Performance Improvement in Ad hoc Wireless Networks with Consideration to Packet Duplication

Takayuki Yamamoto
Department of Informatics and Mathematical Science, Graduate School of Engineering Science, Osaka University, Japan
tak-ymmt@ics.es.osaka-u.ac.jp
Contents

- Introduction of target system
  - Flexible Radio Network
- Packet Duplication Problem
  - Process of the duplication
  - Methods to improve the performance
- Performance evaluation through simulations
- Conclusion and Future Work
Flexible Radio Network

- Wireless data collection system developed by Fuji Electric Co., Ltd.
- Multi-hop network organized by stationary terminals
- Application examples
  - Power consumption collection in manufacturing plants
  - Sales account of vending machines
  - Usage data collection from ski lift gates

http://www.fujielectric.co.jp/eng/index.html
System Description

Network configuration table

- Periodic route data exchange
- Each node maintains multiple routes to all nodes in the same network
- Route data = (Neighbor ID, Hop count to destination)

<table>
<thead>
<tr>
<th>routes</th>
<th>Destination Node ID</th>
<th>B</th>
<th>E</th>
<th>..</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(B,1)</td>
<td>(C,2)</td>
<td>..</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>(C,4)</td>
<td>(B,3)</td>
<td>..</td>
<td></td>
</tr>
<tr>
<td>..</td>
<td>..</td>
<td>..</td>
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<td></td>
</tr>
</tbody>
</table>

Network configuration table at node A
Protocol Description

Fixed time divided slot
- Slot based maximum lifetime of packets
- Relay echo acknowledgement

The forwarded packet by node B can be received by all neighbor nodes. This “relay echo” is used as an ACK at node A. After receiving the relay echo, node A deletes the packet in its buffer.
Protocol Description

Retransmission control

Node A retransmits the packet after pre-specified time when it cannot receive a relay echo from node B.
Packet Duplication Problem

Packet retransmission caused by relay echo receipt failure

Packet Duplication

Additive network load and performance degradation
Packet Duplication Process

Slot 0 1 2 3 4 5

Node A
Node B
Node C

send × echo miss forward
Missing only an echo
Node A considers that as its transmission failure
Retransmission makes a duplicated packet

Normal relay

Left in a buffer due to an echo miss

Need to prevent an echo loss
Policy of Suggestions

- Packet duplication is caused by an echo loss
  - Nodes cannot differentiate a transmission failure and the echo loss

- Focus on the echo loss due to packet collisions
  - Preventing packet collisions leads to decreasing the number of duplicated packets
  - Synergy effect for packet collisions and packet duplications improves the performance
Suggestions

1. Random delay time before packet retransmission
to reduce the probability of continuous echo loss caused by the retransmission feature

2. Drop a packet that lacks lifetime to reach its destination
to prevent network congestion and packet collisions
Detail of Suggestion 1

1. Random delay time before packet retransmission

Case 1: Fixed delay time (3 slots)

Packet collision repeats due to fixed delay time

Slot 0 1 2 3 4 5

Node X

Node A

Node B

send   collisio   resend

send   echo loss   resend

forward   echo

forward   echo
Detail of Suggestion 1

1. Random delay time before packet retransmission

Case 2: Random delay time

Probability of repeated echo loss can be reduced by random delay time
2. Drop a packet that lacks lifetime to reach its destination

Reject the packet whose lifetime is shorter than the minimum hop count to its destination which is maintained in the configuration table.
Simulation Environment

- The Network Simulator - ns-2
- Random node allocation with three packet generating nodes shown in the below figure
- Performance measures are
  - throughput
  - packet loss rate (PLR)
  - duplication rate
Simulation Environment

- Two kinds of the maximum lifetime, 8 and 128
  - See the relationship between the maximum lifetime and each suggestion

- Compared systems under these lifetimes are
  - the original system
  - the systems with each improvement
  - the system with both improvements
Throughput improvements

<table>
<thead>
<tr>
<th></th>
<th>lifetime 8</th>
<th>lifetime 128</th>
</tr>
</thead>
<tbody>
<tr>
<td>random</td>
<td>ineffective</td>
<td>much effective</td>
</tr>
<tr>
<td>drop</td>
<td>a little effective</td>
<td>ineffective</td>
</tr>
<tr>
<td>both</td>
<td>a little effective</td>
<td>much effective</td>
</tr>
</tbody>
</table>

Explanation of labels

original • • • original system
random • • • only suggestion 1
drop • • • only suggestion 2
both • • • both suggestions
Packet Loss Rate (PLR)

Explanation of labels:
- original: original system
- random: only suggestion 1
- drop: only suggestion 2
- both: both suggestions

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Duplication Rate

Maximum lifetime is 8

![Graph showing Duplication Rate with legend: original, random, drop, both suggestions for lifetime 8 and lifetime 128.]

Explanation of labels:
- original: original system
- random: only suggestion 1
- drop: only suggestion 2
- both: both suggestions

Maximum lifetime is 128

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Conclusion and Future Work

Our suggestions are capable to prevent an echo loss and a packet duplication.

The system with both improvements always shows the good performance regardless of the maximum lifetime value.

Future Works

- Effective method to decide the maximum lifetime based on a route length
- Another evaluation on a system with end-to-end upper layer protocol such as TCP