UPMC
SORBONNE UNIVERSITÉS

NETWORK CODING

Thi Mai Trang NGUYEN

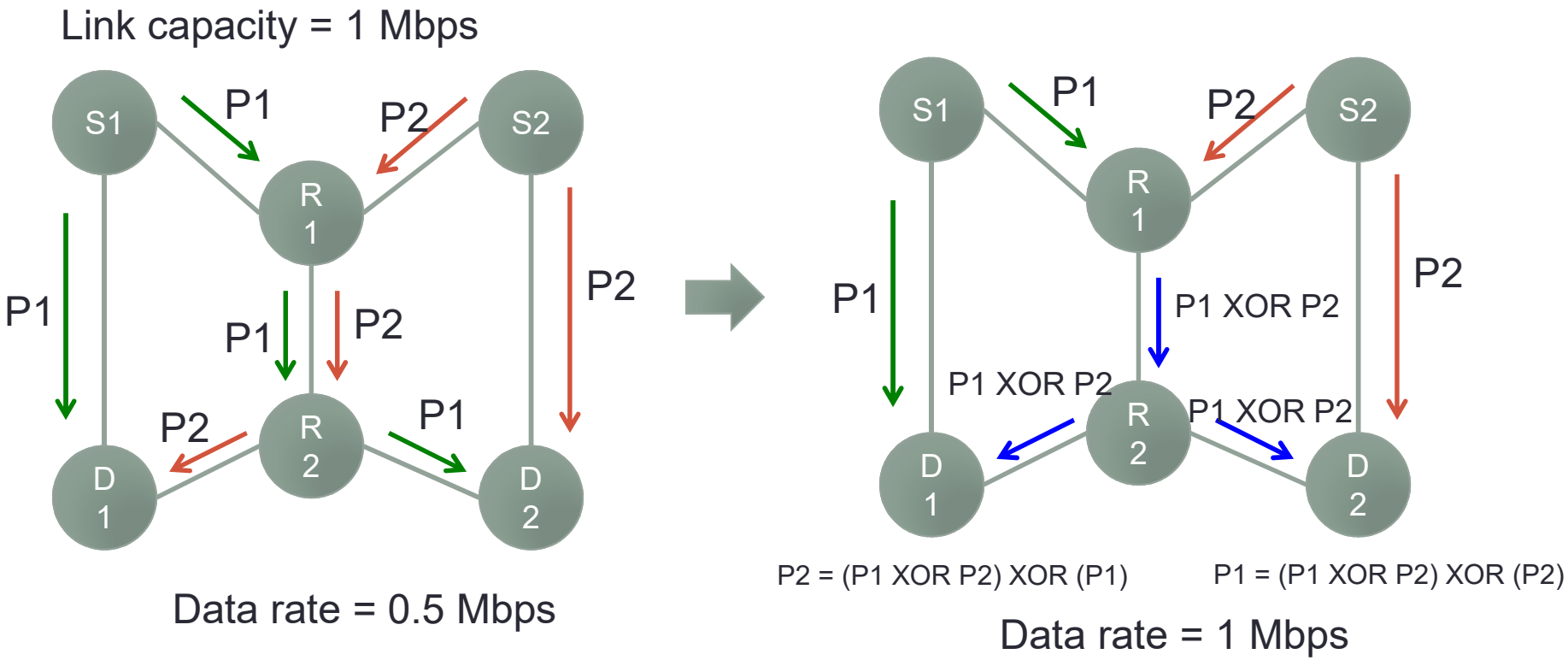
Associate Professor
LIP6 – UPMC
Thi-Mai-Trang.Nguyen@lip6.fr

Outline

- Concept and application
- Inter-flow network coding
- Intra-flow network coding
- Conclusion

Network coding

- **Network coding** is a technique which allows network nodes to **combine** multiple native packets into one coded packet for transmission instead of simply forwarding packets **one by one**

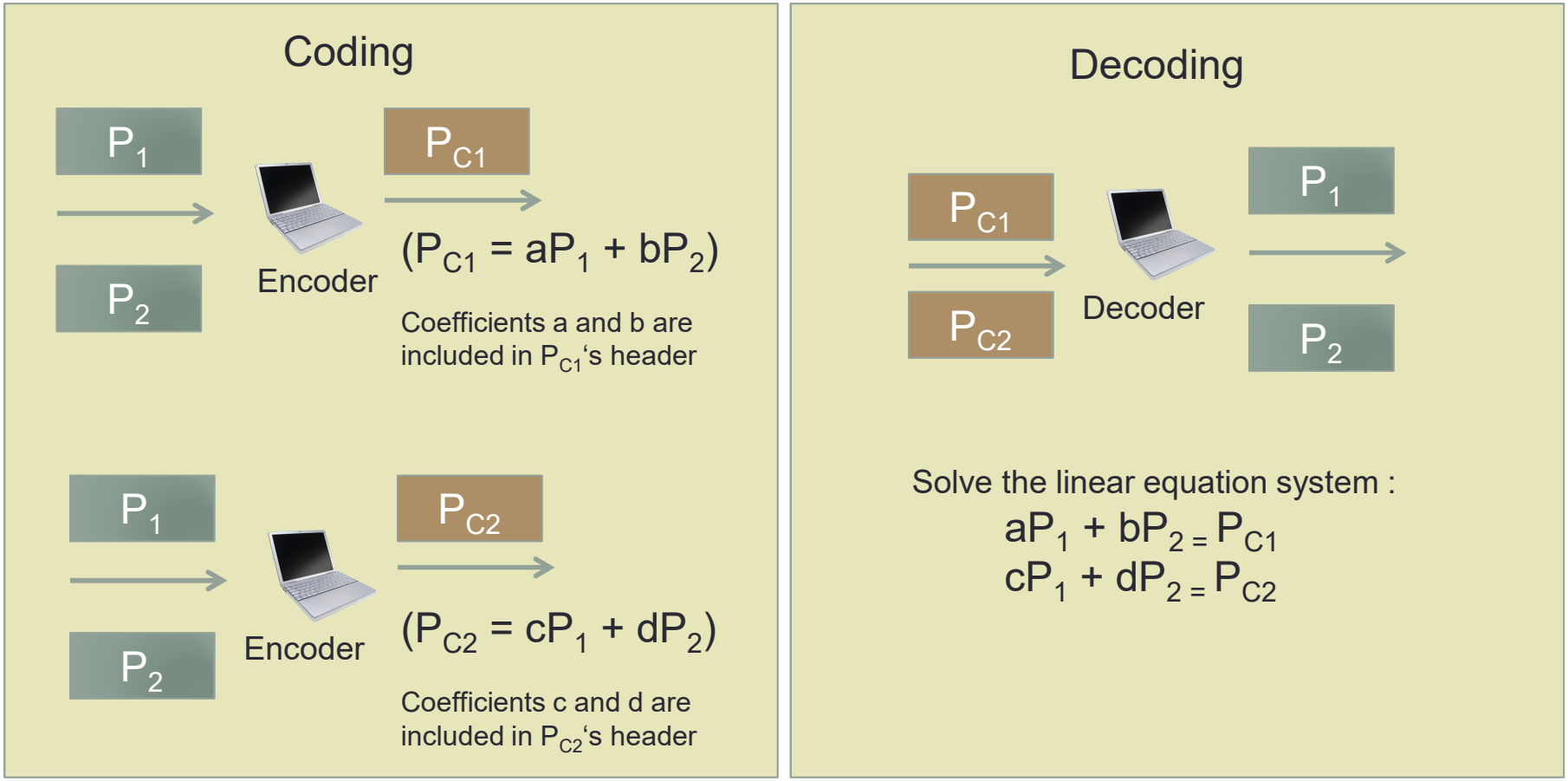


Benefits and applications

- Benefits:
  - Improve network capacity
  - Provide transmission reliability
- Applications:
  - Multicast transmission
  - Peer-to-peer networks
  - Wireless mesh and ad-hoc networks
  - Transport protocol : Transmission Control Protocol (TCP)
  - Distributed storage

