

# **Diversity Routing in Mesh Networks**

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Wireless Networks L11  
**Dr. Ahmed Mahdi Jubair**

# Course Contents

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- 1. Wireless From the Transport Layer Downwards**
  - Transport over wireless, link layer, medium access, routing
- 2. Overcoming Bit Errors**
  - Error Detection/correction, convolutional & “Rateless” codes
- 3. An Introduction to the Wireless Channel**
  - Noise, Multipath Propagation, radio spectrum
- 4. Practical/Advanced Wireless Physical Layer concepts**
  - OFDM, channel estimation, MIMO etc.
- 5. Boutique topics**
  - Visible light communication, low power, Wi-Fi localization

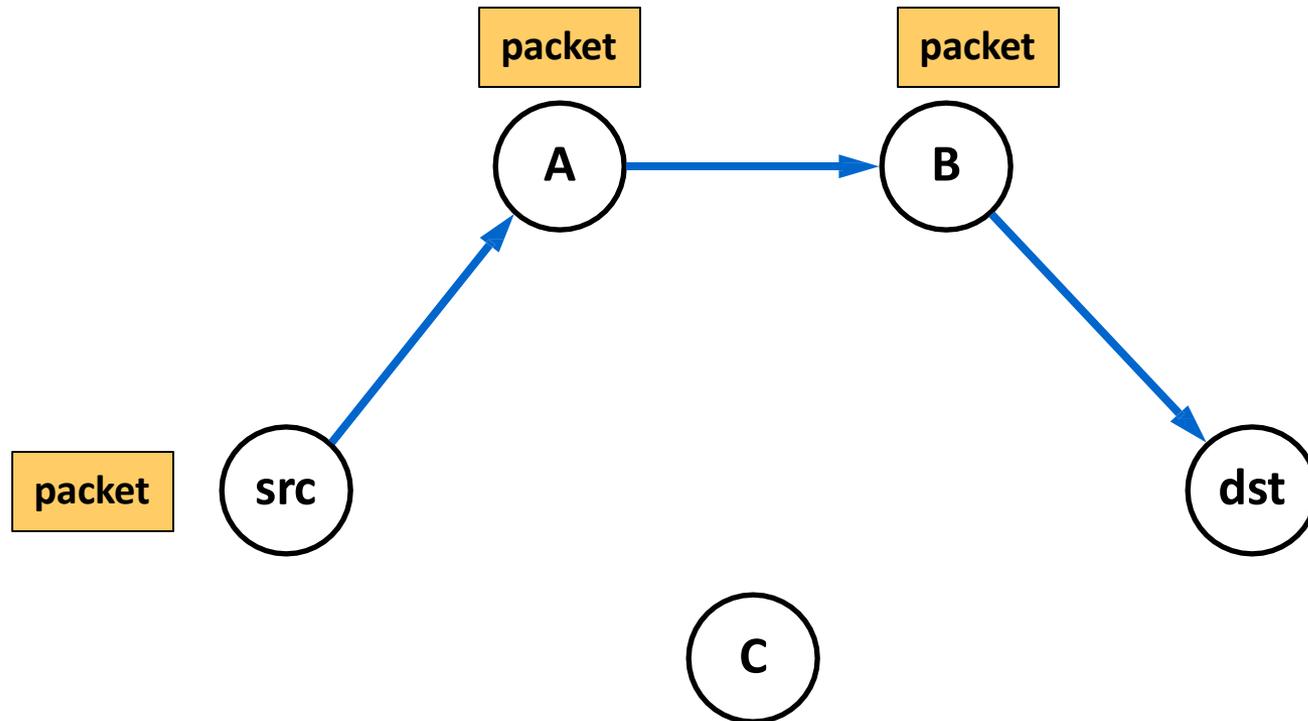
# Today

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1. **Diversity Mesh Routing**
  - **ExOR (Roofnet)**
  - Network Coding

# Initial approach: Traditional routing

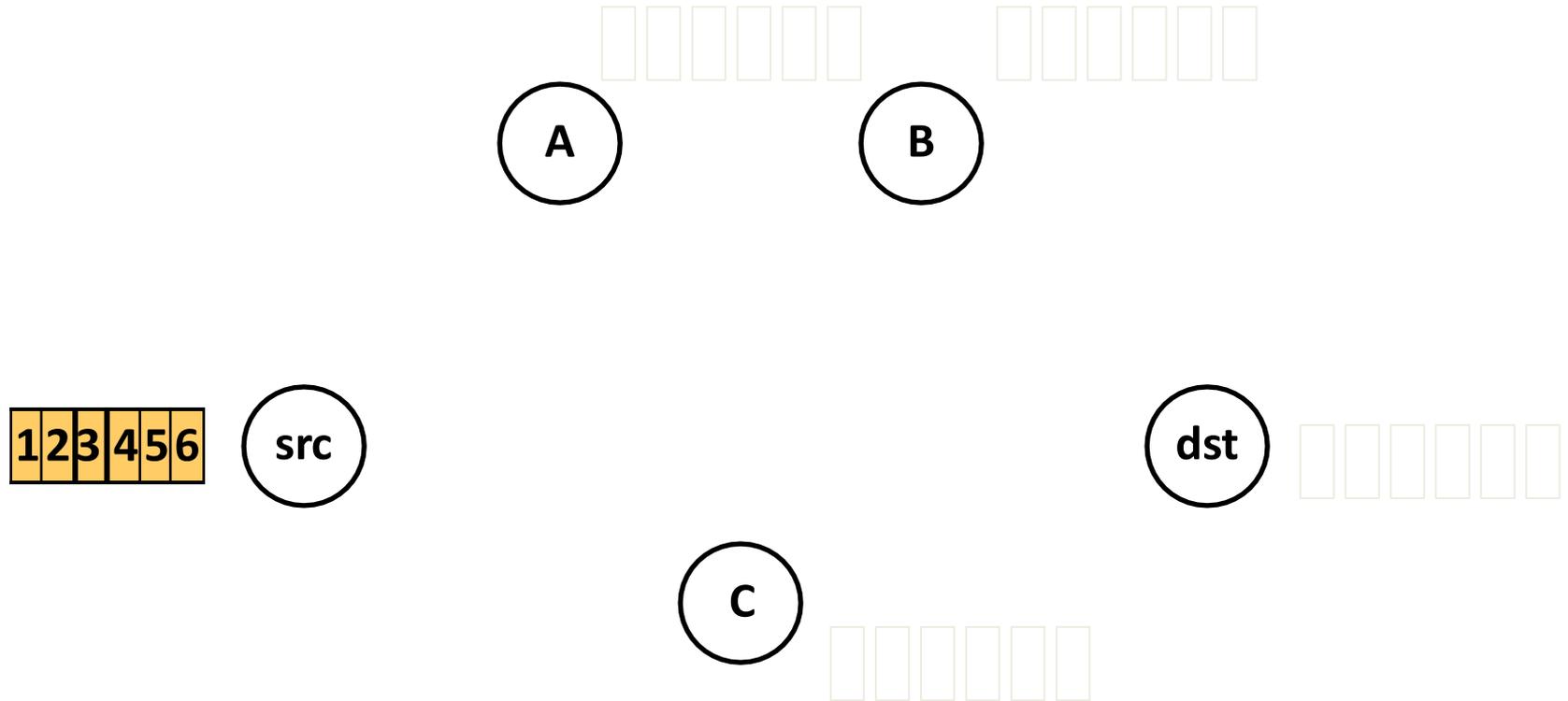
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- Identifies a **route**, forward over those links
- Abstracts radio to look like a wired link

