. When this node fails, the optimum path changes and the network scheme will be changed depending on this failure.

When node failure, computing the cost of the link in terms of energy consumption, capacity of the link, and the average delay; the optimum path has minimum cost over the path with minimum number of hops. Therefore the path with minimum number of hops has consumes more energy and

may be more congested getting more delay.

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Table (1): Routing table from source to destination when failure node.

Des .node	*The situation*	*Optimal path*	*Min. No. of hop*	*C(eng)*	*C(cap,Flow)*	*C(delay)*
Node 8	Before failure node 4	{1,12, 4,9,3,8 }	5	$3.567*10^{3}$	5.272	$1.055 * 10^{-4}$
Node 8	After failure node 4	{1,12, 14,9,3, 8}	5	$3.856*10^{3}$	5.632	$1.127 * 10^{-4}$

Table (2): The value of the parameters [12], [16],[17]

Number of nodes(***N***)	25
Proportional constant (α)	1
Constant that depends on the propagation medium and antenna characteristics(K)	2
The link packet error probability (ρ)	0.01
The transmit signal power (P_t)	0.1W
Noise power (N_o)	10^{-4}W/Hz
Channel bandwidth (W)	10^{6} Hz
Signal travel on transmission medium (v)	$3*10^{8}$m/s
Packet size (b)	1kbit
Mean number of arrivals per second (λ)	2000 packet per second

Table (3): Routing table from source to destination node when failure node.

Des. Node	***The situation***	***Optimal path***	***No. of hops***	***C(energy)***
Node 8	Before failure node 4	{1,21,4,9,3,8}	5	$2.765*10^{3}$
Node 8	After failure node 4	{1,15,17,2,6,22, 23,16,8}	8	$2.969*10^{3}$

Table (4): Routing table from source node to destination node when failure node.

Des. Node	*The situation*	*Optimal path*	*No. of hop*	*C(cap,flow)*
Node 8	Before failure node 4	{1,21,4,9,3,8}	5	4.440
Node 8	After failure node 4	{1,21,12,14,24, 18,8}	6	5.267

Table (5): Routing table from source to destination when failure node

Des. Node	*The situation*	*Optimal path*	*No. of hops*	*C(delay)*
Node 8	Before failure node 4	{1,21,4,9,3,8 }	5	$8.885*10^{-5}$
Node 8	After failure node 4	{1,21,12,14,2 4,18,8}	6	$1.054*10^{-4}$

B:

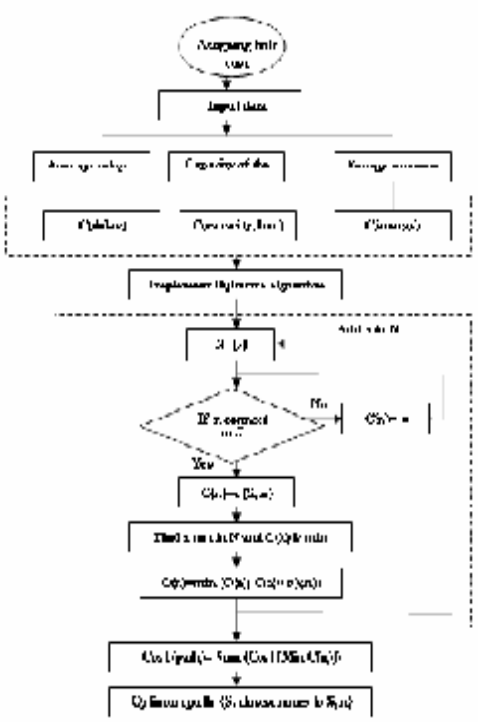

Figure (1): The optimal path from source to destination node when intermediate node fails