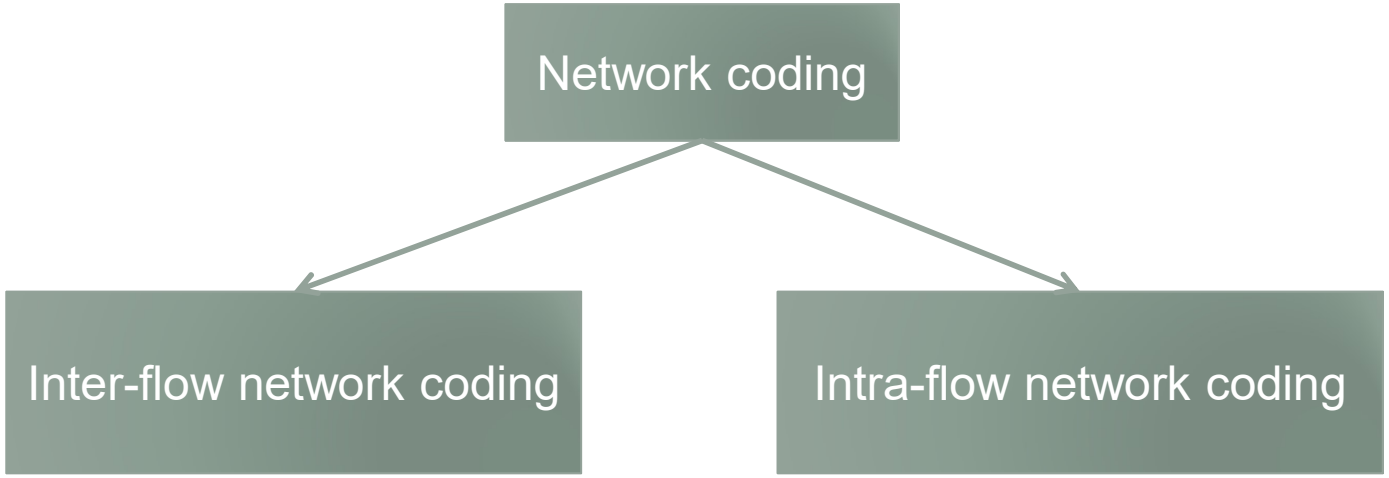
Linear network coding

- Encoding and decoding are based on a **system of linear equations**

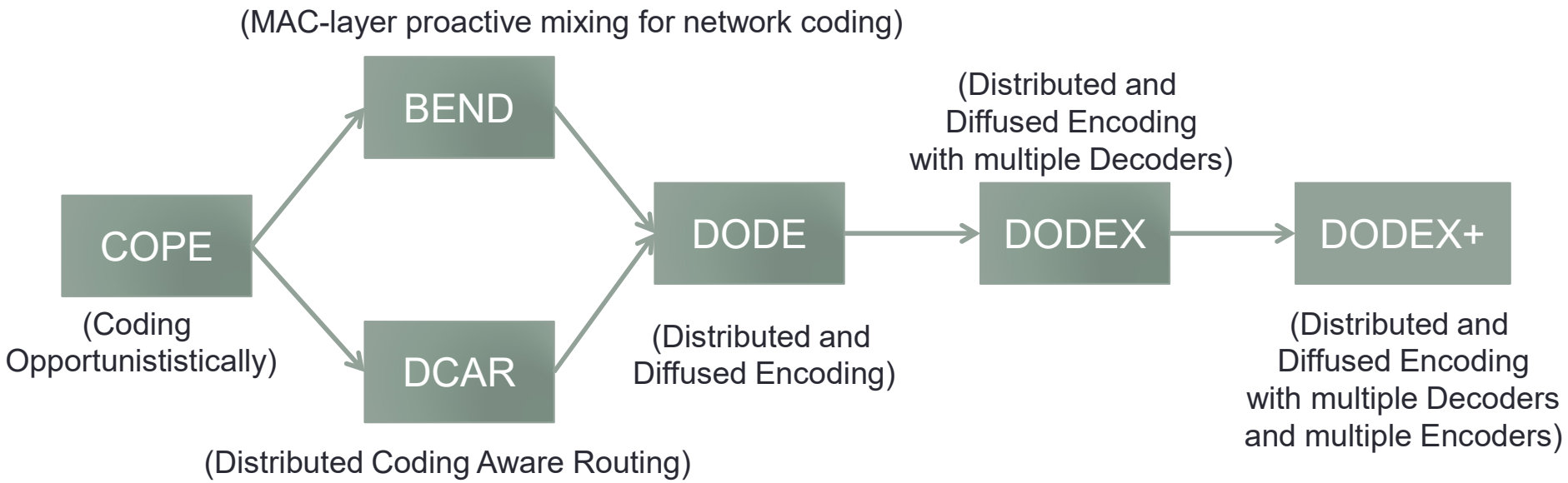


Classification

- Intra-flow network coding
  - Packets belonging to the same flow are mixed together
- Inter-flow network coding
  - Packets belonging to different flows are mixed together

