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A Cross-Layer Dynamic Probabilistic Broadcasting Strategy for Mobile Ad hoc Networks

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Abstract

In order to solve the broadcast storm problem caused by blind flooding, a cross-layer dynamic probabilistic broadcasting strategy for mobile ad hoc networks (CLDPB) is proposed. CLDPB adopts the cross-layer design, which let routing layer share the received signal power information at MAC layer while still maintaining separation between the two layers. The additional transmission range that can benefit from rebroadcast is calculated according to the received signal power, which is applied to dynamically adjust the rebroadcast probability. CLDPB reduces the redundant retransmission and the chance of the contention and collision in the networks. Simulation results reveal that the CLDPB achieves better performance in terms of the saved-rebroadcast, the average packet drop fraction, the average number of collisions and average end-to-end delay, which is respectively compared with the blind flooding and fixed probabilistic flooding applied at the routing layer while IEEE 802.11 at the MAC layer.

Index Terms: Mobile Ad Hoc Network; flooding; broadcasting; cross-layer design; rebroadcast probability

1. Introduction

Mobile ad hoc networks (MANETs) are self-organizing mobile wireless networks that do not rely on a preexisting infrastructure to communicate[1]. In MANETs, broadcasting is a fundamental and effective data dissemination mechanism for route discovery, address resolution and many other network services [2]. The simplistic form of broadcasting called flooding, where every node in the network retransmits every unique received packet exactly once but may lead to the broadcast storm problem[3], which is characterized by redundant rebroadcast, high contention and collision in the network. This problem leads to significant network performance degradation.

In this paper, we propose a cross-layer dynamic probabilistic broadcasting strategy for mobile ad hoc networks, named CLDPB. We adopt the cross-layer design, which let the routing layer share the received signal power information of MAC layer. Then, we apply the received signal power information to calculate the

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additional transmission range, which is applied to dynamically adjust the rebroadcast probability. Simulation results reveal that CLDPB demonstrates better performance than blind flooding and fixed probabilistic flooding at the routing layer and IEEE 802.11 at the MAC layer.

The rest of the paper is organized as follows: In Section 2, we introduce the related work. We descript the design and implementation of CLDPB in Section 3. The parameters used in the experiments and the performance results and analyses are presented in Section 4.Finally, section 5 concludes the paper and outlines the future work.

2. RELATED WORK

There are five proposed flooding schemes[3] in MANETs called probabilistic, counter-based, distance-based, location-based and cluster-based broadcasting. Jamal-Deen Abdulai et al. [4] proposed two new probabilistic methods that can significantly reduce the number of RREQ packets transmitted during route discovery operation, which can result in significant performance improvements in terms of routing overhead, MAC collisions and end-to-end delay .The disadvantage of these methods is that they decrease the network performance when the network is sparse. Zhang and Agrawal [5] proposed a Dynamic probabilistic broadcast scheme as a combination of the probabilistic and counter-based approaches, which has the drawback of increases latency. Yassein et al.[6] have analyzed the performance of adjusted probabilistic broadcasting scheme where the forwarding probability p is adjusted by the local topology information. This scheme increases the saved rebroadcast, but lead to an extra overhead by constructing one-hop neighbor list. Wang et al.[7] proposed a cross-layer approach for efficient flooding, in which a novel MAC layer access-deferring scheme based on the received signal power is presented. Although this approach has good performance in terms of throughput, average delay and energy efficiency, it leads to network performance decreased when the nodes in the network are moving.

3. DESIGN AND IMPLEMENTATION OF CLDPB

A. Architecture of CLDPB

A strict layered design is not flexible enough to cope with the dynamics of MANETs environments, and will thus prevent performance optimizations[8]. The main drawback of this design is the lack of cooperation among adjacent layers: each layer works in isolation with little information about the network[9]. The cross layer approaches attempt to exploit more interactions among layers to achieve better performance. CLDPB apply cross layer design, which let the routing layer share the received signal power information at MAC layer while still maintaining separation between the two layers. The MAC layer of CLDPB is implemented based on the IEEE802.11 and the routing layer based on the flooding. The architecture of CLDPB is shown as Fig.1.

