

# Decoding Buffer Management in Practical Wireless Network Coding

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# Outline

- Opportunistic coding system, decoding buffer, decoding buffer management (DBM)
- Decoding buffer filtering
- Packet information distributing
- Performance

# Opportunistic coding system

By employing network coding, a relay node can mix multiple packets together and broadcast them in a single transmission, leading to a more efficient usage of network bandwidth. Opportunistic coding systems (e.g. COPE) can prominently improve the throughput of wireless network by employing only simple coding (e.g. XOR).

## Opportunistic coding system

- **Opportunistic coding**

A node codes as more as possible packets together, while ensuring the coded packet can be decoded by each intended nexthop.

- **Opportunistic listening**

A node overhears all packets over the wireless medium and stores the overheard packets for potential opportunistic coding and decoding in the future.

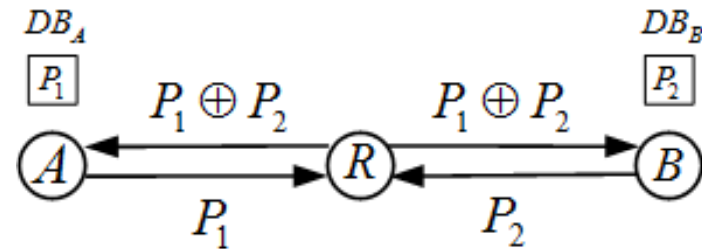
- **Packet information announcing**

A node makes its neighbors known what packets it stores in its decoding buffer.

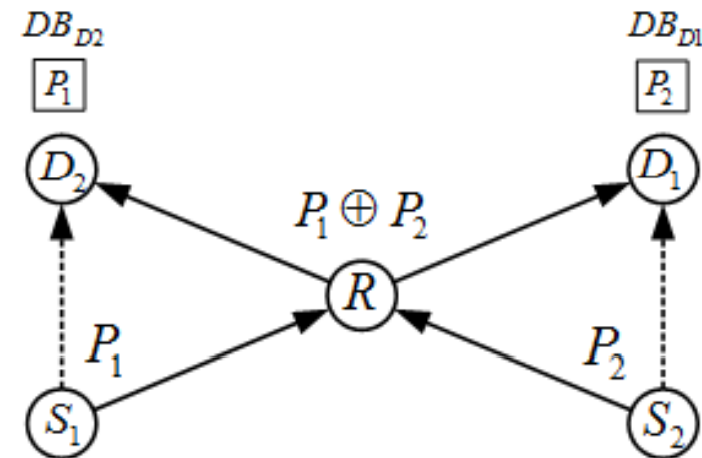
# Decoding buffer

There are two types of packets stored in the decoding buffer:

1. **transmitted packet** (originated from unicast forwarding)
2. **overheard packet** (originated from opportunistic listening)



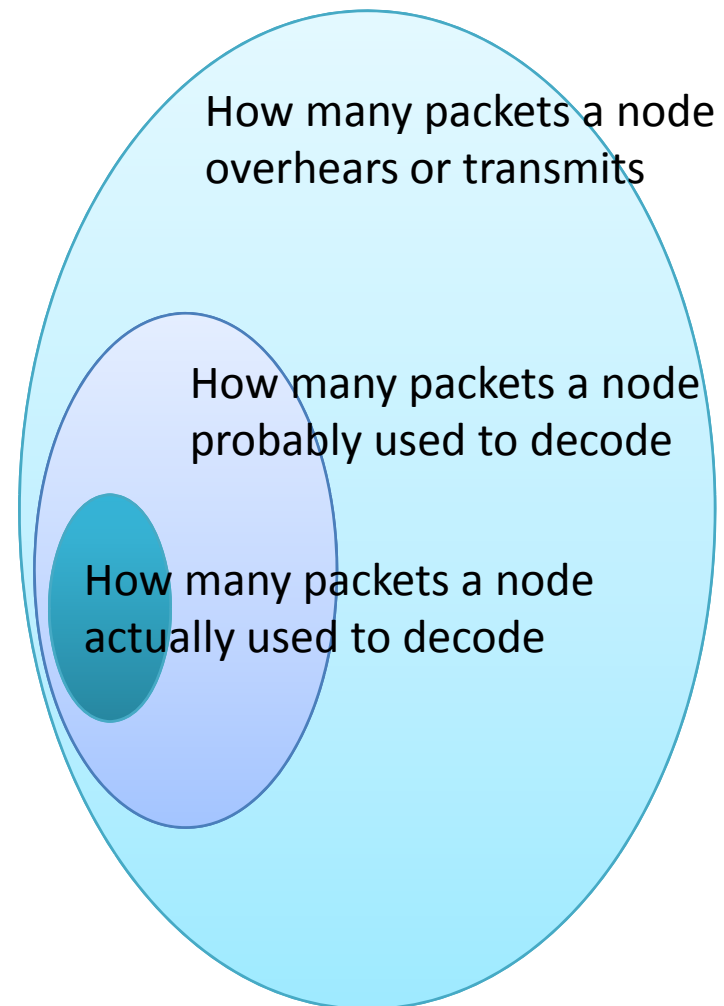
(a) Coding scenario without opportunistic listening.