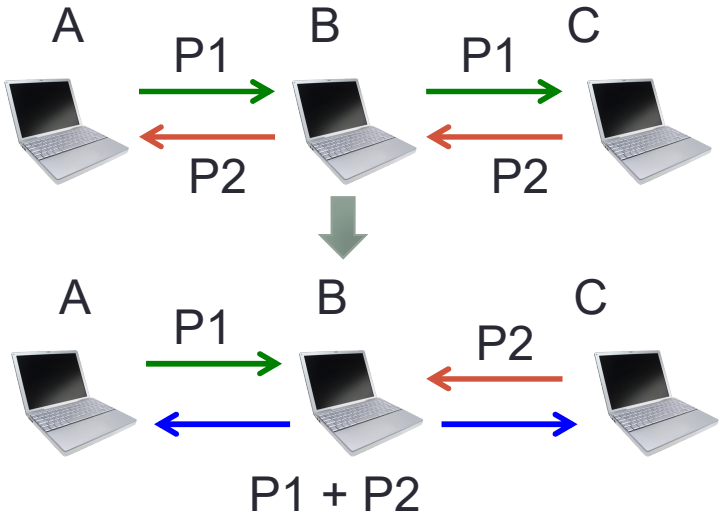


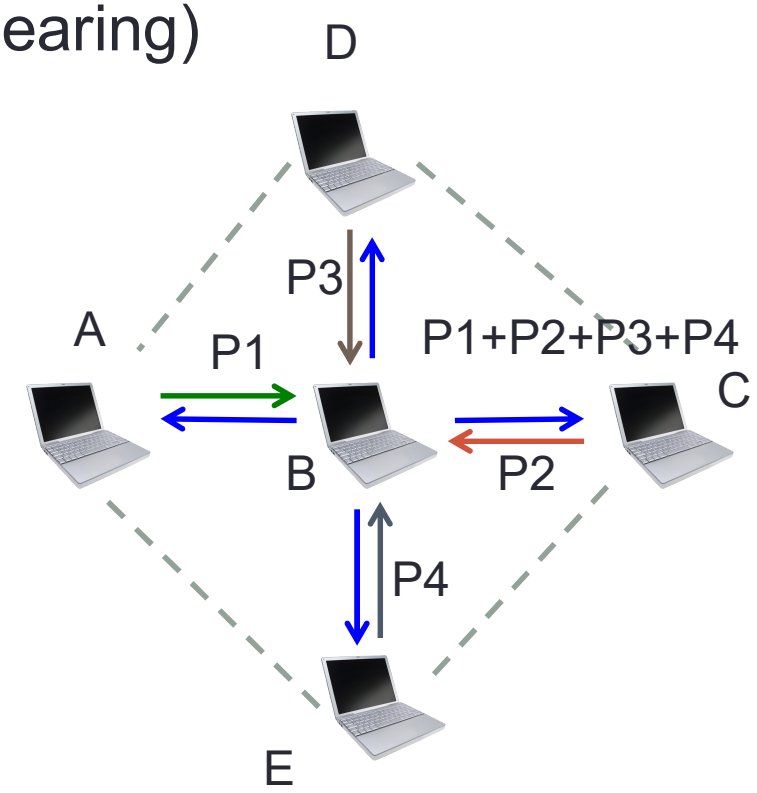
Inter-flow network coding



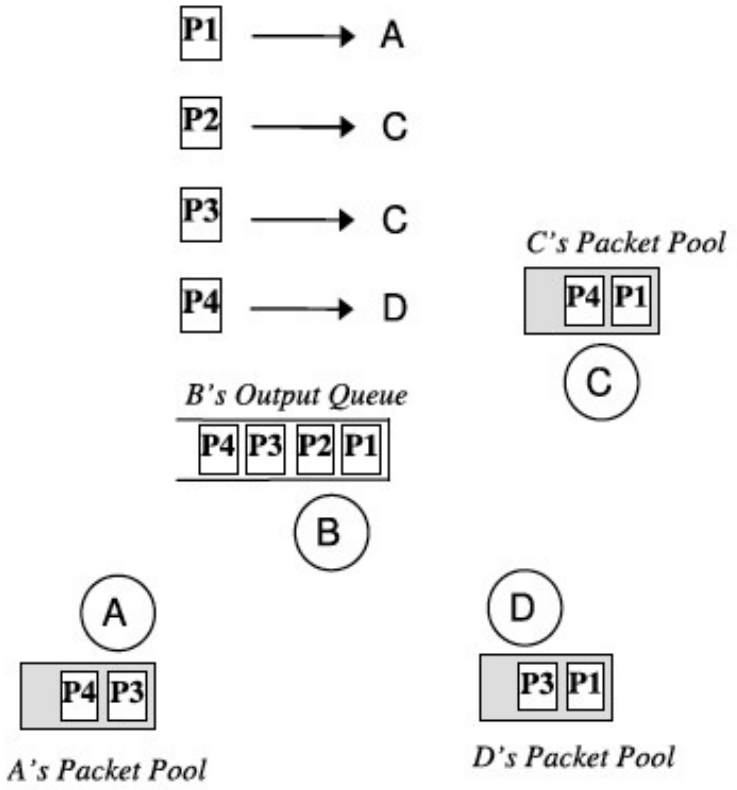
COPE

- Coding Opportunistically
- Two-hop coding pattern
- Different flows cross at a common intermediate node
- Opportunistic listening (Overhearing)



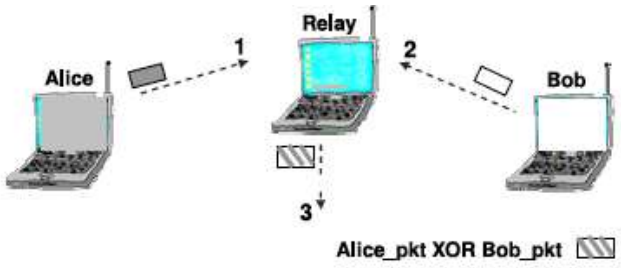


How to make coding decision?

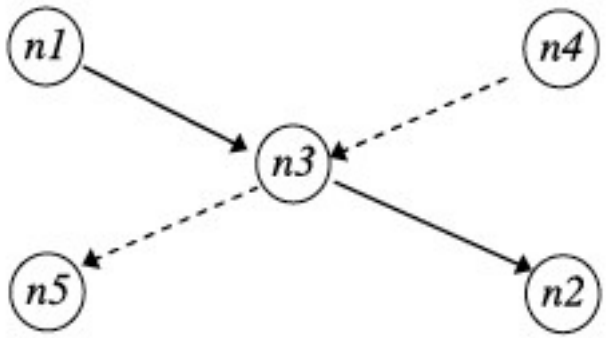


Coding Option	Is it good?
P1 + P2	Bad Coding (C can decode but A can't)
P1 + P3	Better Coding (Both A and C can decode)
P1 + P3 + P4	Best Coding (Nodes A, C, and D can decode)