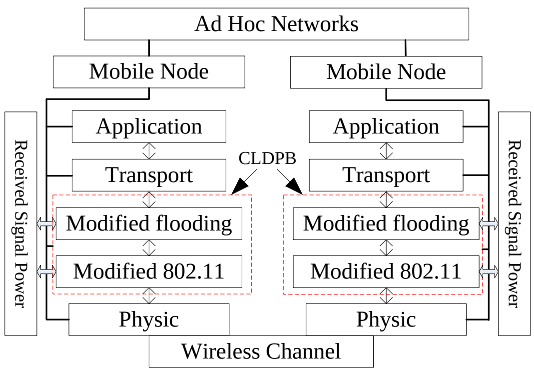

Figure1.CLDPB architecture

B. Theory analysis

MANETs can be modeled as a graph $G(V,E)$, where $V=\{V_1,V_2,\ldots V_n\}$ is the set of nodes and $E=\{(i,j)\,|\,d(i,j)\le r\}$ is the set of edges that represent wireless links; $d(i,j)$ represents the distance between node V_i and node V_j; r is the transmission radii of node. A link is assumed to exist between two nodes if and only if the two nodes are within each other's radio range. Fig. 2 shows an example, in which node **A** sends a broadcast message, and node **B** decides to rebroadcast the message. $S_{A\cap B}(d)$ is the intersection area of the two nodes' transmission range. The additional area that can benefit from **B**'s rebroadcast is denoted as $S_{\bar{A}\cap B}(d)$.

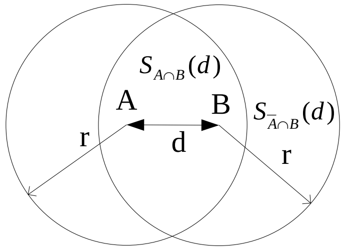

Figure2. Analysis of the additional area benefited from rebroadcast.

According to[3], the intersection area of the two nodes' transmission range $S_{A\cap B}(d)$ is given by

$$\begin{aligned} S_{A\cap B}(d) &= 4\int_{d/2}^{r}\sqrt{r^2-x^2}\,dx \\ &= \pi r^2 - d\sqrt{r^2-\frac{d^2}{4}} - 2r^2\arcsin\frac{d}{2r} \end{aligned} \quad (1)$$

The additional area $S_{\bar{A}\cap B}(d)$ can be computed as follows:

$$S_{\bar{A}\cap B}(d) = d\sqrt{r^2-\frac{d^2}{4}} + 2r^2\arcsin\frac{d}{2r} \quad (2)$$

We can obtain derivative of (1) as follow:

$$S_{\bar{A}\cap B}{}'(d) = \frac{2r^2-\frac{1}{2}d^2}{\sqrt{r^2-\frac{d^2}{4}}} > 0 \quad (3)$$

From (3), we know that $S_{\bar{A}\cap B}(d)$ is a monotonically increasing function. If the distance d between **A** and **B** is very small, there is little additional coverage **B**'s rebroadcast can provide. If *d* is larger, the additional coverage will be larger. In the extreme case, if *d* = 0, the additional coverage is 0 too. If *d* = r, the additional coverage will be the largest.

$$S_{\bar{A}\cap B}(r) = \left(\frac{\pi}{3}+\frac{\sqrt{3}}{2}\right)r^2 \approx 0.6090\pi r^2 \quad (4)$$

From the analysis above, we know that let the nodes with the larger additional coverage rebroadcast the received packet with high probability, which can reduces the redundant retransmission and the chance of the contention and collision. On the other hand, covers more neighbor nodes, which decreases delay that the packets coverage the whole network.

C. Implement of CLDPB

Accord to[10], the relationship between transmission power and the received signal power in the two-ray ground propagation model can be calculated as follow:

$$P_r = P_t(\frac{\sqrt{G_l}h_t h_r}{d^2})^2 \tag{5}$$

Where P_t is the default transmission power and P_r the received signal power; G_l is the antenna gain; h_t and h_r are the heights of the antennas, and d is the distance between the sender and the receiver. We assumed that the network is homogeneous that all nodes use the same parameters.