# But radios aren't wires

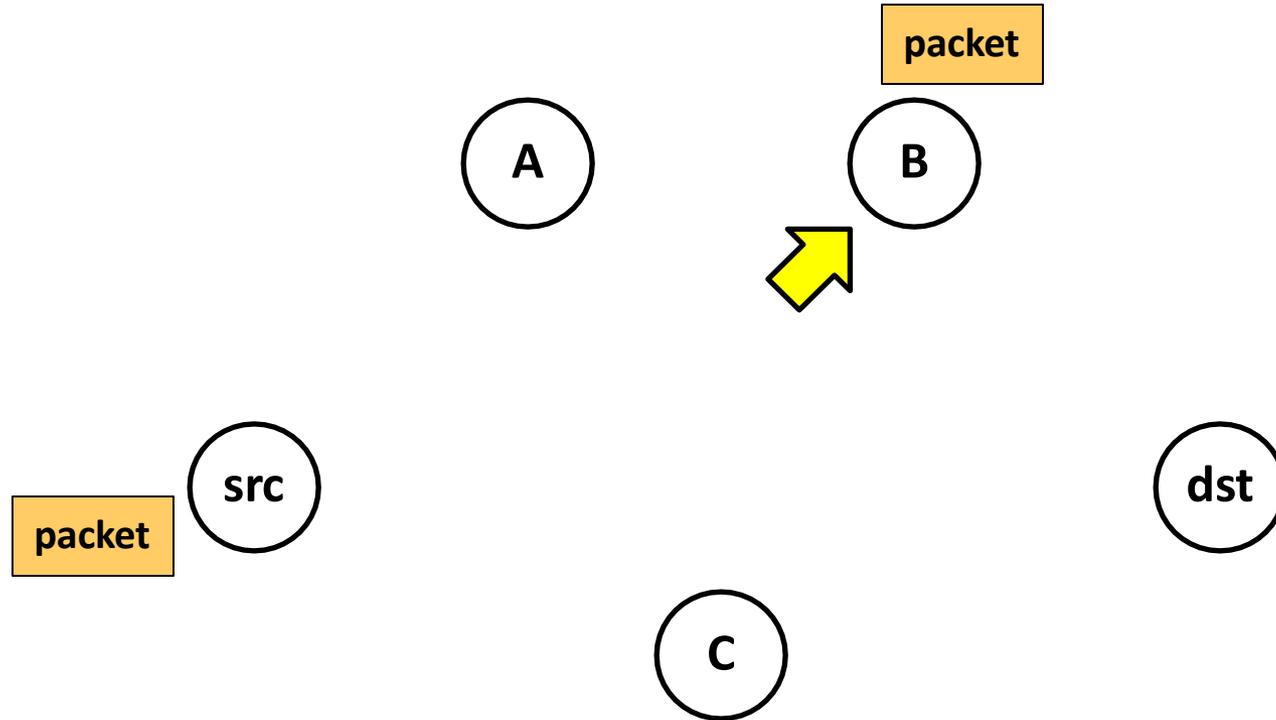
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- Every packet is **broadcast**
- Reception is **probabilistic**

# ExOR: exploiting probabilistic broadcast

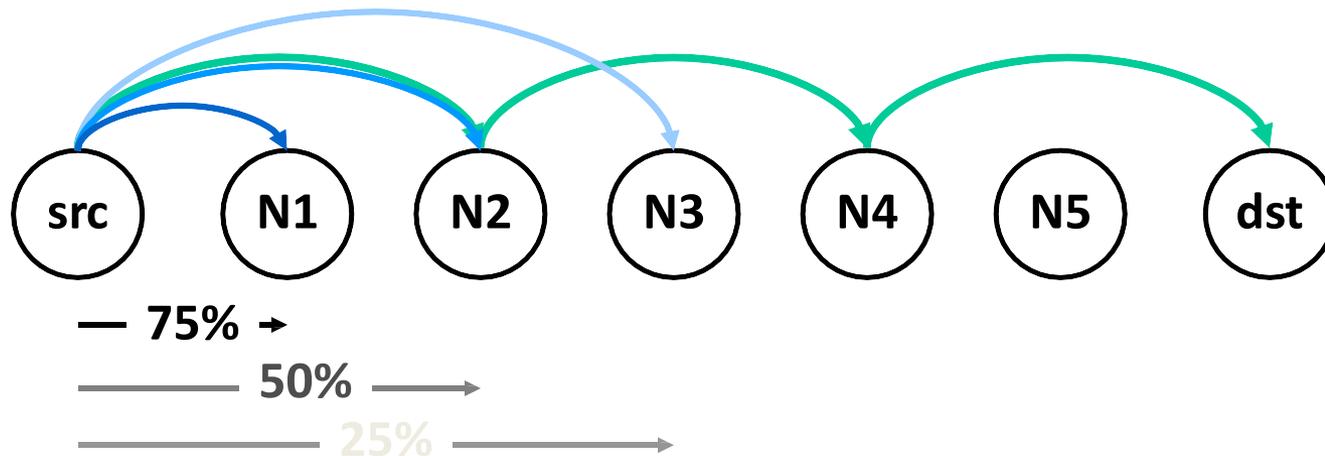
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- Decide who forwards **after** reception
- Goal: only **closest** receiver should forward
- **Challenge:** agree efficiently, avoiding duplicate xmits