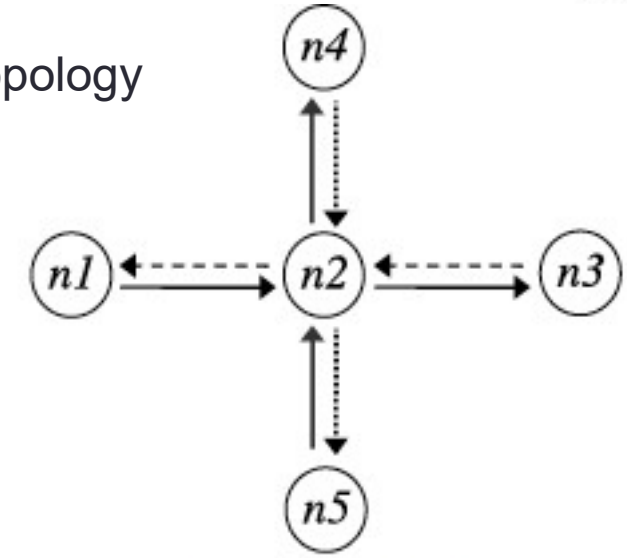
COPE topologies



(a) Alice-and-Bob topology

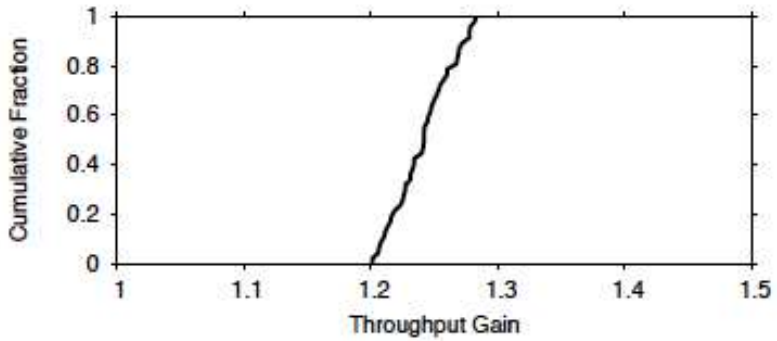


(b) "X" topology

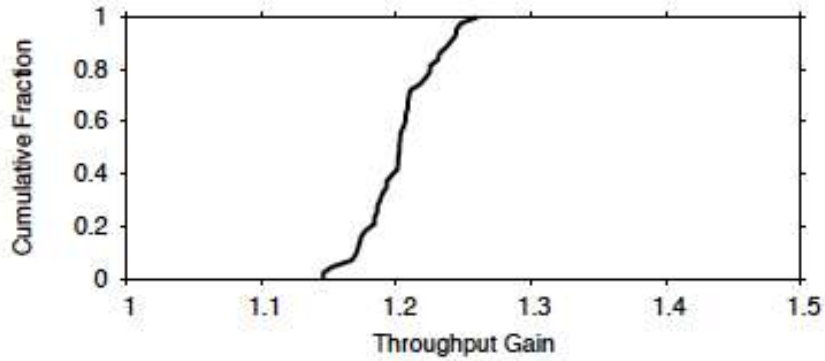


(c) Cross topology

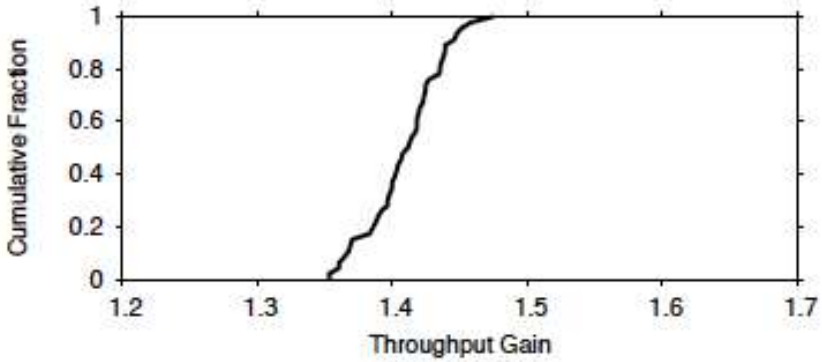
COPE performances - TCP



(a) TCP gain in the Alice-and-Bob topology

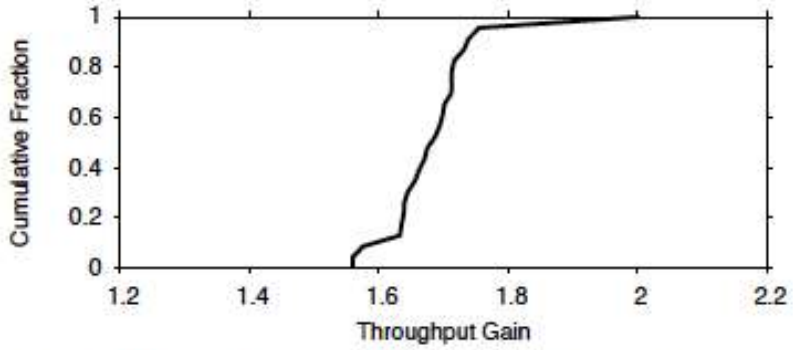


(b) TCP gain in the X-topology

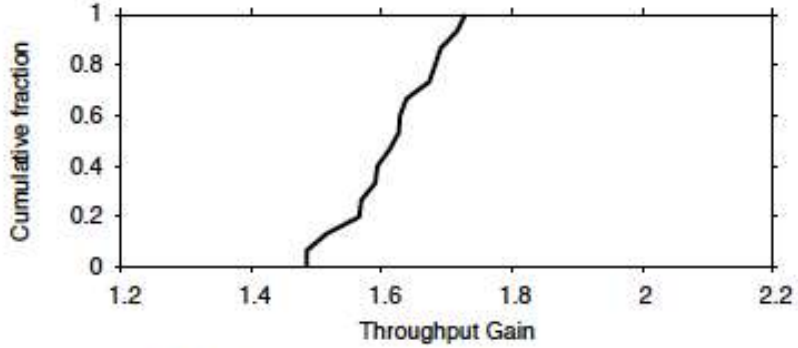


