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A Reliability Aware Flooding Algorithm (RAFA) In Wireless Multi-hop Networks

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ABSTRACT

Flooding is a mechanism that distributes packets to every node of the network. The flooding mechanism is frequently used in many operations in wireless multi-hop networks. Since flooding exploits hop-by-hop broadcasting that suffers from unreliable transmission and fading, it is hard to achieve the reliability in flooding. As unreliable flooding may lead to a coverage hole,it will have a negative effect upon upper layer protocols. In this paper, we introduce a Reliability Aware Flooding Algorithm (RAFA), which estimates the expected reliability using two-hop topology knowledge. The estimated reliability is used for deciding whether or not to retransmit a packet. Using NS-2 simulator, we show that RAFA achieves the higher reliability than RBP by adjusting the number of retransmissions considering the network topology, regardless of the network topologies, the node density or the number of bottlenecks.

1.INTRODUCTION

Flooding is a mechanism that propagates a packet throughout network. Due to its viability, there is a plenty of flooding based protocols in wireless networks. In fact, most of routing protocols leverage the flooding mechanism. For example, DSR and AODV use a flooding message for discovery, maintenance and update of routes. In Directed Diffusion flooding is used for disseminating interests to sensors. Overall, the flooding mechanism is exploited in sensor networks, MANETs, and vehicular networks, etc. Almost all the above protocols assume that flooding can propagate a packet to every node in a network. However, since flooding commonly exploits hop-by-hop broadcasting that suffers from unreliable link quality, collision and fading, it is hard to achieve the sufficiently high reliability. As a matter of fact, because there is a frequent transmission failure due to the above reasons, when flooding needs to achieve higher reliability, it should be augmented by some mechanism. For this reason, many researchers have proposed a lot of schemes that cope with the collision and/or the link error. For the reduction of collision, PHY-Iayer capture, MAC-layer TDMA, random slot selection, and application-layer jitter schemes are used. Although these approaches do not guarantee collision-free, it may help reduce collisions. To deal with the link error, there are some studies how to exploit the retransmission mechanism. When the transmission of a packet fails, these schemes increase the reliability by retransmitting at the

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MAC, network, or application layer. This retransmission mechanism leverages ACKs to figure out whether the transmission of the packet is successful or not. There are two kinds of ACKs, Le., *explicit* and *implicit* ACKs as Shown in Fig 1.

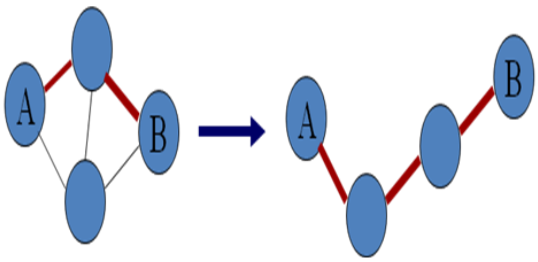

Fig 1. Bottleneck Link

An *explicit* ACK refers to an ACK packet transmitted by a receiver to confirm the success of transmission, *directly*. While An *implicit* ACK happens as follows. When node A sends a data packet to node B, and overhears B's forwarding the packet to another node. In this way, A confirms that the packet is successfully received by B. The cost of a flooding scheme highly depends on how to combine these two kinds of ACKs, which will be detailed later. To the best of our knowledge, RBP is a state-of-the-art protocol on the retransmission based flooding mechanism. RBP improves the reliability of flooding using the knowledge about the node density and bottleneck link. A node's retransmission policy is to retransmit the packet only if the ratio of the received ACKs from its neighbors is less than a certain threshold. This threshold is adjusted by the neighborhood density and whether the link with its neighbor is bottleneck or not bottleneck link. The bottleneck link represents the link which uniquely connects two nodes each other and may largely affect the reliability of the network. RBP assumes that the nodes in the network are deployed uniformly and it considers only one source of packets to flood. We propose a Reliability Aware Flooding Algorithm (RAFA), which guarantees the required reliability of flooding. The remainder of this paper is organized as follows. We first state some preliminaries and motivations. After that, we describe RAFA in Section III. In Section IV, we show the performance evaluation. Finally, we conclude our work and discuss the future directions.