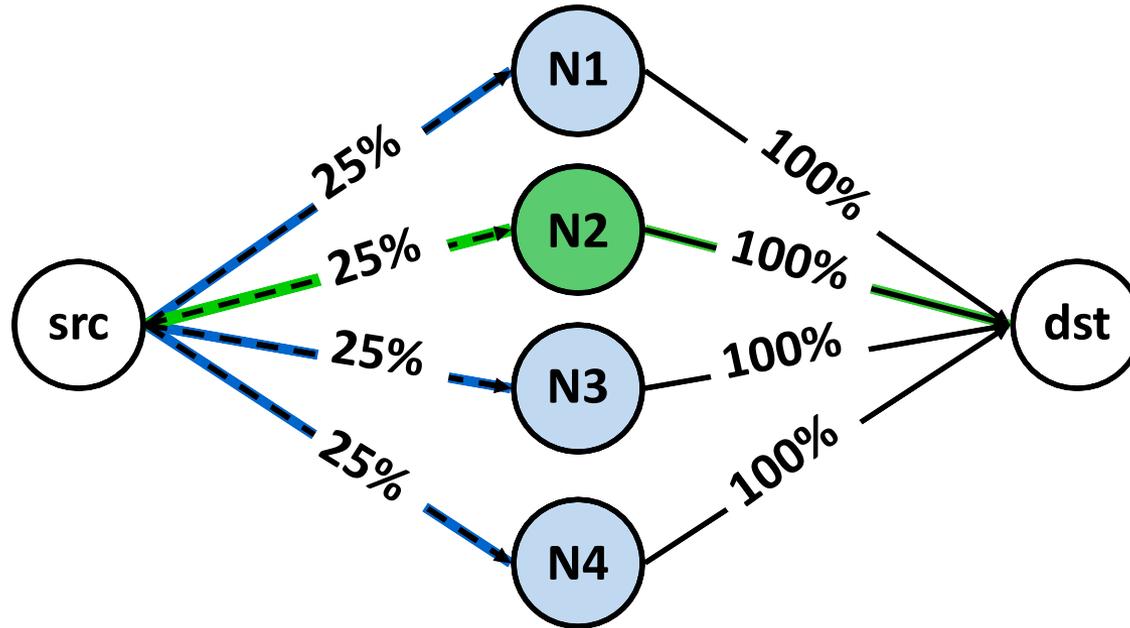
# Why ExOR might increase throughput? (1)

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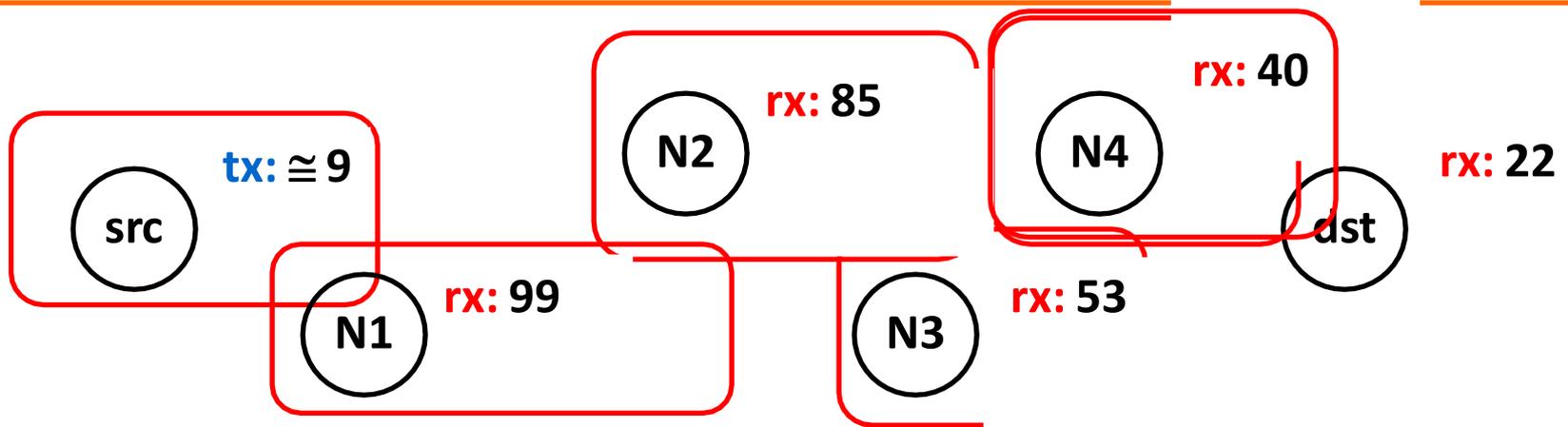
- Throughput  $\cong 1/\# \text{ transmissions}$
- Best traditional route is over the 50% hops:  $3(1/0.5) = 6 \text{ tx}$
- ExOR **exploits** lucky long receptions
- ExOR **recovers** unlucky short receptions

# Why ExOR might increase throughput(2)



- Traditional routing:  $1/0.25 + 1 = 5$  tx
- ExOR:  $1/(1 - (1 - 0.25)^4) + 1 \approx 2.5$  transmissions
- **Diversity of links, paths** in mesh networks

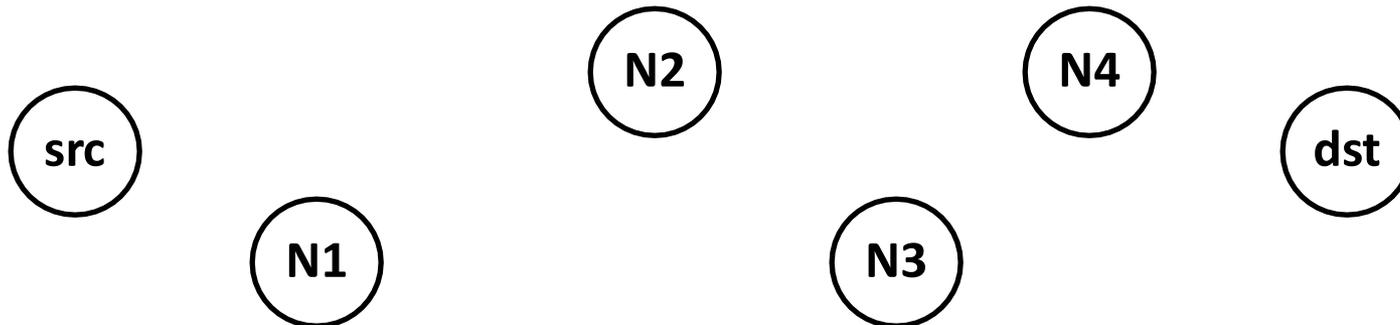
# ExOR packet batching



- Finding the closest receiver involves coordination **overhead**
  - Want to **avoid** paying this overhead once per packet
- **Idea:** Send **batches of packets** to amortize overhead
- Node closest to the destination sends first
  - Other nodes **listen**, send **just the remaining** packets in turn
- Repeat schedule until destination has whole batch