(c) TCP gain in the cross topology

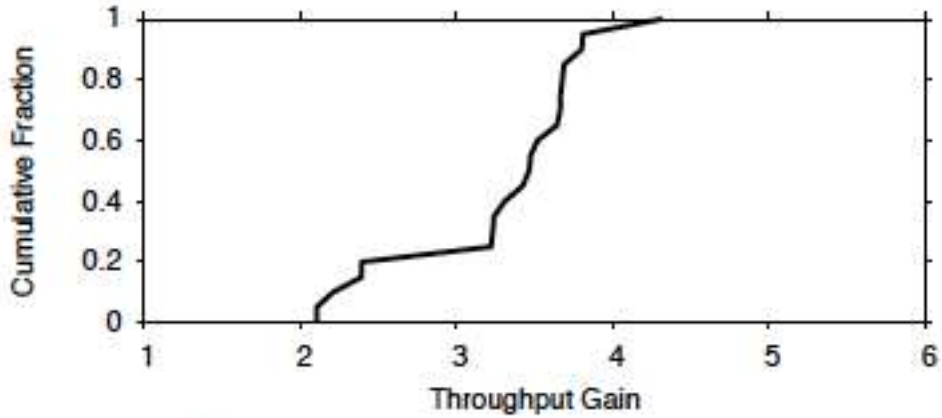
COPE performances - UDP



(a) UDP gain in the Alice-and-Bob topology



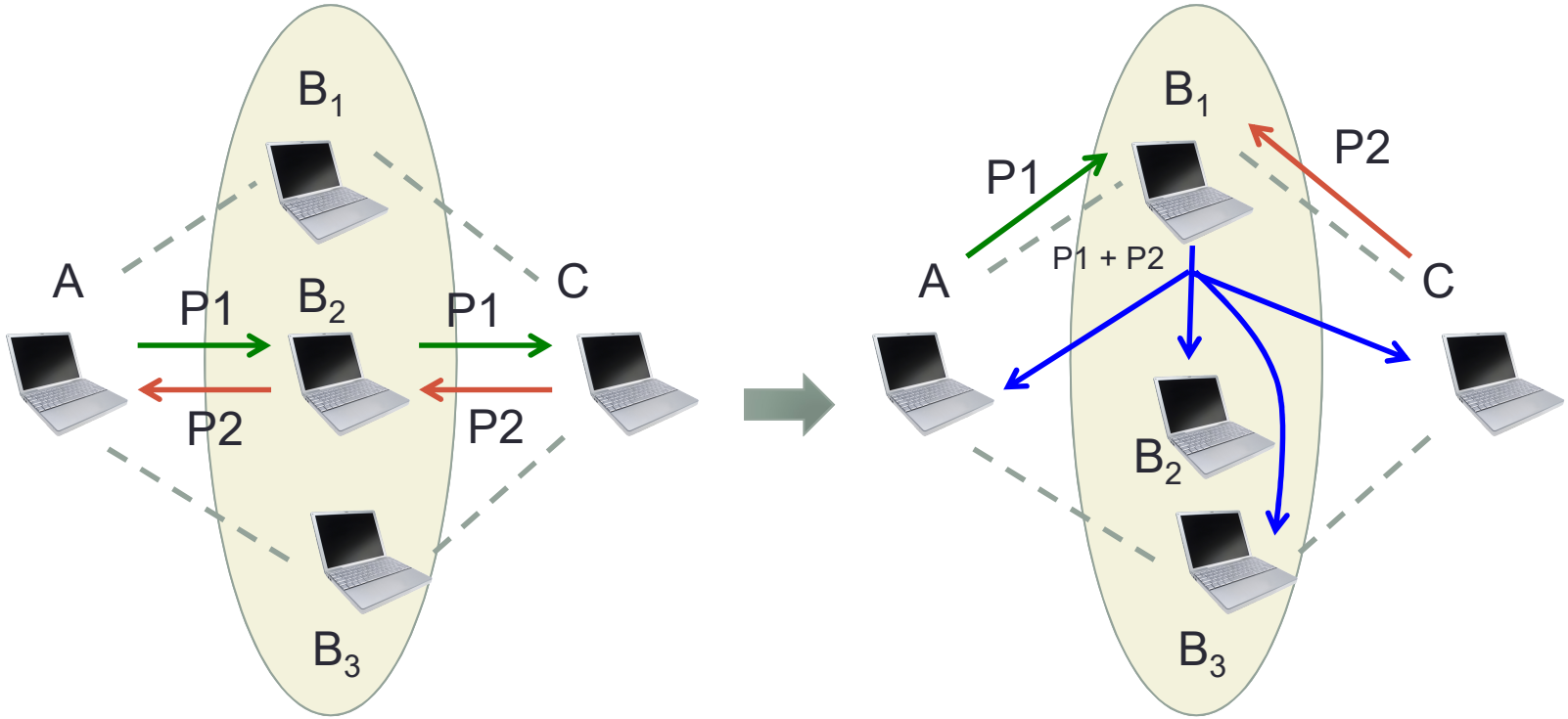
(b) UDP gain in the X-topology



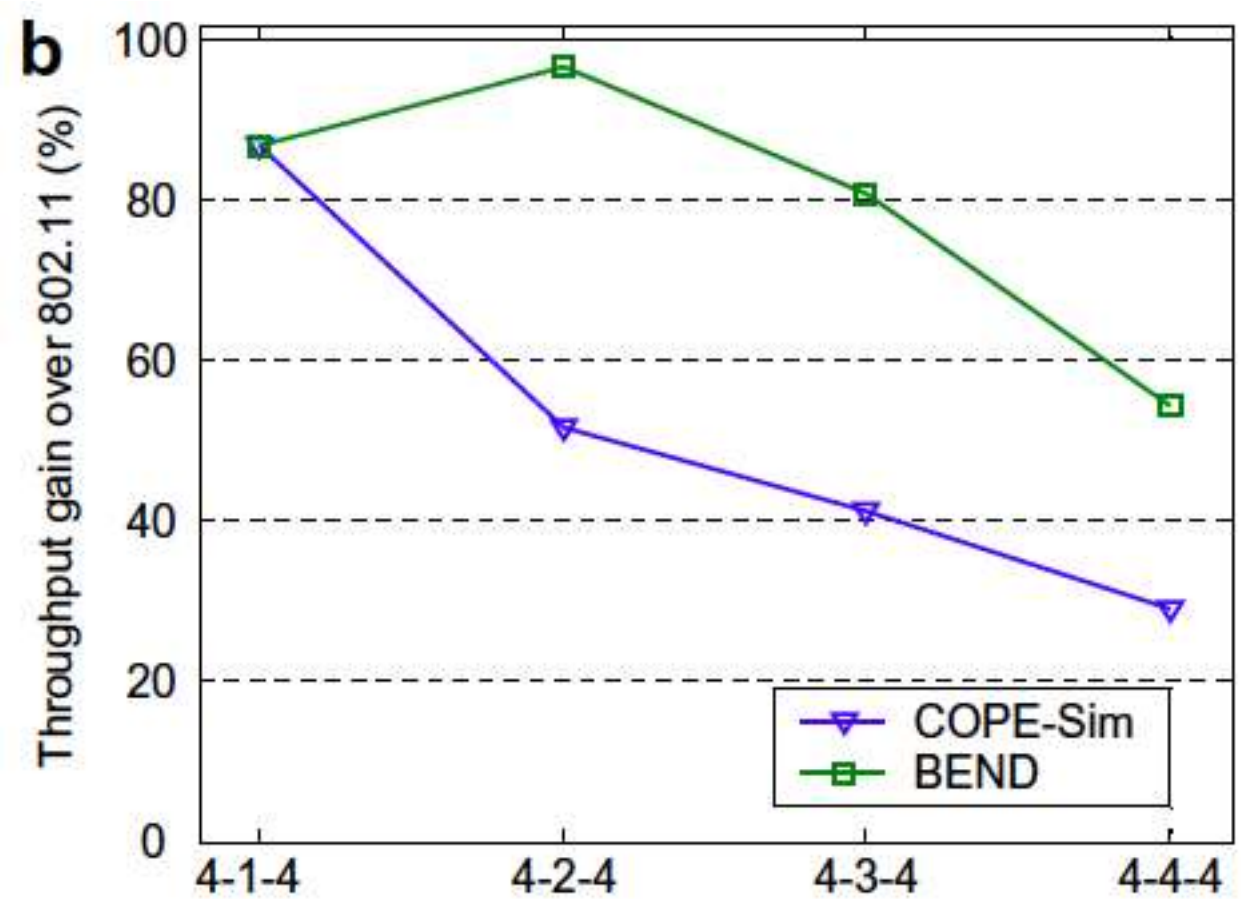
(c) UDP gain in the cross topology

BEND

- MAC-layer proactive mixing for Network Coding
- Extension of COPE
- 2-hop coding pattern for an encoder group