From (7), the d is given by

$$d = \sqrt[4]{\frac{P_t G_l (h_t h_r)^2}{P_r}} \tag{6}$$

When a node receives a broadcasting packet, it refers to its additional coverage of rebroadcast to determine rebroadcast probability. If the packet is received for the first time, the node applying CLDPB uses its coverage area to determine its rebroadcast probability as follow:

$$p = \begin{cases} \frac{S_{\bar{A}\cap B}(d)}{S_{\bar{A}\cap B}(r)} = \frac{d\sqrt{r^2 - \frac{d^2}{4}} + 2r^2 \, arcsin\frac{d}{2r}}{(\frac{\pi}{3} + \frac{\sqrt{3}}{2})r^2}, \\ for\ 0 < d \le r \\ 0, \\ for\ d > r \end{cases} \tag{7}$$

From (7), we know that CLDPB dynamically calculates the value of rebroadcast probability *p* at each mobile host according to its additional coverage area benefited from rebroadcast. If the additional coverage area is larger, the rebroadcast probability is higher. The probability is lower when the additional coverage area is smaller. Higher value of *p* means lower number of redundant rebroadcast. The procedure of CLDPB is shown in Table I.

TABLE I. The procedure of CLDPB

Protocol receiving ()
1. On hearing a broadcast packet *m* at the MAC layer of node *X*
2. If wireless channel is busy
3. Collision is detected.
4.End if
5.Else Get the *received signal power* P_r
6. On hearing the packet *m* at the routing layer of node *X*
7.If packet *m* received for the first time then
8. Get *distance* d from the sender according to (6).
9.If $d > r$
10.Drop the packet
11.End if
12. Else Get *rebroadcast probability* p by (7).
13.If *RN* $\le P$
14. Rebroadcasts the packet.
15.End if
16..Else Drop the packet

4. PERFORMANCE ANALYSIS

A. Simulation Setup

We use ns-2 packet level simulator (v.2.31) to simulate a square 1000m by 1000m area populated with 25, 50, 75, …, 150 mobile nodes that are uniformly distributed in the region. Protocol:(1)CLDPB(2) flooding applied at the routing layer ,while IEEE802.11 at the MAC layer (flooding+802.11)(3) probabilistic flooding applied at the routing layer ,while IEEE802.11 at the MAC layer (fp-flooding+802.11). Other simulation parameters that have been used in our experiment are shown in Table II.

TABLE II Simulation Parameters

Simulation Parameter	**Value**
Simulation time	300s
Transmission range	250m
Traffic type	CBR
Movement model	RWP
Queue length	50
Queue	PriQueue
Propagation Model	TwoRayGround
Antenna	OmniAntenna
Maximum speed	50m/s
Packet rate	10Packet/s
Pause time	100s

B. Performance Metrics

The four performance metrics are defined as flowing:

1) Saved-Rebroadcast SRB

$$SRB = \frac{pa_r - pa_f}{pa_r} \times 100\% \tag{8}$$

Where pa_r is number of the received non-repetitive packets by the nodes and pa_f the number of the forwarded non-repetitive packets by the nodes.

2) Packet Drop Fraction P_{drop}

$$P_{drop} = \frac{\frac{P_d}{P_S}}{n} \tag{9}$$

Where P_d is the number of packets dropped by the nodes and P_S the number of packets send by the source nodes and n represents the number of nodes in the network.

3) Average number of collisions-This is the average number of collisions at the MAC layer.

4)End-to-end delay-This is the average time difference between the time a data packet is sent by the source node and the time it is successfully received by the destination node.

C. Simulation Results

Fig.3 shows that CLDPB can significantly achieve a higher saved rebroadcast than flooding+802.11 and fp-flooding+802.11. This is because nodes rebroadcast a packet with a dynamic probability value according to the additional transmission range, which significantly reduce the number of the rebroadcast.

