Network Coding-Based Broadcast in Mobile Ad hoc Networks

INFOCOM 2007
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2008/1/24
Outline

- Introduction
- Related work
- CODEB
- Performance evaluation
- Conclusion
Introduction

- The overhead of using flooding to support broadcast is very high.

- Due to the broadcast nature of wireless media, not all nodes need to transmit in order for the message to reach every node.
Introduction

- Network coding has been shown to significantly improve transmission efficiency in wired networks, and has been adapted to wireless networks.

- In this paper, we show how network coding can provide significant gains when applied to a deterministic broadcasting approach.
Related work

- Two main approaches for efficient broadcast:
  - **Probabilistic** (gossiping-based)
    Broadcast to neighbor with a given probability.
    Disadvantage:
    Difficult to tune the proper probability.
  - **Deterministic**
    Predetermine and select the neighboring nodes that forward the broadcast packet.
Opportunistic listening:
- Node knows it’s 2-hop neighbor and store the overheard packets for a limited period $T$.

Forwarder selection and pruning:
- Use PDP to select forwarder, a node only rebroadcasts a packet when it is chosen.

Opportunistic coding:
- Each node examines its to-be-forwarded packets and its current neighbor table to determine if it can send coded packet(s).
Neighbor reception table

<table>
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<th></th>
<th>p₁</th>
<th>p₂</th>
<th>p₃</th>
<th>p₄</th>
<th>p₅</th>
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</tbody>
</table>
Partial Dominant Pruning (PDP)

- Each node knows its 2-hop neighbor. (By broadcast its 1-hop neighbor to neighbors.)

- A node only rebroadcast when it chosen as forwarder.

- Node chose forwarders from its 1-hop neighbor based on the number of 2-hop neighbor it can cover.
Partial Dominant Pruning (PDP)

\(N(u)\): set of 1-hop neighbors of node \(u\)
\(N(N(v))\): 2-hop neighborhood of node \(v\).

\[P(u, v) = N(N(u) \cap N(v))\]
\[B(u, v) = N(v) - N(u)\]
\[U(u, v) = N(N(v)) - N(u) - N(v) - P\]

- Greedy choose nodes in \(B(u, v)\) to full cover \(U(u, v)\).
Partial Dominant Pruning (PDP)

\[ P(u, v) = N(N(u) \cap N(v)) \]

- \( B = N(v) - N(u) \)
- \( U = N(N(v)) - N(u) - N(v) - P \)
Packet encoding algorithm

- XOR-based:

- Reed-Solomon code based:
Use XOR-based algorithm:

\[ P = P_1 \text{ xor } P_2 \]

recover \( P_1 \)

recover \( P_2 \)

recover \( P_2 \)
Reed-Solomon codes

- Block-based error correcting codes with a wide range of applications in digital communications and storage.

- N data blocks with M checksum blocks.

- Can reconstructed from any of M blocks fail in the (N+M) blocks.
Use Reed-Solomon codes

5 \rightarrow 2 = 3

Compute \( c_1 \sim c_3 \)

recover \( P_1 \sim P_5 \)

have 2 packets

recover \( P_1 \sim P_5 \)

have 2 packets

recover \( P_1 \sim P_5 \)

have 3 packets
Packet decoding

- Each node maintains a **Packet Pool**, in which it keeps a copy of each native packet it has received or sent out.
- The table is garbage collected every few seconds.
- When a coded packet is received, the node decodes and then processes the packet.
CODEB flow chart

1. Receive a new Pkt P
2. Update neighbor receive table
3. If forwarder
   - yes: If all neighbor receive
     - yes: If native P
       - yes: If can Encode
         - yes: SendCodePkts
         - no: Queue(P)
       - no: Decode(P)
     - no: Process(P)
   - no: Exit

4. no: Exit
Performance evaluation

- **Coding gain:**
  - The ratio of the number of transmission required by PDP, to the number of transmissions used by CODEB.

- **Packet delivery ratio**
Performance evaluation

Dense topology

Sparse topology:
Performance evaluation

(a) Coding gain for low load

(b) Packet delivery ratio for low load
Performance evaluation

(a) CODE:RScode over CODE+GOSSIP

(b) Packet delivery ratio
This paper shows how to incorporate network coding into a non-coding based localized algorithm called PDP for improving broadcast efficiency.

The CODEB coding algorithm can potentially be applied to other non-coding based schemes.
Discussion

- How about joint forwarding and coding?
- Whether there exists efficient schemes where nodes implicitly volunteer to be forwarders based on the local RF condition.