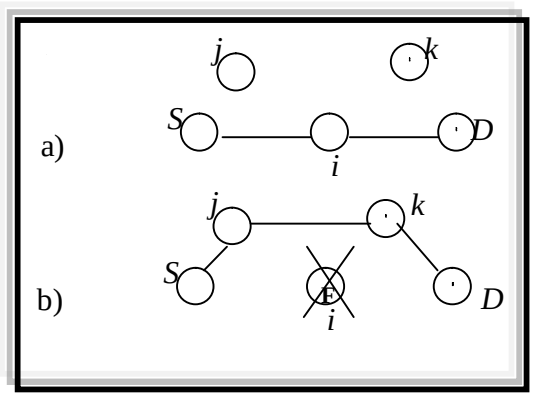

Figure (2): flowchart of the steps tofinding the optimum path

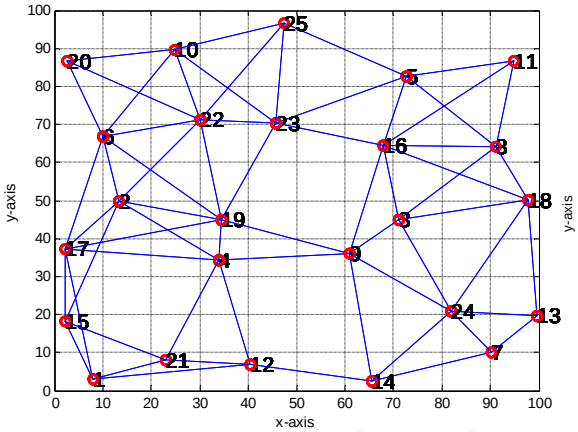

Figure (3): Network scheme with 25 nodes

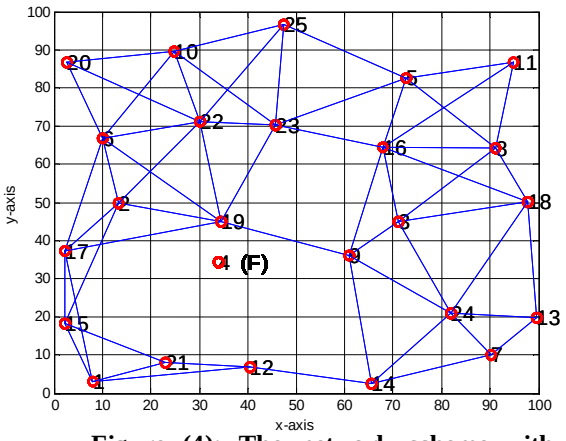

Figure (4): The network scheme with failure node

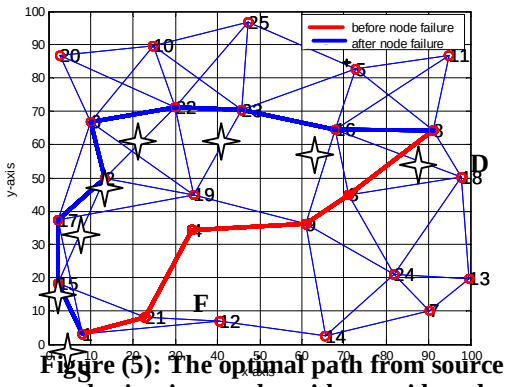

Figure (5): The optimal path from source to destination node with consider the node failure

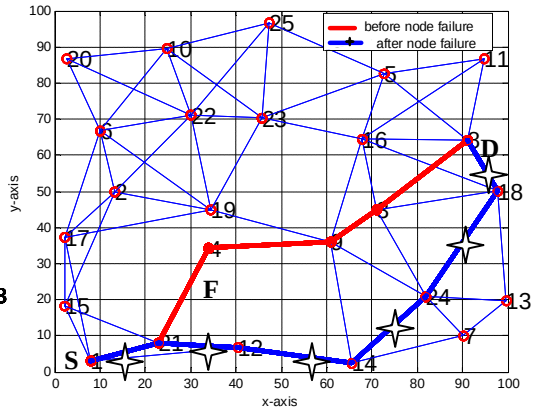

Figure (6): Optimal path from source to destination node with consider the failure node

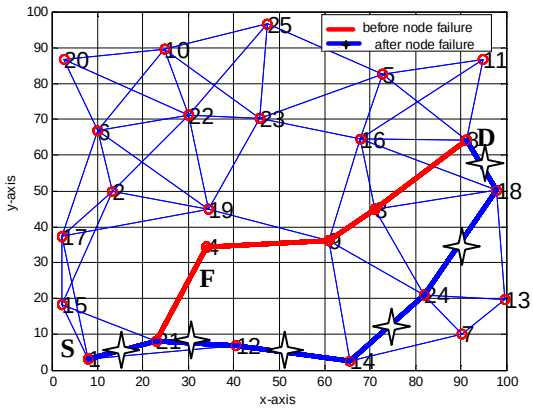

Figure (7): The optimal path from source to destination node with consider the failure node.