# The *forwarder list* establishes transmit order

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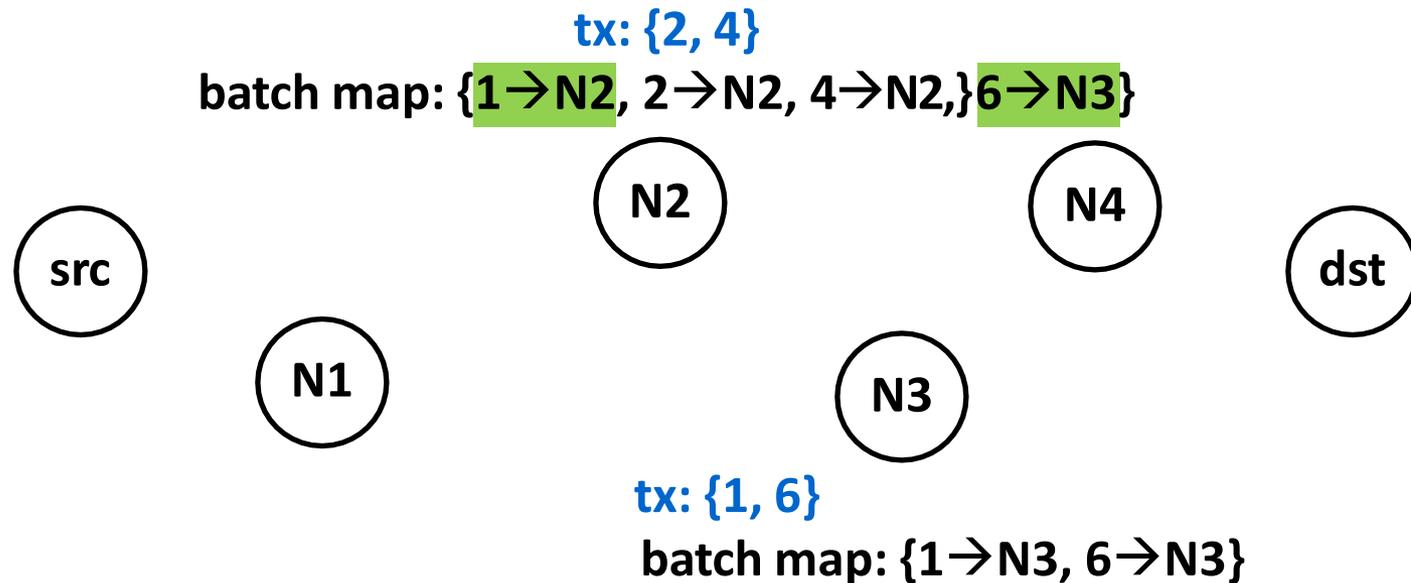


priority:  low medium high

- One node sends at a time, highest priority first
- Source includes a *forwarder list* in ExOR header
  - The forwarder list is sorted by *path ETX* metric to dst
    - Link ETX: Expected number of transmissions required
    - Nodes periodically flood link ETX measurements
    - Path ETX is weighted shortest path (Dijkstra's algorithm)

# Batch maps track who received what

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- Nodes include a **batch map** in every data packet header
  - For each packet, batch map gives **highest priority node** known to have **received** a copy of that packet
  - Nodes **suppress** packets **higher priority node** received
  - Allows source to **receive acknowledgement**

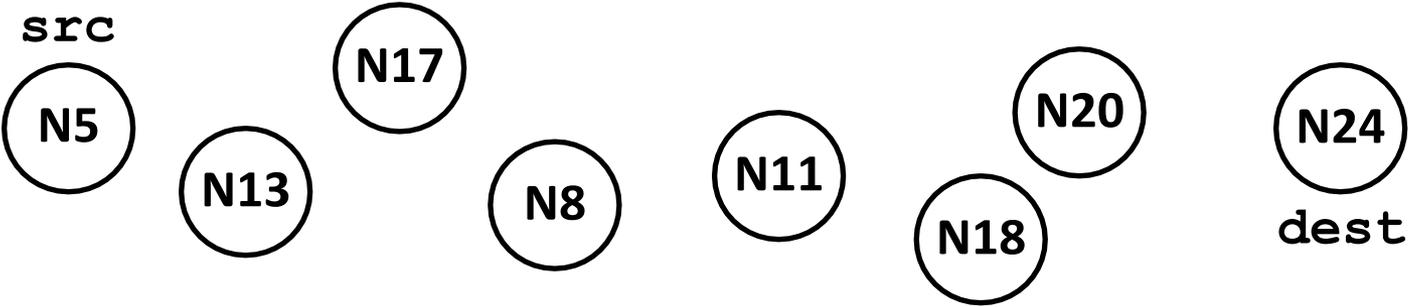
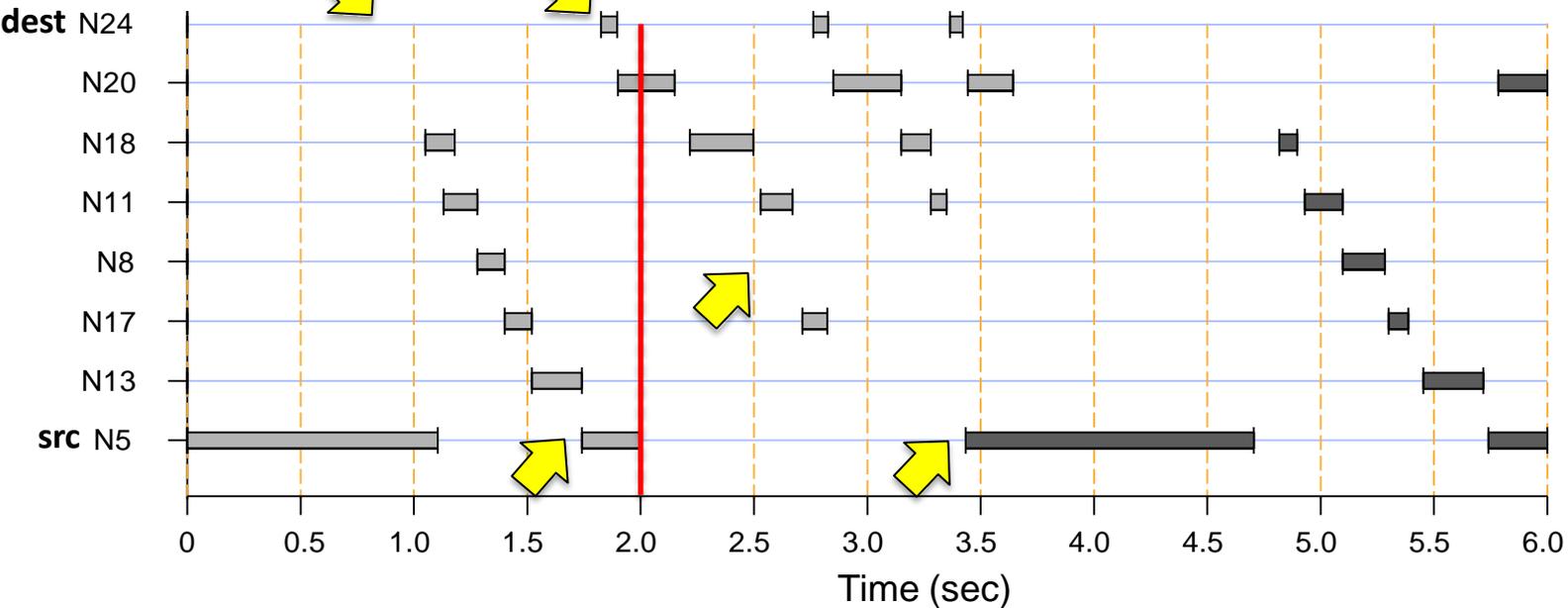
# Completion

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- If node's batch map indicates higher priority node has received  $>90\%$  of the batch, it remains quiet
- **Removes excessive overhead** due to “straggler” packets that get unlucky due to wireless conditions
- ExOR routing itself only guarantees  $> 90\%$  delivery
- Destination requests remaining  $< 10\%$  packets via **traditional routing**

