An Extended Location-based Routing Approach for Disaster Recovery of Wireless Networks

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1 Introduction

With extensive research over the past few years, several routing protocols, which do not make use of location information, have been defined within MANET working group of IETF. These protocols mainly adopt some mechanisms of flooding, either to detect routes on-demand, or to maintain routing information proactively on each node. Due to the overhead introduced by flooding, such protocols are considered not to scale in networks with more than some hundred nodes. In order to solve this problem, geometric algorithm is introduced. Recent availability in inexpensive and low-power GPS receivers provides feasibility in adoption of location information in routing algorithms for ad hoc networks. This research's motivation is to establish communication under natural disasters especially earth quake disaster or tsunami disaster.

In location-based routing, usually the whole transfer process of a packet from a source node to a destination node consists of a series of sub-processes of next-hop selection, based on the three types of information as follows, location of the current node, location of destination, and location of one-hop neighboring nodes within the transmission range of the current node. The first information is achieved via GPS, and the second is available through some location management schemes, such as VHR, GLS, and is contained in the packet's header. The third can be attained through a beaconing mechanism – exchange of location information via small packets broadcasts – which introduces some traffic overhead and power consumption. With the three above information, a notion named progress can be valued, and according to this value, the current node makes a selection out of all neighboring nodes as a next-hop in order to achieve optimum of the routing in a certain sense. But locating a node indoors remains a challenging problem. In an indoor situation, the GPS approach cannot provide precise location information. In this case, RSS (Received Signal Strength) can be used as an approach of location estimation.

2 Related Work

Lately, a new class of location-based algorithms and protocols, such as BLR[1], IGF[2], and CBF[3], has achieved a feature of being beaconless. In these algorithms, the selection decision is not made by the current node, but via a new mechanism of transmission time contention - DFD (dynamic forwarding delay), where the third information above is not necessary, thus the beaconing is not needed. In another word, only the first and the second information is needed. With the avoidance of periodical beacon messages, signalling overhead and battery consumption are significantly reduced. Here the DFD mechanism and the selection process of BLR are explained.

As shown in Fig 1, a bunch of mobile nodes exist as the hosts of the network. They all have the functions of sending/receiving as well as forwarding packets for others. A packet from a node S is to be sent to a node D. Following the BLR algorithm, S broadcasts the packet, and the neighboring nodes within the transmission range of S, receive the packet. Direction from S to D is considered forward, and node A1 and node A2 know that they are within the forward 60° sector and thus consider themselves the candidates of the next-hop selection. So they schedule to relay the packet with respective delay time according to the notion of progress. In this algorithm, progress is defined as a projection of the line from the current node to a candidate on the line from the current node to the destination, as explained in the figure. Here the delay time formula is defined as:

$$\text{Delay time} = \text{Max\_Delay} * (r - p) / r \qquad (1)$$

Where Max_Delay is a global constant known by all nodes, r is the broadcast radius, and p is the progress. Candidate nodes have different progress, and they have different delay time. The candidate with the minimum delay time will broadcast the packet first. On hearing this broadcast, other candidates will cancel the scheduled relay, and meanwhile some other nodes in forward direction will become new candidates. So the routing continue hop-by-hop until reaching D. The above routing behavior is efficient, and is called basic mode.

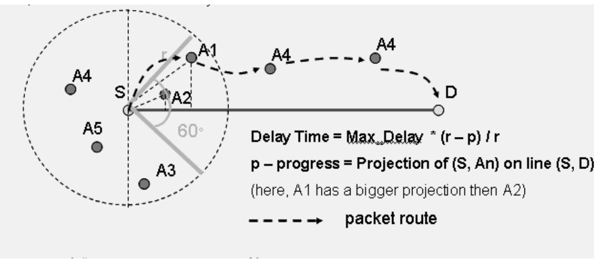

Fig 1: beaconless routing

3 BLR Algorithm with Received Signal Strength

3.1 Avoidance of routing into sparse area

For the above beaconless protocols, operating mostly in the basic mode is a key to efficiency, thus letting the routing happen as much as possible in a dense area is desired. Information of neighboring nodes could have been helpful for picking out a node in relatively dense area during the next-hop selection. But as a feature of such class of algorithms, the knowledge of neighboring nodes is not required and not available without beaconing.

But actually the broadcasts received from other nodes give hints of existence of the neighbors, even though the update of information is not as guaranteed as periodic beaconing. So if the network traffic is above a certain level, the neighboring info is possible to be obtained by short-termed historical traffic. In this paper, the total signal strength from neighboring nodes within a latest historical period, e.g. 0.5 second, is considered as a measure for the neighboring density. It is assumed that the stronger the neighboring signal strength is, the more dense area the node is possibly in.

As in Figure 2 (a) and (b), A1 and A2 become the candidates of next-hop, and the delay time is to be calculated. A candidate might have received some signal from its neighboring right before this moment. The strength of the signal received can be taken into consideration for calculating delay time.