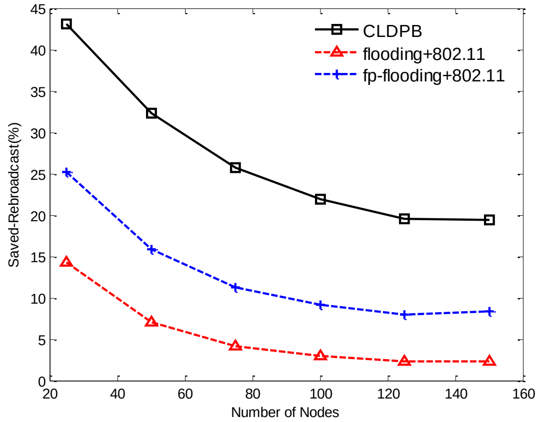

Figure3. Saved-Rebroadcast

Fig.4 displays that CLDPB has lower packet drop fraction than flooding+802.11 and fp-flooding+802.11. This is due to that CLDPB let the nodes receive little duplication packet, therefore, reduce the number of dropping packets.

Fig.5 shows that CLAPB incurs fewer collisions than flooding+802.11 and fp-flooding+802.11 when the network density varies. This is because CLAPB mitigates the contentions and collisions during broadcasting.

Fig.6 shows that CLDPB displays the lower end-to-end delay than flooding+802.11 and fp-flooding+802.11. This is because CLDPB has the highest saved rebroadcast, which decreases the contention for the shared channels and collision among the neighboring nodes and consequently generating the lowest end-to-end delay.

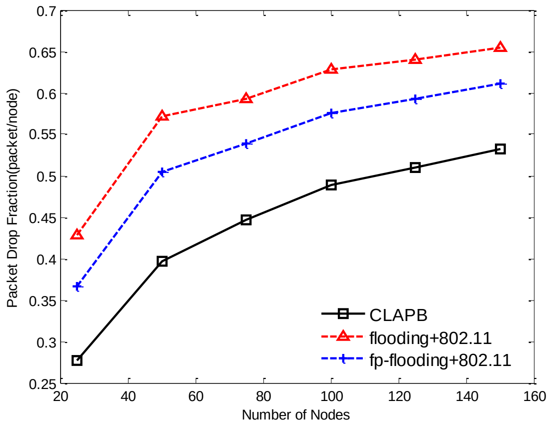

Figure4. Packet Drop Fraction

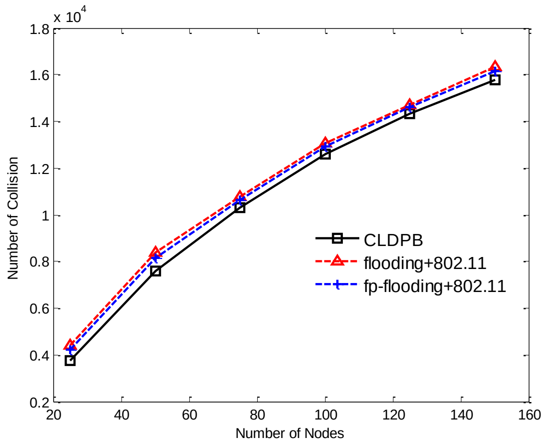

Figure.5 Average number of collisions

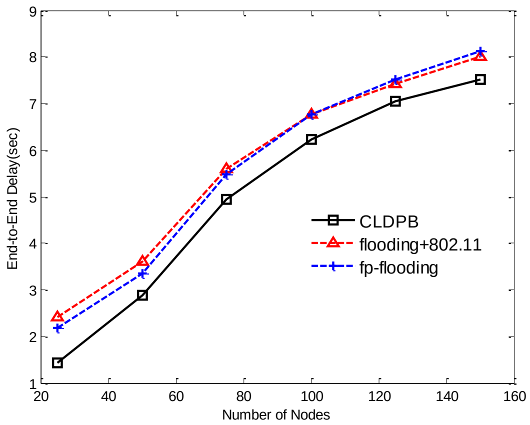

Figure.6 End-to-End Delay

5. CONCLUSION

In this paper, we proposed a cross-layer dynamic probabilistic broadcasting strategy for mobile ad hoc networks (CLDPB) that mitigate the broadcast storm problem associated with flooding. CLDPB adopts the cross-layer design and adjusts the value of the rebroadcast probability dynamically according to its additional transmission range benefited from rebroadcast. Our simulation results show that CLDPB performs better than the blind flooding and fixed probabilistic flooding applied at routing layer ,while the IEEE802.11 at the MAC layer.

As a continuation of this research in the future, we plan to adjust the rebroadcast probability using the neighbor information and the energy level of the intermediate node.

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