(b) Coding scenario with opportunistic listening.

# Decoding buffer

- To maximize coding opportunities, a node tends to store both kinds of packets in its decoding buffer as much as possible.
- The decoding buffer is limited in practical wireless networks and often tends to overflow, especially in a densely deployed wireless network.
- While the decoding buffer is limited, some cached packets have to be moved out, or be dropped before entering decoding buffers. That means coding opportunities for these packets are lost.
- The decoding buffer could be a bottleneck in practical wireless network coding.



# Decoding buffer management (DBM)

quite a number of packets cached in decoding buffer are actually invaluable to opportunistic coding. Hence, filtering these invaluable packets in decoding buffer will not reduce any coding opportunities.

## Decoding Buffer Management (DBM)

- **Decoding buffer filtering**

A node filters the (overheard or transmitted) packets which are invaluable for future decoding, instead of storing them in the decoding buffer.

- **Packet information distributing**

A node can further reduce the overhead brought by packet information announcing, by distributing different packet information to different neighbors.

### Question:

what is the invaluable (overheard or transmitted) packet?  
How to filter those (overheard or transmitted) packets?

# Outline

- Opportunistic coding system, decoding buffer, decoding buffer management (DBM)
- **Decoding buffer filtering**
  - ① **What is the invaluable decoding packet**
  - ② **How to filter the invaluable decoding packet**
- Packet information distributing
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# What is the invaluable decoding packet

Definition: for a specific node, the *invaluable decoding packet* is a (overheard or transmitted) packet which is impossible to take part in decoding at this node in the future.

For a specific node, the validity of a (overheard or transmitted) packet is up to:

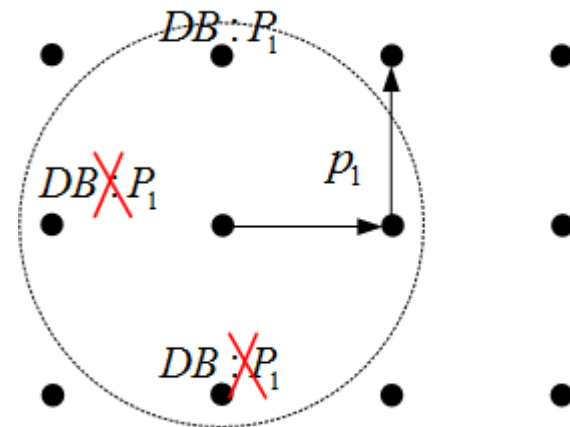
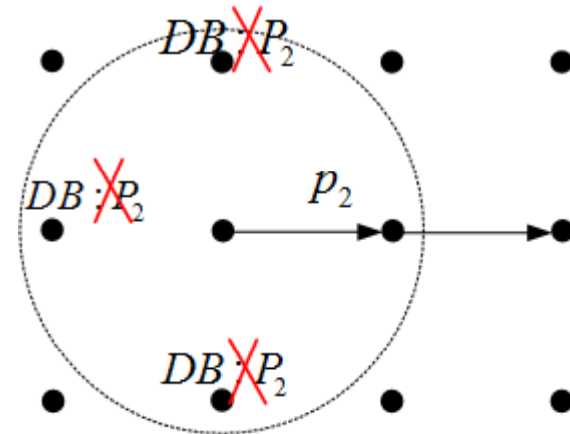
1. **forwarding route** (of this packet)
2. **traffic flow** (to this node)

# Invaluable overheard packet

## Forwarding route:

When overhearing a packet, the node needs to find out the 1<sup>st</sup>-nexthop and the 2<sup>nd</sup>-nexthop of this packet (base on Theorem below). If at least one of the two successive next-hops is in its neighborhood, each neighboring nexthop can be deemed as a **potential coding node** for this overheard packet.