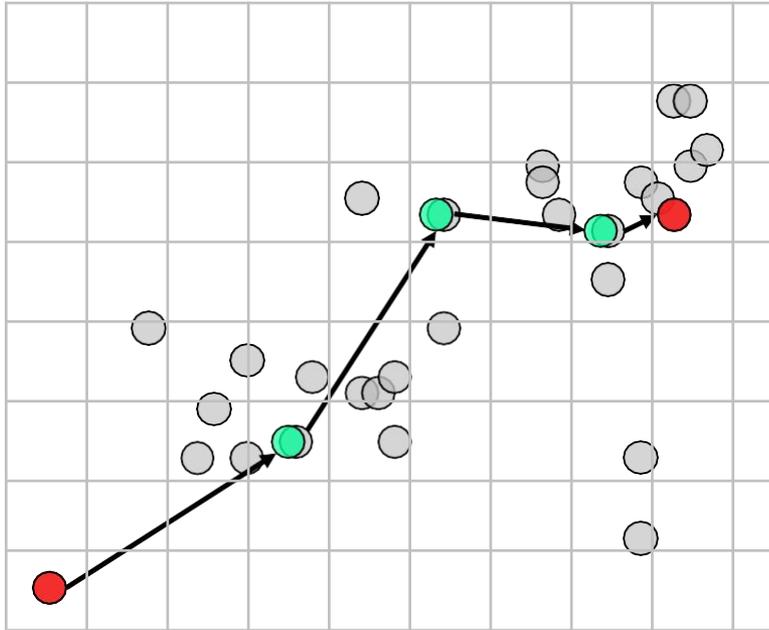
# Transmission timeline

priority:

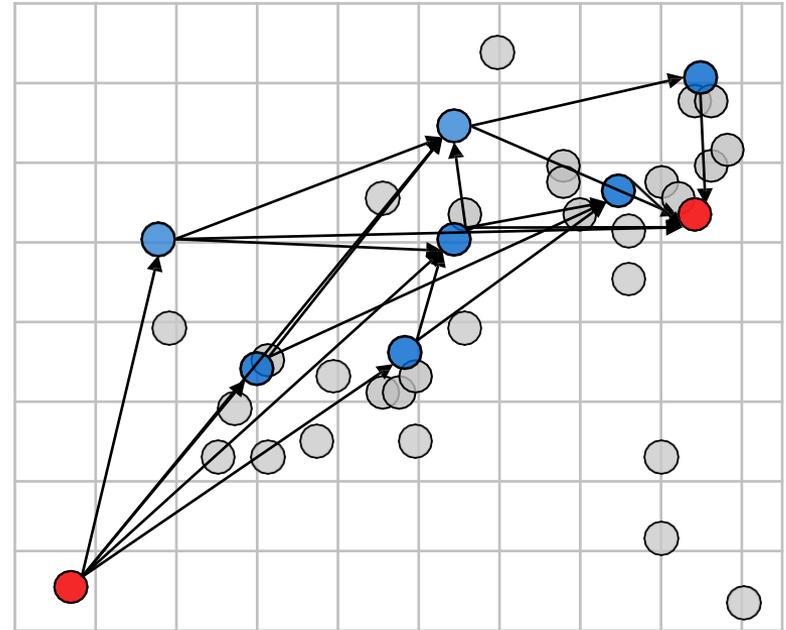


# ExOR uses more links in parallel

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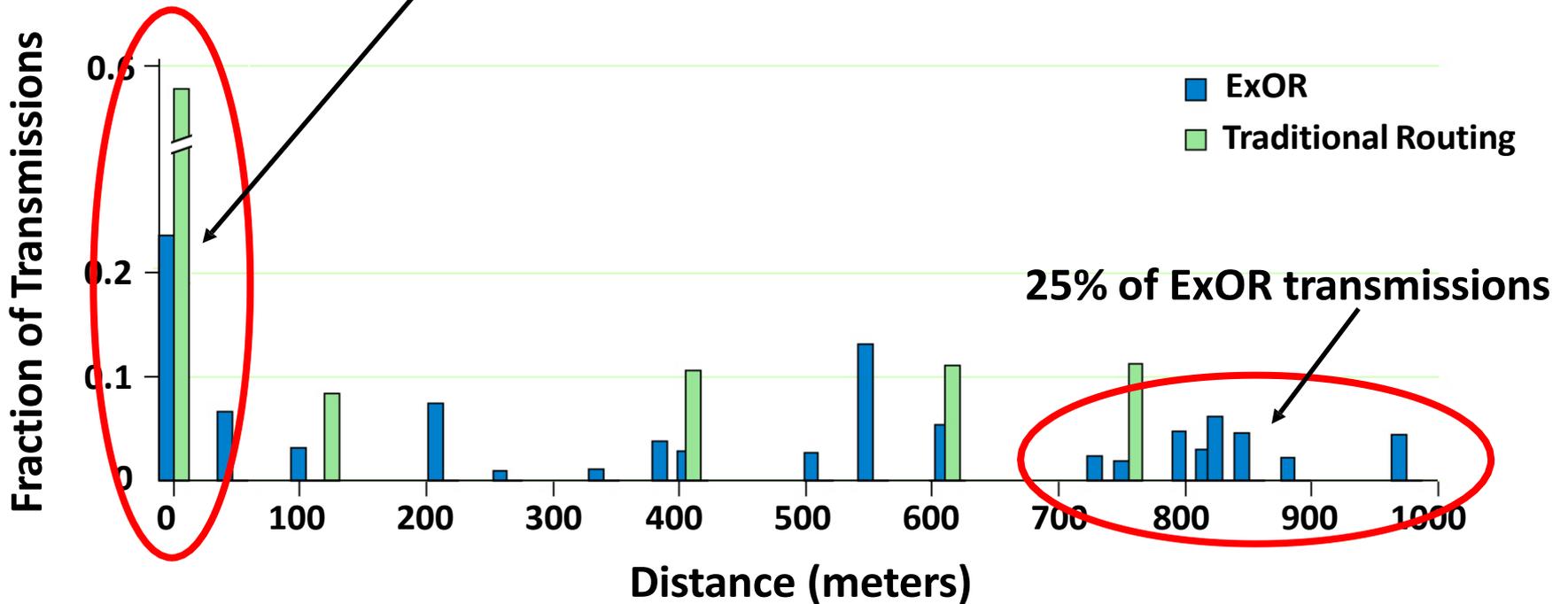
**Traditional:** 3 forwarders, 4 links



**ExOR:** 7 forwarders, 18 links

# ExOR moves packets farther

58% of Traditional routing transmissions



**ExOR average: 422 meters/tx Traditional: 205 meters/tx**

# Today

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1. Geographic (Location-Based) Mesh Routing
2. Diversity Mesh Routing
  - ExOR (Roofnet)
  - **Network Coding**

