Flipped Diversity Aloha in Wireless Networks with Long and Varying Delay

Lei Zheng    Lin Cai

Department of Electrical & Computer Engineering
University of Victoria, British Columbia, Canada
{zhengl, cai}@ece.uvic.ca

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Outline

1 Motivation
   • The Propagation Delay Problem & Challenges
   • Existing Solutions
   • Main Contributions Of The Paper

2 The Flipped Diversity Aloha
   • Our Solution
   • Performance Analysis
   • Simulation Results

3 Summary
The Basic Problem That We Studied

• Medium Access Protocols In Wireless Networks.
  • With coordinator ⟹ such as PCF in IEEE 802.11, TDMA/CDMA based scheduling for Cellular Networks, etc.;
  • Random access (without coordinator) ⟹ such as Aloha, \( p \)-persistent CSMA, DCF in IEEE 802.11, etc.;
  • Most of these protocols are designed without considering the propagation delay.

• Propagation Delay In Wireless Networks.

<table>
<thead>
<tr>
<th>Propagation Distance</th>
<th>Terrestrial</th>
<th>Satellites</th>
<th>Underwater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propagation Speed</td>
<td>Fast</td>
<td>Fast</td>
<td>Slow</td>
</tr>
<tr>
<td>Propagation Delay</td>
<td>Short</td>
<td>Long</td>
<td>Varying</td>
</tr>
</tbody>
</table>

The Challenges Of The Problem

• Synchronization
  • Scheduling or coordination becomes difficult;
  • Slotted based random access would also fail.

• Communications Efficiency

\[
\text{Throughput}_{\text{estimal}} = \frac{\text{PacketTransmissionDelay}}{\text{RoundTripTime} + \text{PacketTransmissionDelay}}
\]

• Communications Effectiveness
  • CSMA based: Carrier Sensing may not be effective any more;
  • Slotted Aloha degrades to pure Aloha: About 50% throughput loss.
Existing Solutions

- Diversity Slotted Aloha (DSA) [1]
  - Slotted Aloha based;
  - Each Packet is transmitted multiple times.

- Collision Resolution Diversity Slotted Aloha (CRDSA) [2]
  - Extending DSA with Interference Cancellation (IC).

Remarks

- Relying on Time Synchronization;
- Vulnerable to Delay Uncertainty;
- Still Not Efficient.

Figure: Packet decoding in CRDSA.

Our Design Goals & Contributions

- Our Goals of Designing
  - A random access MAC protocol;
  - Be an asynchronous MAC protocol;
  - Be immune to long & varying propagation delay.

- Our Contributions
  - A new random access MAC protocol
    \[\Rightarrow\] The **Flipped Diversity Aloha (FDA)**;
  - Analysis of performance bound;
  - Comprehensive simulations.
Assumptions

- A scenario with one central destination node and multiple uniformly distributed source nodes;
- Single channel & Single half-duplex radio;
- Channel information is known at receiver;
- Protocol channel model.

Zigzag Decoding [3]
- Designed to solve the "Hidden Terminal Problem" in IEEE 802.11.

Zigzag decoding

Remarks

- Diversity Slotted Aloha (DSA) anti-long delay
- Zigzag decoding anti-varying delay
What does "Flipped" mean?

- Diversity Slotted Aloha with Zigzag decoding?  
- Packet identifying problem when collision happens;  
- Channel estimation error.

**Flipped Diversity Aloha (FDA)**  
To combine Diversity Aloha & Zigzag decoding in a Flipping way.

**Cases Study**

- Identified Six Resolvable Collision Cases.  
  - According to the overlapping of packet collision.

**An example, case (a): no collision or two-packet collision**

\[ P_1 = P_c^2 + 2P_c \left( e^{-\lambda T} - e^{-2\lambda T} \right), \text{ where } P_c = e^{-2\lambda T} \]
### Performance Bound

- **Upper Bound For Packet Loss Ratio, $PLR_U$**
  \[
  PLR_U = 1 - P_s
  \]

- **Lower Bound For Throughput, $S_L$**
  \[
  PLR_U = \lambda \cdot P_s
  \]

where:

\[
P_s = P_1 + P_2 + P_u \cdot \left(1 + P_r/P_c\right)^2,
\]

\[
P_r = P_c \cdot \sum_{k=1}^{\infty} \left(P_4/P_c + e^{-\lambda T} - e^{-2\lambda T}\right)^k,
\]

\[
P_u = \left[C_2^1 P_3 + C_3^1 P_5 + C_3^1 P_6\right].
\]

### Simulation Settings

- Uniformly distributed nodes;
- Uniformly distributed propagation delay;
- Poisson traffic with the aggregated load $\lambda$.

### Benefits Of "Flipping"

- **Case-I**: throughput contribution from flipping;
- **Case-II**: throughput contribution from Zigzag decoding.

**Figure: Analysis throughput.**
Results-2

**Figure:** Simulation throughput.

**Figure:** Simulation PLR with finite nodes.

Results-3

**Definition of Admission Region:**

The maximum admissible number of source nodes with given $\lambda$.

- Given PLR threshold as 0.1, $\lambda = 0.3$;
- FDA: more than 10 source nodes;
- Pure Aloha or DSA: only one source node.
In this paper, we proposed a **Flipped Diversity Aloha (FDA)**, which is
- combining Diversity Aloha & Zigzag decoding in a flipped way;
- suitable for asynchronous wireless networks;
- immune to impact of duration & variation of propagation delay.

**Outlook**
- The performance of FDA with signal capture effect;
- An opportunistic channel estimation based on FDA;
- Application of FDA for channel access with limited delay.

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**For Further Reading**


Thanks!

Question/Comment?