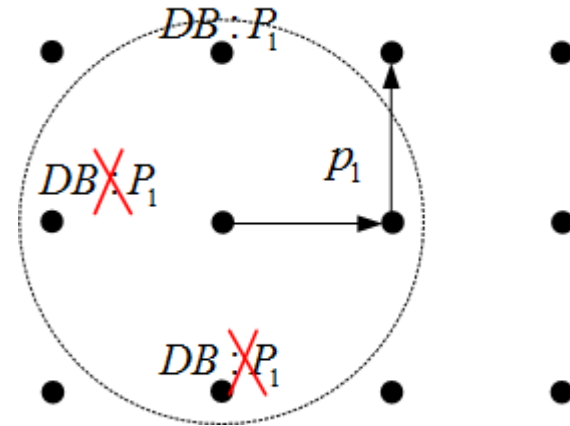
**Theorem** For an unicast packet  $p_i$  transmitted by node  $i$ , based on shortest path routing rule, the nodes one-hop away from  $i$  (i.e. neighbors of  $i$ ) are never neighboring with the nodes over two-hop away on the routing path of  $p_i$ .



# Invaluable overheard packet

## Traffic flow:

For a overheard packet at a node, if there is no traffic flow from its potential coding node to this node for the moment, the overheard packet is invaluable.



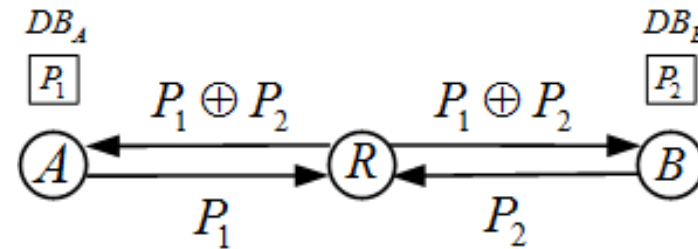
the ***invaluable overheard packet*** could be:

An overheard packet at a node, while the 1<sup>st</sup>-nexthop and the 2<sup>nd</sup>-nexthop of this packet are both not neighboring with the node, or there is no traffic flow from the neighboring nexthop to this node for the moment (i.e., the period when this packet stays in the forwarding queue of the neighboring nexthop).

# Invaluable transmitted packet

## Traffic flow:

For a transmitted packet, the only potential coding node is the nexthop. Therefore, if there is no reverse traffic flow from the nexthop to it for the moment, the transmitted packet is invaluable.



(a) Coding scenario without opportunistic listening.

the *invaluable transmitted packet* could be:

A transmitted packet at a node, while there is no traffic flow from the nexthop to the node for the moment (i.e., the period when this packet stays in the forwarding queue of the nexthop).

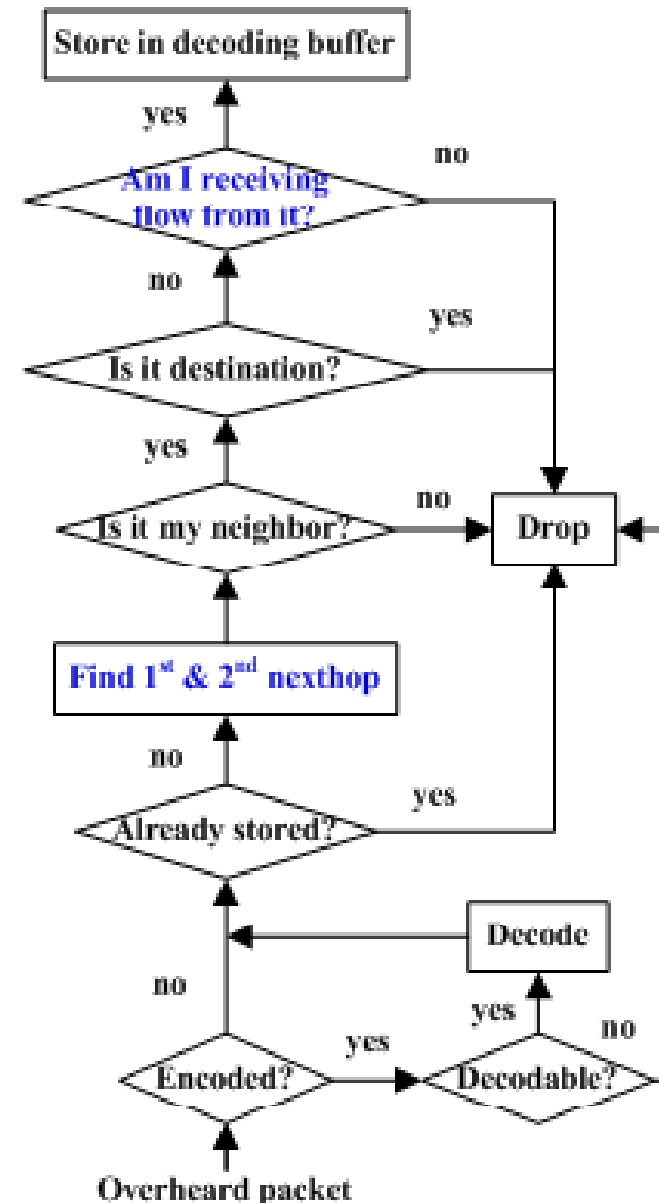
# filter the invaluable overheard packet