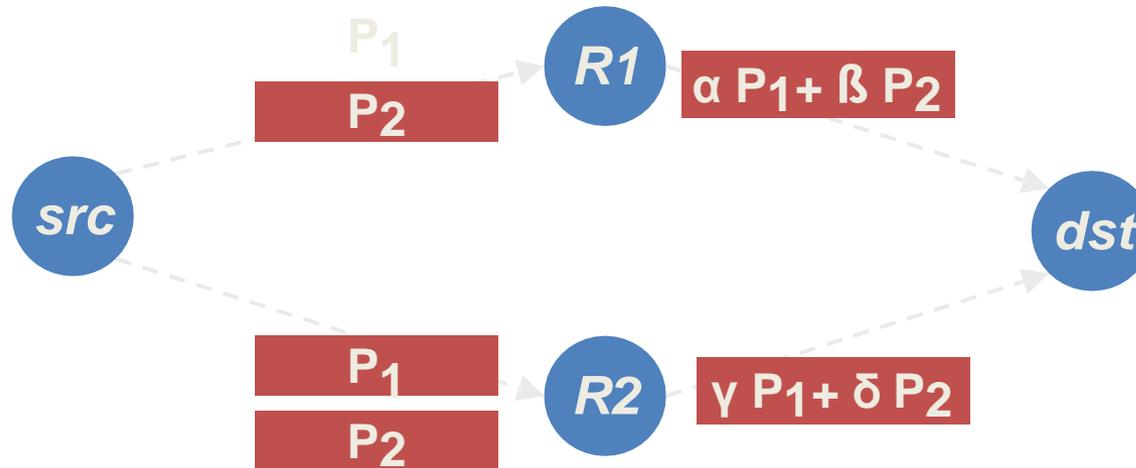
# Network Coding

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- **ExOR** uses a global scheduler
  - **Requires coordination:** Every node knows who received what
  - **Only one node transmits at a time,** others listen
- **Network Coding Idea:** Nodes do not relay received packets verbatim
  - Instead **combine several packets together** to send in one single transmission

# Random Linear Codes

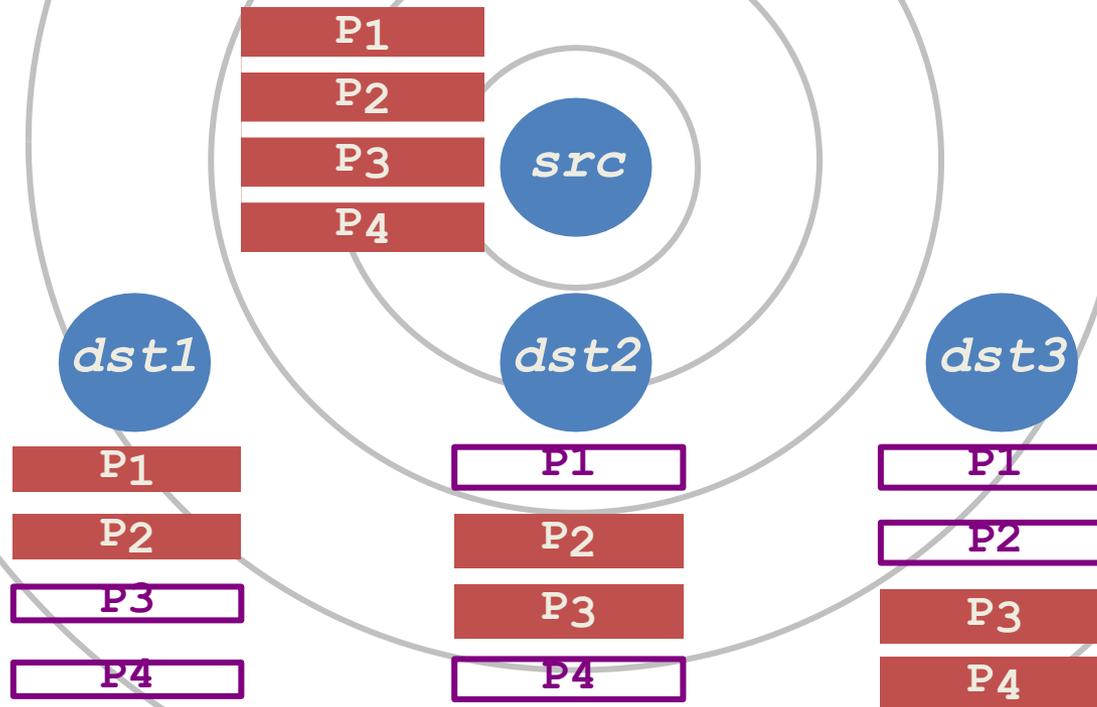
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- Each router forwards **random linear combinations** of packets
  - Randomness **makes duplicates unlikely**
  - **No scheduler; No coordination**
    - **Simple, better exploits spatial reuse**