2. Connectivity between neighbors

RBP improves the reliability of flooding, by using the retransmission mechanism. The retransmission policy of RBP is to perform retransmissions only if the received ACK ratio is less than a certain threshold. The ACK ratio is the of the received ACKs to the number of neighbor nodes. This threshold of each node is determined by the neighborhood density. That is, when the neighborhood density is low, RBP sets the threshold high and when the neighborhood density is high, it sets the threshold low. The intuition behind the above adaptive threshold is that the higher the density of neighborhood becomes, the higher reliability will flooding achieve.

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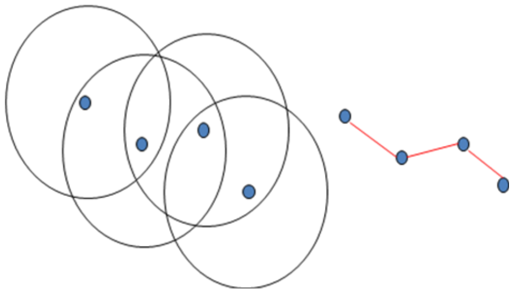

Fig 2.Retransmission in Multihop wireless network

See Fig. 2 for an illustration of the RBP retransmission policy. The retransmission threshold of node A, whose neighbor number is 3, is 66% while that of node B, whose neighbor number is 5, is 50%. By adjusting the retransmission threshold according to the number of neighbors, RBP reduces the number of unnecessary etransmissions without having a negative effect on the reliability. As stated above, the intuition behind RBP is that the reliability of the flooding is proportional to the number of neighbors. This intuition seems reasonable but, unless nodes are uniformly distributed, the number of neighbors cannot directly indicate the reliability of flooding. For example, in Fig. 2, nodes A and B have the same number of neighbors, four. However, the reliability of flooding on each topology is not same at all. The reliability of the right topology is much higher than that of the left one because neighbors of B are neighbors of one another. On the other hand, neighbors of A have no neighbors except A. In other words, reliability is also affected by connectivity between neighbors as well as the number of neighbors. In RBP, the retransmission threshold of A and B will be same which leads to either perform unnecessary retransmissions or decrease the reliability.

3.. Bottleneck link effect

Another issue is the effect of bottleneck links. In Fig.1.there is a bottleneck link, i.e., the link between A and B. Success of transmission on that link largely affects the reliability of the network-wide flooding because all of six nodes located on the right side of node B cannot receive the flooding packet if the transmission from A to B fails. The problem is that the bottleneck link may exist irrespective of the number of neighbors. When we consider the number of neighbors only, the bottleneck link may not be detected. Therefore, if the number of neighbors is considered in the retransmission policy (like RBP), the reliability of flooding may be severely poor. The authors of RBP were aware of the importance of the bottleneck link with respect to the reliability of the flooding. So, they proposed a simple mechanism that finds out the bottleneck link. The proposed mechanism is to make every node record the first sender of the flooding packet. If most of flooding packets arriving first are sent by a particular node, then the link from the node is regarded as the bottleneck link. The effectiveness of this mechanism is affected by the distribution of source nodes of the flooding packets. If there is only one source node or source nodes are gathered together, this mechanism will work well. On the other hand, if source nodes are distributed uniformly, the above mechanism will not be effective in detecting the bottleneck link. This is the severe constraint because any node in the network may be the source of the flooding in many

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protocols such as AODV, DSR, etc. Motivated by the above observations, we propose a Reliability Aware Flooding Algorithm, dubbed RAFA, that reflects the network topology better than RBP. Furthermore RAFA estimates the expected reliability using two-hop topology knowledge. Estimated reliability is used for deciding whether or not to retransmit a packet. The details of RAFA is described in the next section.