**Forwarding route:** how does a node know the forwarding route (1<sup>st</sup>-nexthop & 2<sup>nd</sup>-nexthop) of the overheard packet?

- the MAC header of the overheard packet
- route sharing between neighbors

**Traffic flow:** how does a node know whether or not there is a traffic flow from a specific neighbor to it?

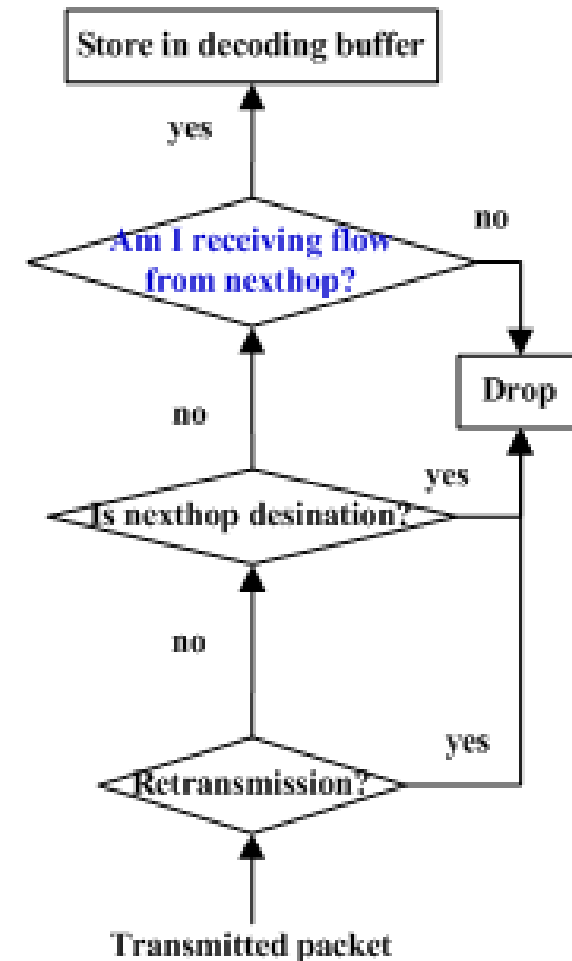
- Flow indication



# filter the invaluable transmitted packet

**Traffic flow:** how does a node know whether or not there is a traffic flow from a specific neighbor to it?

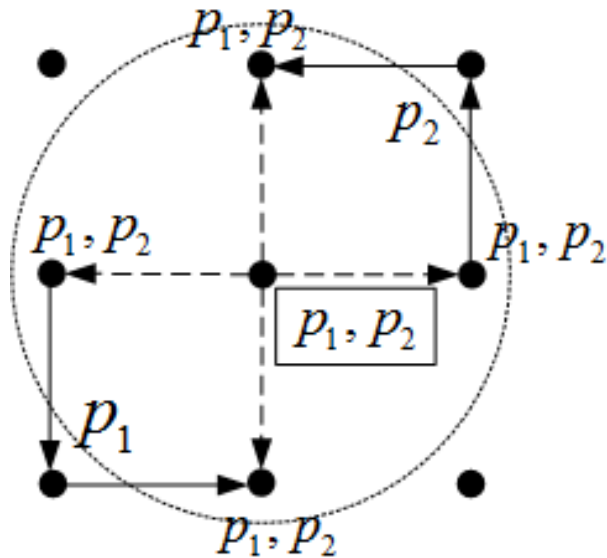