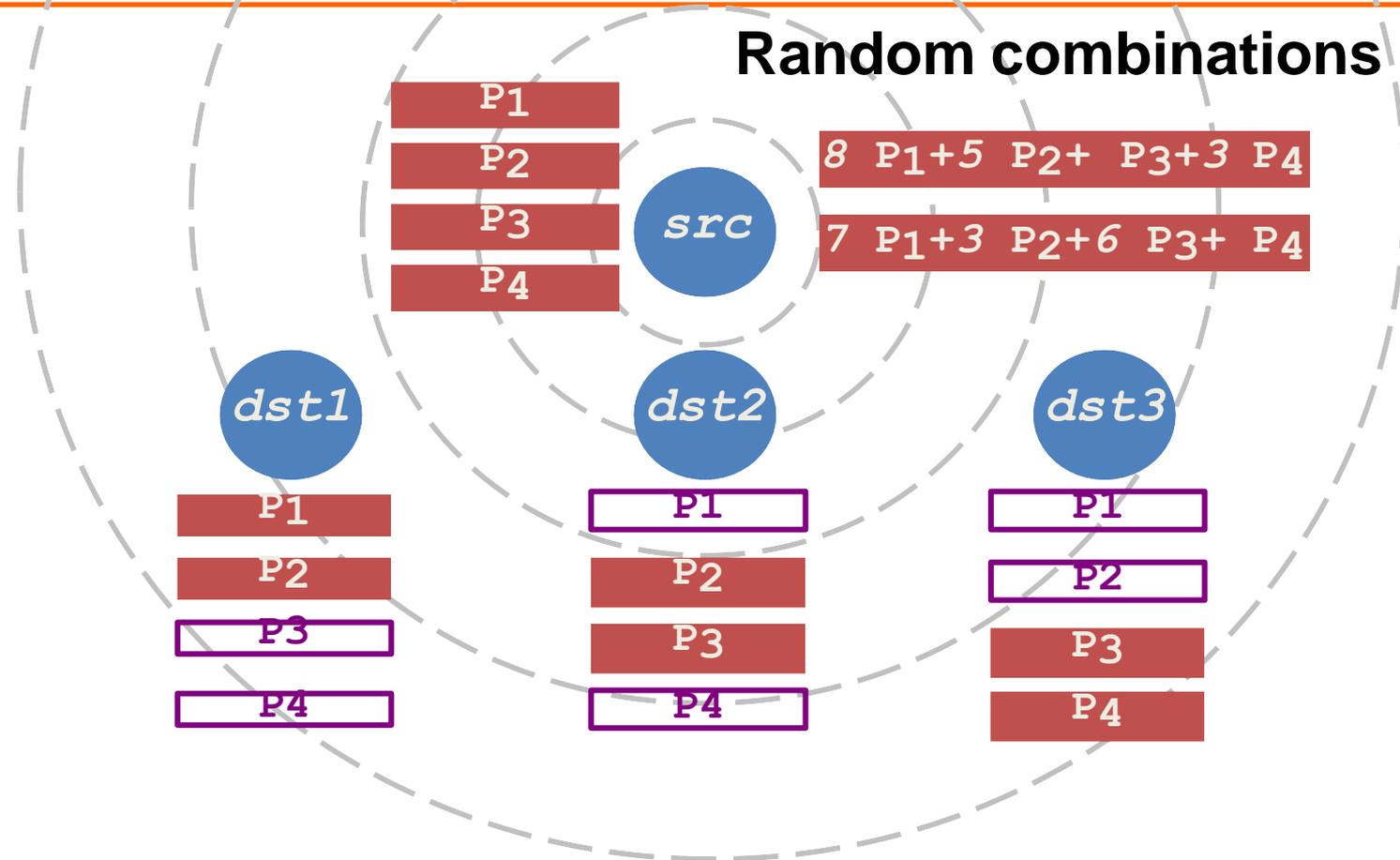
# Network Coding: Multicast example

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Without coding → source retransmits all 4 packets