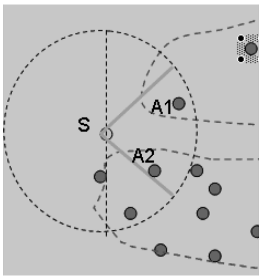

Fig 2 (a) A1 & A2 are candidates

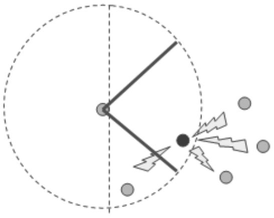

Fig 2 (b) historical signal strength is considered

3.2 Procedures of the Algorithm

Network nodes attain the information of their own location coordinates via GPS, Galileo, or other location service technology. And via a location management scheme, a source node can attain its destination's location coordinates accurately enough. (Such location management schemes are not the research topic of this article.) There are two global constants that are widely known by all nodes. One is Max_Delay, which indicates the maximum time that a candidate node delays before relaying a packet. Another one is transmission rage r, with which the network is modeled with unit disk graph where two nodes can communicate directly in one-hop if their distance is less than r. Thus the radio links are bi-directional and the antennas are omni-directional. When a source node is to send a packet, it first retrieves the geographical coordinates of the destination, and put it into the packet's header. The coordinates of the source node will be put into the header as well. Then the source node broadcast the packet. If there are nodes within the transmission rage, they will receive it. Now each of these neighboring nodes has the location information of the source and the destination, and in associate with its own location, they can via geometrical calculation determine whether they are in a forward area and evaluate progress. The nodes within the forward area become candidates of next-hop relay and apply Dynamic Forwarding Delay, while other neighboring nodes drop the received packet. The candidate with the shortest delay time will make a broadcast as a relay first of the packet and other candidates will receive it and cancel the scheduled relay. Each candidate node will replace in the packet header the previous node's location coordinates with its own location coordinates. Thus, during the whole routing, each intermediate node repeats a same behavior and eventually the packet will reach the destination.

3.3 Location Estimation Model with Received Signal Strength Indicator

About the received signal strength distribution, path loss as well as shadow effect is considered. Rayleigh fading is neglected here because it can be averaged out over the time scale considered. So the RSSI distribution is modeled as

$$y = K_1 - K_2 \log(d) + \mu + \upsilon \qquad (2)$$

where y is the value of RSSI, K_1 and K_2 represent the path loss factors, d denotes the distance between the signal sending node and a receiving node, and μ and υ represent the shadowing and mobility variables and, which are modeled as independent WSS Gaussian process.

4 Simulation

4.1 Network Model

Simulation has been done on the platform of OMNET network simulator with module mobility-framework, version 1.0a6. On the playground, a certain numbers of mobile nodes are initially distributed in random. As the test begins, the nodes will start to move and communicate with each other. The nodes are designed to move at a constant velocity and change to a random direction at a constant interval. At every sampling time, subject to a global packet rate, a certain numbers of sender-receiver pairs are selected to perform packet transmission. One time of the test lasts 10 minutes. The simulated protocols are the original BLR and the BLR with historical signal strength which is proposed in this article, operating in basic mode if possible, else in backup mode. The backup mode that is employed here is the Half-transmission Rang Approach.

4.2 Result of Delivery failure ratio

If a packet delivery failure happens in basic mode, the routing will have to be switched to a backup mode. To evaluate the performance of the next-hop selection algorithms, the failure ratio of delivery in basic mode is taking as a performance criterion. Tests have been performed with gradually increased global packet rates, which specify a total number of the packets to be send in a time unit (10 ms) by all nodes. This packet rate indicates the global traffic level.

Figure 3 shows the failure ratios in basic mode of the original and the proposed algorithms. It is shown that in general the failure ratio of the original algorithm is higher than the proposed one. This is less evident when the network traffic is too low, but as the traffic increases, the difference turns more apparent. This is because as the traffic increases, the nodes update their neighbors more frequently, so nodes in dense area gain more priorities. The result shows that the proposed algorithm keeps the routing working in basic mode more.

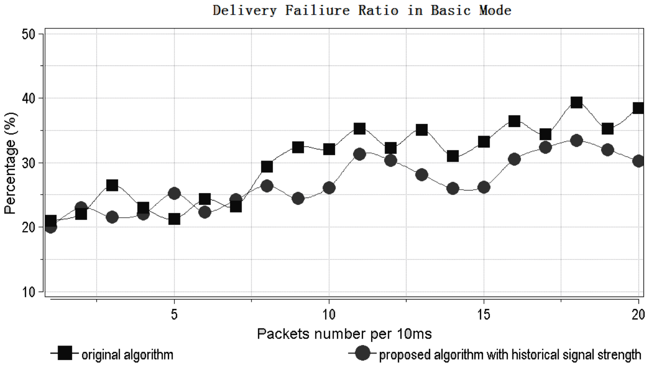

Fig. 3 Failure ratio in basic mode

5 Conclusion

Location-based routing algorithms have the advantage that no global topology information is needed, and that these algorithms are more adaptive to the changes in the networks than the topology based protocols. Beaconless location-based routing algorithms further the sparing of signaling overhead and battery consumption, but give up the knowledge of neighborhood. Actually the neighboring information is possible to be extracted from signal strength and location estimation is possible.

References

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