- Flow indication



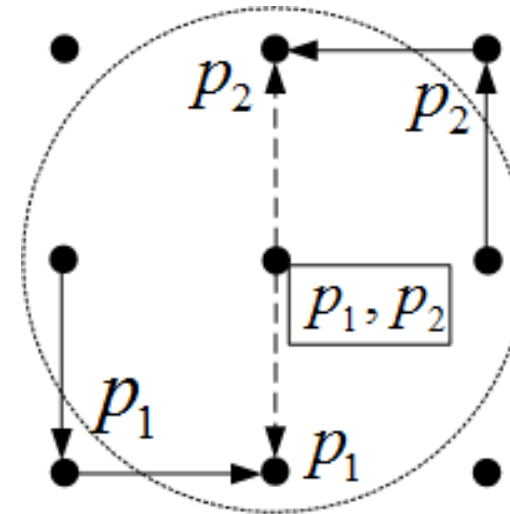
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- Decoding buffer filtering
- **Packet information distributing**
- Performance

# Packet information distributing



(a) Packet information announcing.



(b) Packet information distributing.

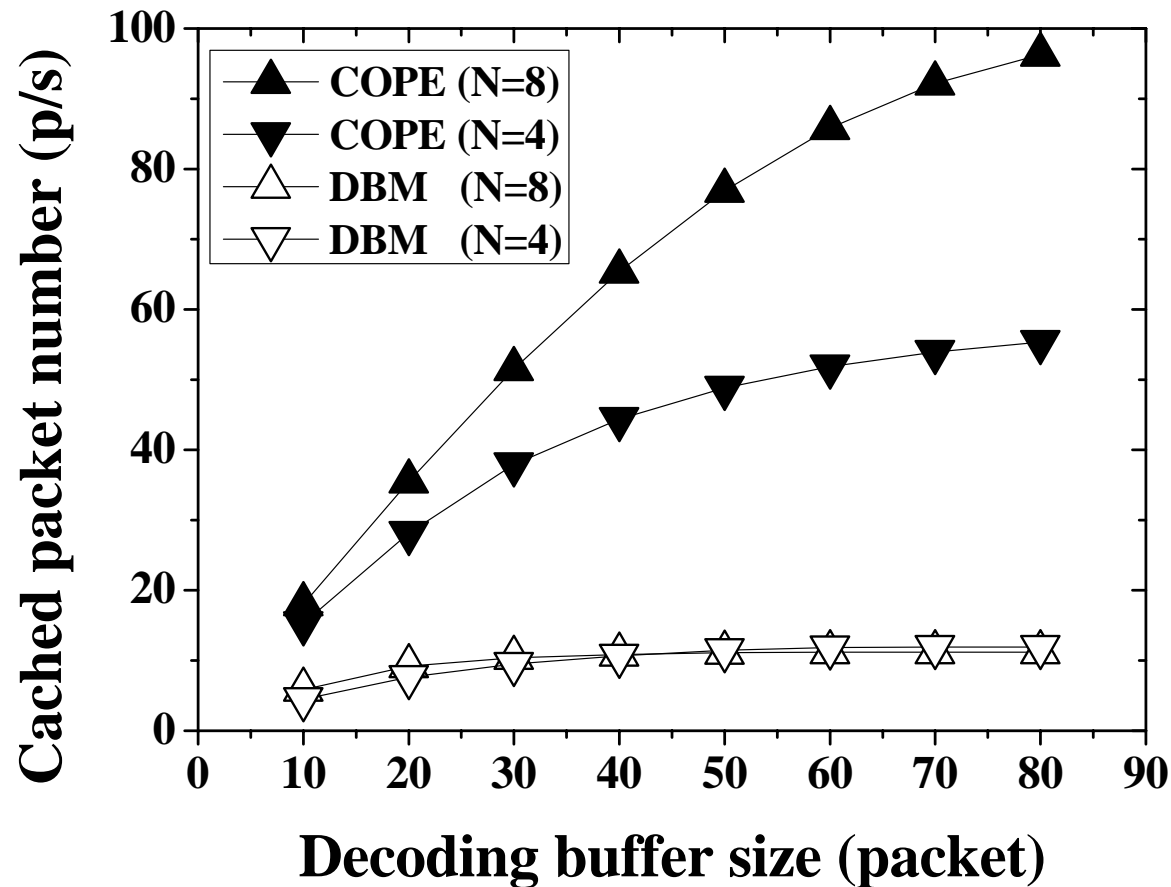
## Packet information distributing

- only overheard packet is involved
- a node distributes different packet information of overheard packets to their respective potential coding nodes
- a node only collects the packet information distributed to it