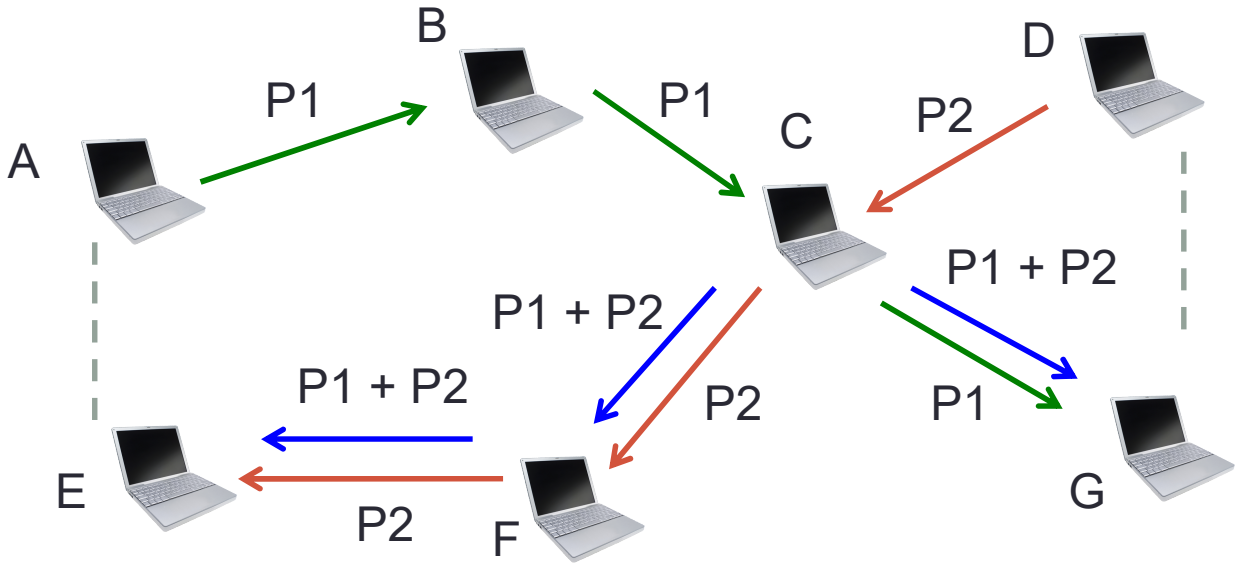


BEND performances

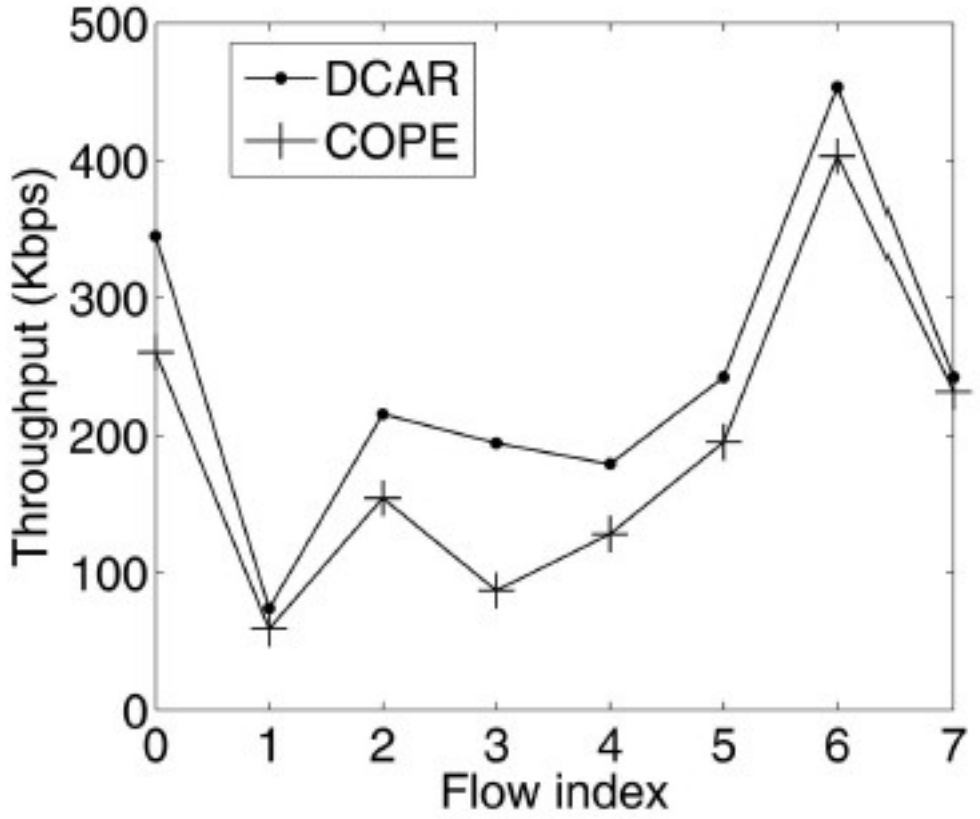


DCAR

- Distributed Coding-Aware Routing
- Extension of COPE
- More-than-2-hop coding pattern
- Flows cross at a common intermediate node