4 ALGORITHM DESCRIPTION

In RAFA, both kinds of ACKs are used to enhance reliability.To reduce the number of ACK transmissions, RAFA first exploits *implicit* ACK (like RBP). When the sender learns that a certain neighbor rebroadcasts the flooding packet by overhearing, the sender concludes that the neighbor has received the flodding packet sccessfully. At the receiver side, the receiver sends back the ACK packet only when receives a duplicate flooding packet from the same sender, *explicitly*. In addition to ACK scheme, RAFA adopts a retransmission echanism for reliability. In RAFA, whether or not to retransmit a packet is decided by an *expected reliability*, which is a probability that neighbors that do not send ACK (we call them unconfirmed neighbors) receive the packet by other nodes' flooding. Since a receiver rebroadcasts the packet, unconfirmed neighbors may receive the lost packet on another path, even though the sender does not retransmit the packet. RAFA employs an algorithm that estimates the *expected reliability*. ***A. Basic Algorithm*** The *expected reliability* is determined by the network topology and link quality. To calculate the *expected reliability* more exactly in a distributed fashion, total network topology and qualities of all of the links in the network must be known to all the nodes. However, in wireless multi-hop networks, RAFA, nodes calculate the approximate values of the *expected reliability*. The *expected reliability* is estimated in a distributed fashion using the knowledge of the two-hop topology and the quality of all of the links on the two-hop topology. Every node knows this information by exchanging its own neighbor list with its neighbors' lists. Algorithm for calculating expected reliability

Receive the flooding packet

- **ERi = calculateER(i, in})**
- **calculateER(node i, S)**
- **if node i's reception is acknowledged then**
- **return 1**
- **else**
- **fp = 1**
- **for all a E (NLi - S) do**
- **fp * == (1 - Lai · calculateER(a, S U {i}))**
- **end for**
- **return (l-fr)**

end if

the *expected reliability* for a particular neighbor node i is estimated by node *n* as shown.Node *n* is the one that is running this algorithm, and the set *S*whose initial value is *{n}* contains all the nodes that will be excluded in relaying the flooding packet to node i. The *calculateER* function returns 1 if node i's reception is acknowledged (line 5). Otherwise, the return value is calculated by calling *calculateER* for node i's each neighbor recursively. Since the *expected*

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reliability of node i is equal to the probability that at least one of node i's neighbors delivers the flooding packet to node i, it can be calculated as follows.

ERi == 1 - II (1 - *Lai* . *ERa)* -------------------(1)

This algorithm is the basis for the retransmission policy. In RAFA, the retransmission is triggered when the minimum of all the unconfirmed neighbors' *expected reliability* is less than the target reliability.

Alg 2 shows the Retransmission algorithm

- ERmin == 1
- for all unconfirmed neighbor u do
- E Ru =calculateER(u, {n})
- if ERmin> ERu then
- ERmin == ERu
- end if
- end for
- if ERmin < TR then
- Retransmit the packet.
- end if

Where ERmin = Minimum expected reliability

T R = Target reliability

In the above algorithm, the target reliability, *T R*, can be less than the required reliability by applications. For example, if .99 reliability is required, *T R* can be set to a certain value less than .99. Since the *expected reliability* is estimated by using only the two-hop topology information, RAFA's *actual reliability* will be higher than the *T R*. This difference generally increases as the node density becomes higher due to the availability of more alternate paths which are not included in the twohop topology. Therefore, for the same required probability, we can decrease the *T R* as the node density increases. The analytic study on the relation between the *T R* and the required reliability is our future work.

5. Simplified Algorithm

The proposed retransmission algorithm is relatively simple but its computational cost can be very high with high node density. In order to alleviate this problem, we simplify the proposed retransmission algorithm. In the basic retransmission algorithm (Alg. 2), the sender of a flooding packet estimates the *expected reliability* for all the unconfirmed neighbors because the sender needs to know the minimum of the *expected reliability* of unconfirmed neighbors for retransmission decision. We streamline this part by inferring the minimum of *expected reliability* without calculations for all of the unconfirmed neighbors. The idea is to use the number of confirmed common neighbors to reduce the computation overhead of estimating the reliability. The confirmed common neighbors for an unconfirmed neighbor *u* are nodes whose receiving the packet is acknowledged and are common neighbors of both nodes *n* and *u*. We denote the number of confirmed common neighbors by *NC*, and *NC* for a certain neighbor *u* by *NCu* . We consider that *NCu* is roughly proportional to the *expected reliability* of *u*. Thus, the minimum of the *expected reliability* is approximated by the *expected reliability* of a neighbor whose *N* C is the minimum.