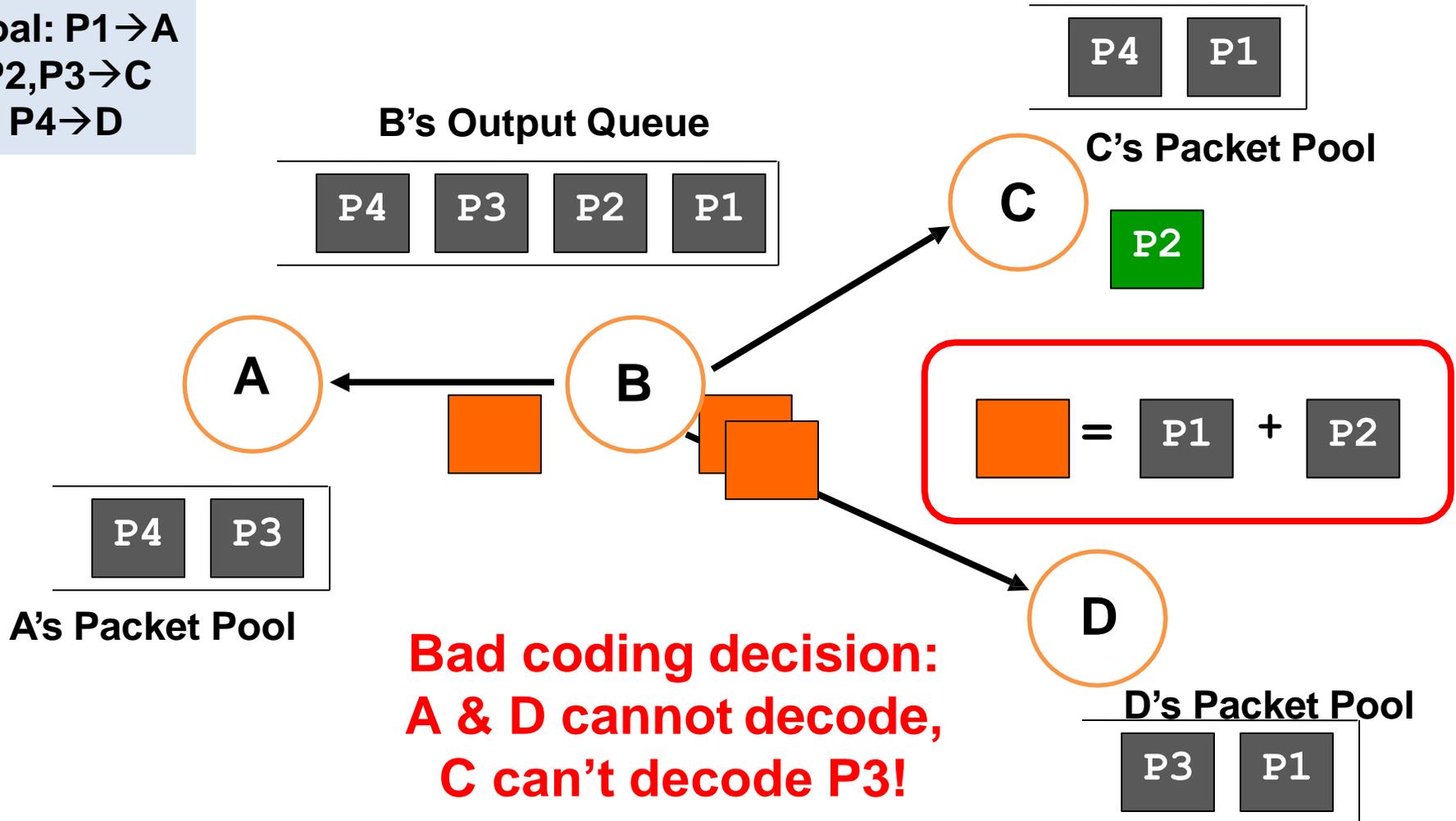
# Network Coding: Multicast Example



With random coding  $\rightarrow$  2 packets are sufficient

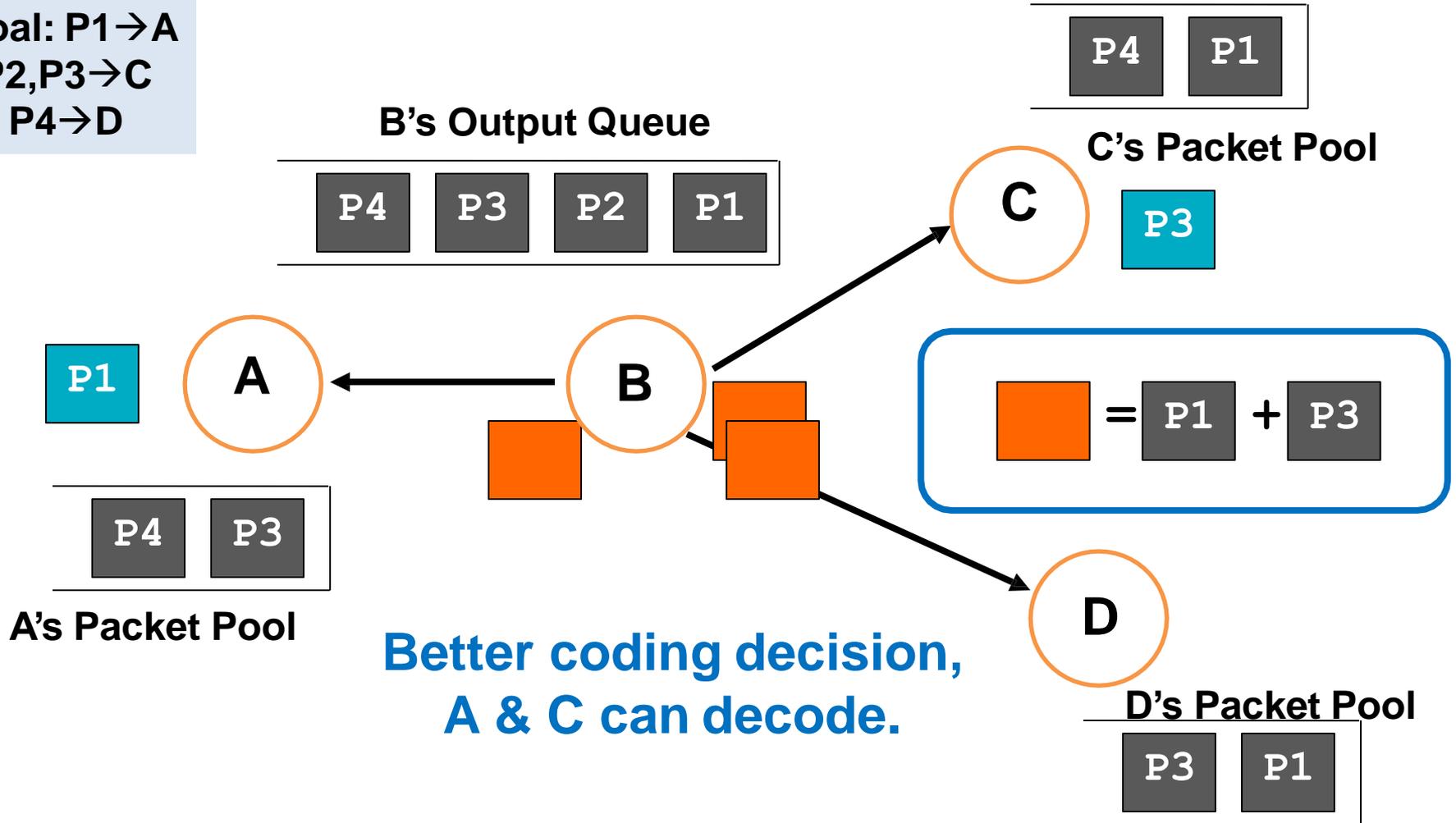
# Choice of Coding Matters

Goal: P1→A  
P2,P3→C  
P4→D



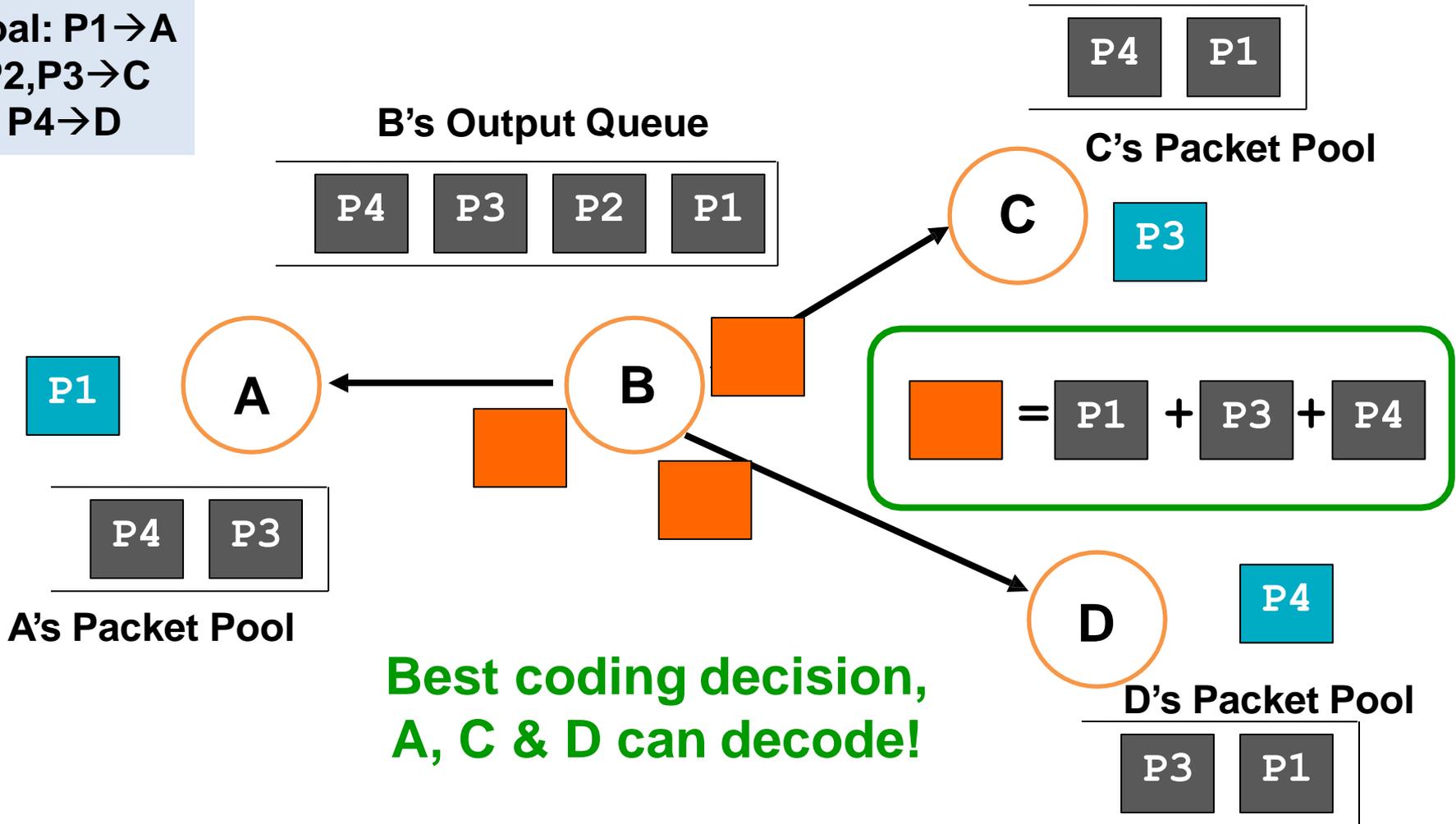
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Goal: P1→A  
P2,P3→C  
P4→D



# Network coding: Caveats

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- Practical **throughput gains** over ExOR / traditional routing:
  - With **static nodes**
  - **Traffic quantities** need to be **large enough**
    - **Delay increases (batching)**
  - **Opposing flows** need to exist in some traffic topologies