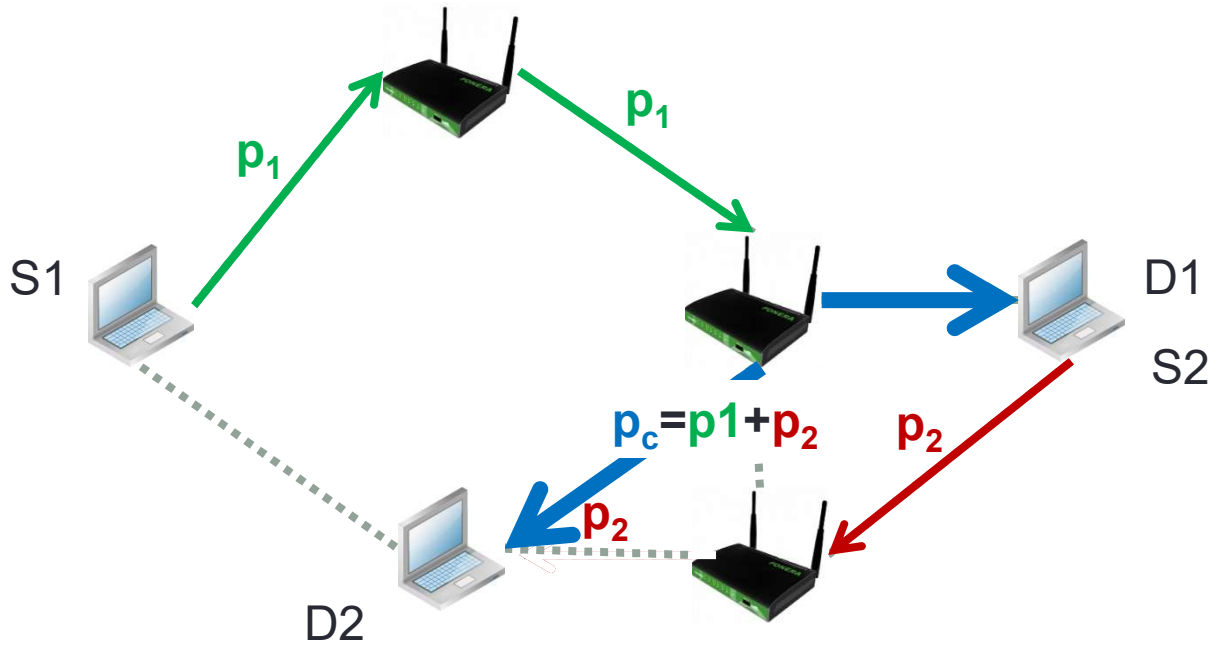


DCAR performances

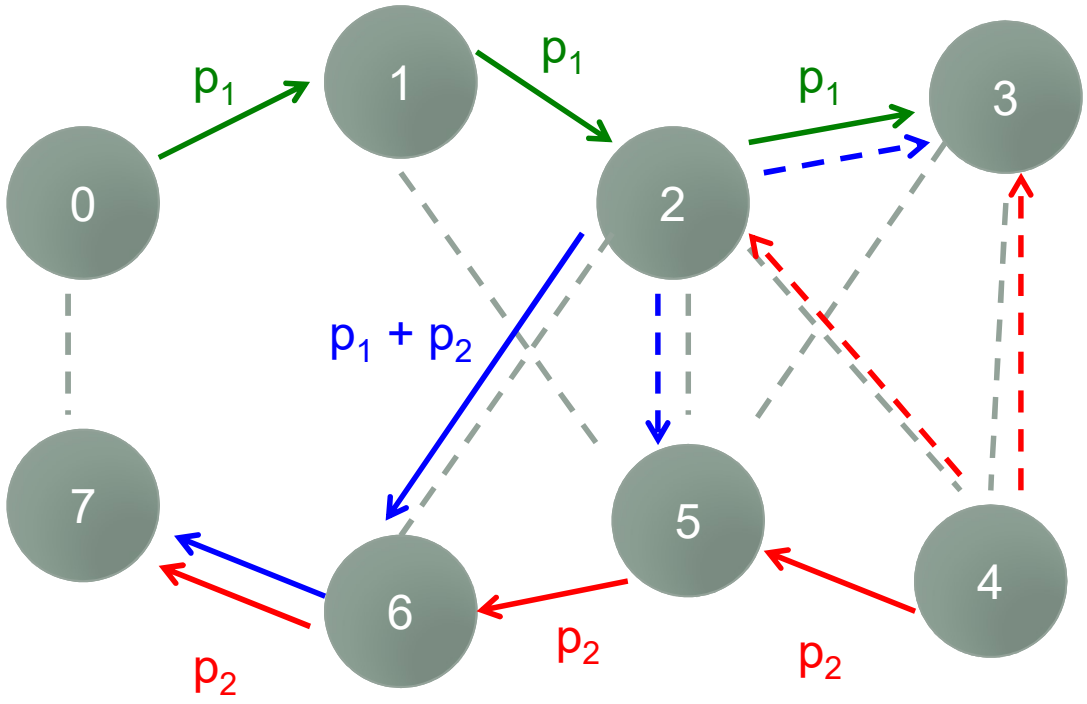


DODE

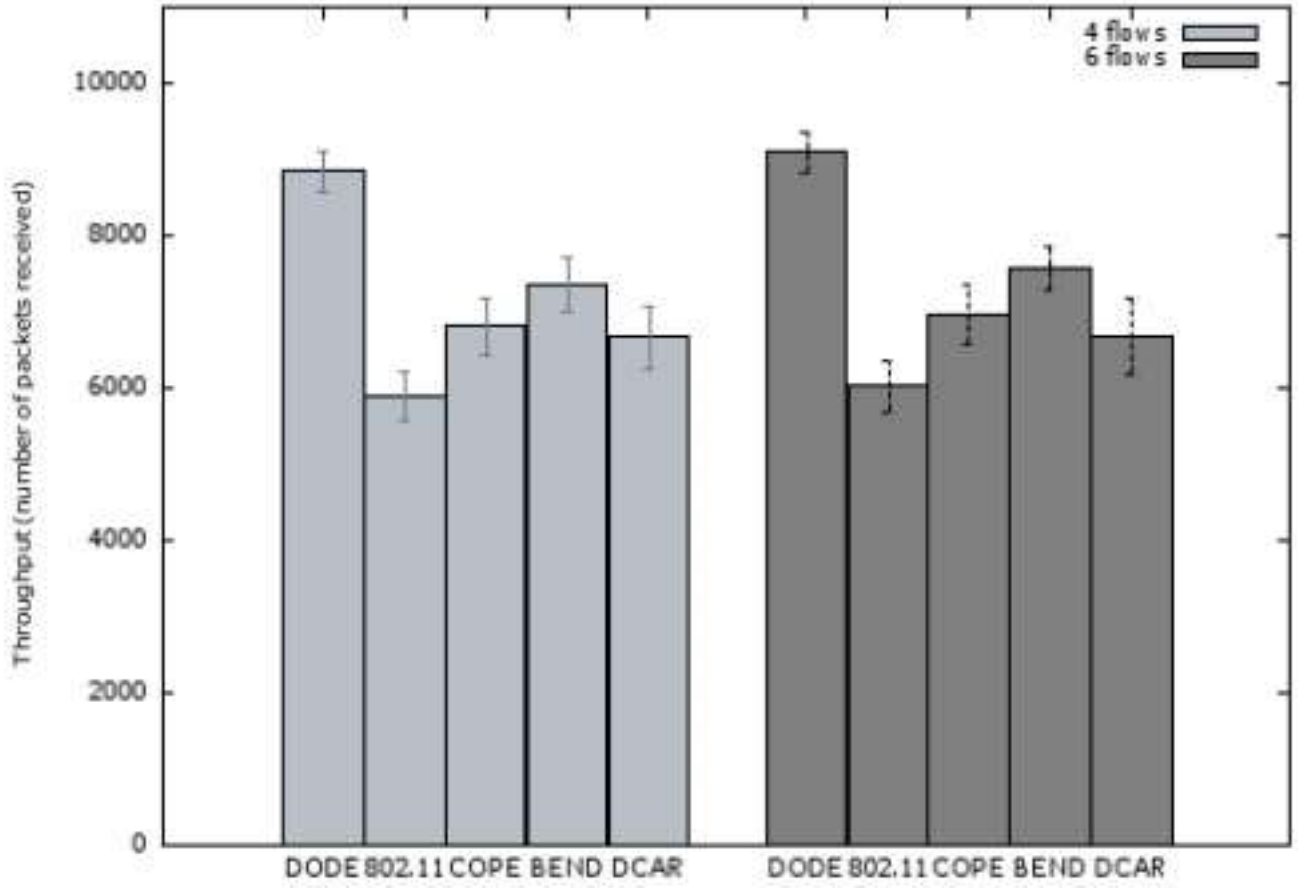
- Combination of BEND and DCAR
- Flows can be more than 2 hops
- Flows do not need to cross at a common intermediate node