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Alg. 3 shows the modified retransmission algorithm. We denote this modified version by RAFA-NC.

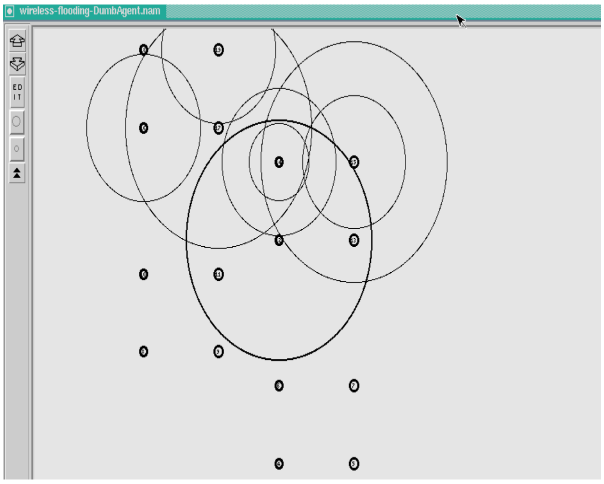
- NCmin == number of neighbors of the sender +1
- for all unconfirmed neighbor u do
- if NCmin > NCu then
- NCmin == NCu
- NNC==U
- end if
- end for
- if calculateER(NNc, {n}) < TR then
- Retransmit the packet.
- end if
- Where NCi = Number of confirmed neighbors among the common neighbors of nodes n and I

  NCmin =Minimum of NCi for every neighbor i

  NNC = Identifier of a node who has NCmin

the computational cost is significantly reduced. Note that the computational cost of deriving *NCs* is much lower than than of estimating the *expected reliability.*

6.SIMULATION RESULTS &ANALYSIS



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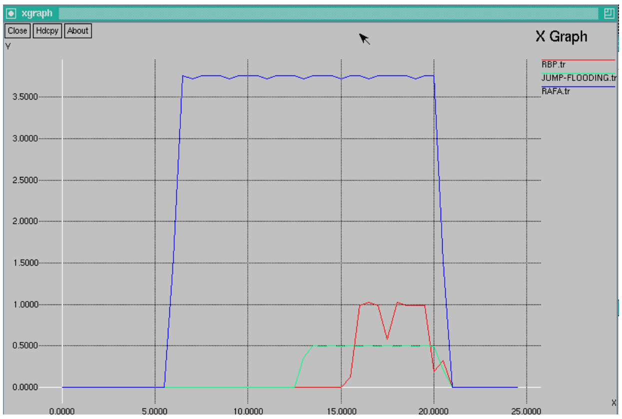

Fig 6. Simulation Result

shows the *RCM* of RAFA, RAFA-NC and RBP with respect to the number of nodes. *RCM* of RBP is higher than that ofRAFA by about 28% when there are 10 nodes, while the difference of *RCM* between RBP and RAFA is reduced when the network becomes dense. The *RCM* of RBP is decreased by about 32% as the number of nodes becomes from 10 to 30. This result indicates that the performance of RBP is more affected by the node density than RAFA. RBP achieves higher performance in the dense network than in the sparse network. As the node density becomes higher, it is more likely that nodes are uniformly distributed. RBP performs best where nodes are uniformly. This is why the performance of RBP increases as the number of node increases. In case of RAFA, the node density affects the performance less than RBP. Although there is a little decrease of *RCM* in RAFA, in Fig. 6, as the number of nodes increases, it is due to the increase of chances receiving the lost packet through other paths without retransmissions.

IV. CONCLUSION

In this paper, we present Reliability Aware Flooding Algorithm (RAFA) in wireless multi-hop networks. It decides whether to retransmit the flooding packet by estimating the expected reliability with only two-hop neighbor information. To reduce the computational overhead of estimating the reliability, we also devise a simplified version, RAFA-NC, which takes into account the number of confirmed common neighbor for each unconfirmed neighbor. With extensive simulations using NS-2 , we validated RAFA, achieves the higher reliability than RBP by adjusting the number of retransmissions considering the network topology, regardless of the network topologies, the node density or the number of bottlenecks.

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