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# Performance

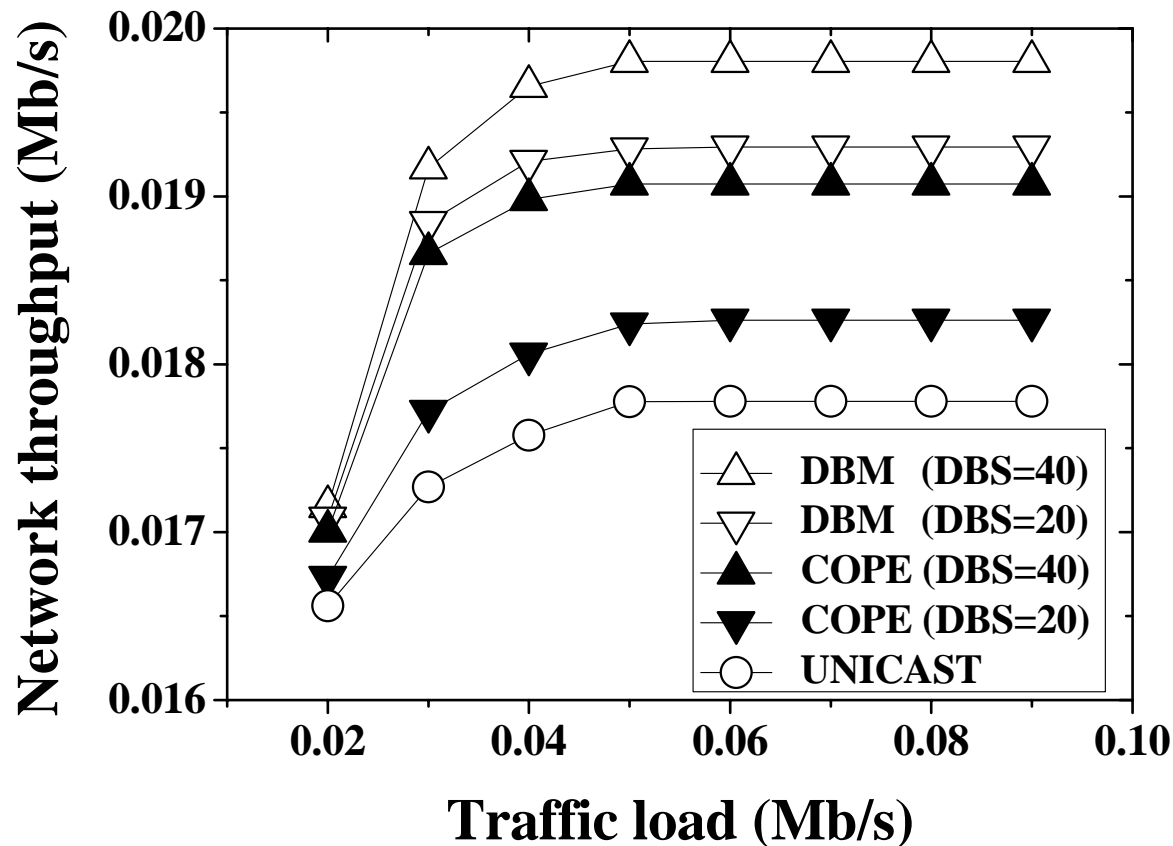


- Comparing with COPE, the cached packet numbers in DBM are reduced by probably 88% and 78% in 8-neighbor and 4-neighbor scenarios respectively.

# Performance

- DBM has more coding opportunities than COPE while decoding buffer is limited
- DBM lose very few (or even no) coding opportunities while decoding buffer is sufficient

# Performance



- The simulation results show that DBM always outperform COPE under the same constrained decoding buffer size regardless the traffic loads. Even when the decoding buffer size is 20 for DBM and 40 for COPE, DBM still outperforms COPE.
- The amount of packet information announcing is generally reduced by over 95% in DBM as compared to COPE in the simulations.

# Thanks !

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