Another topology for DODE

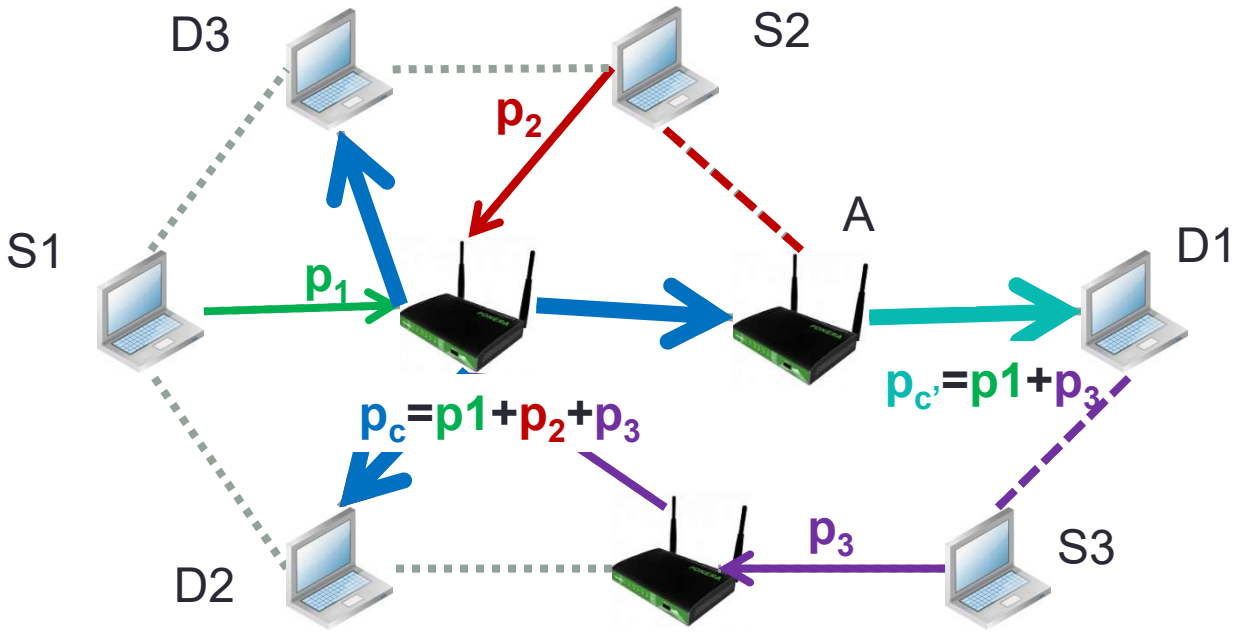


DODE performances

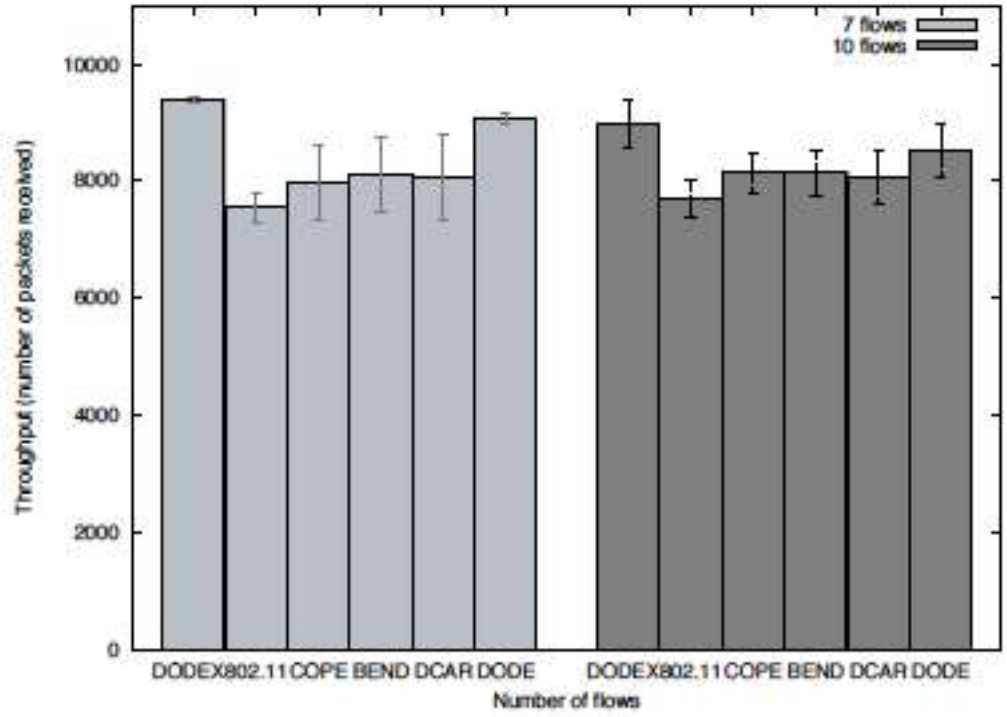


DODEX

- Extension of DODE
- Multiple decoders
- A decoder can partially decode an encoded packet

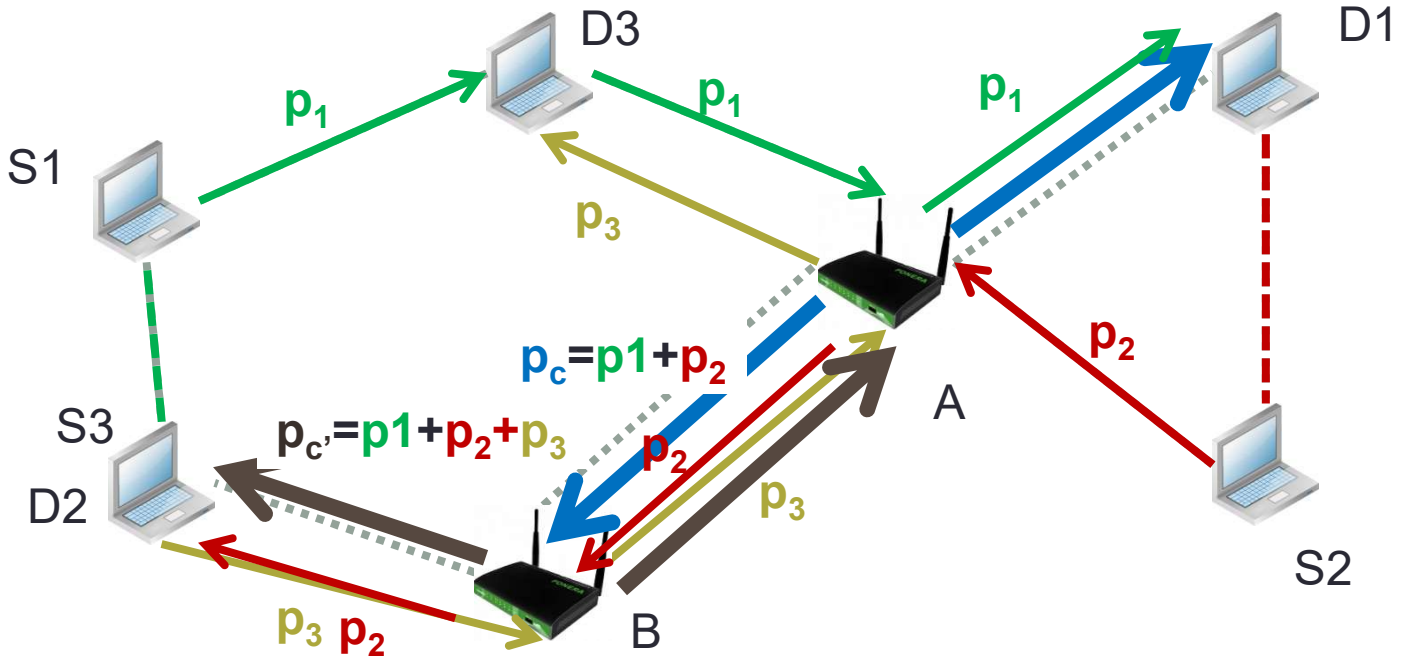


DODEX performances

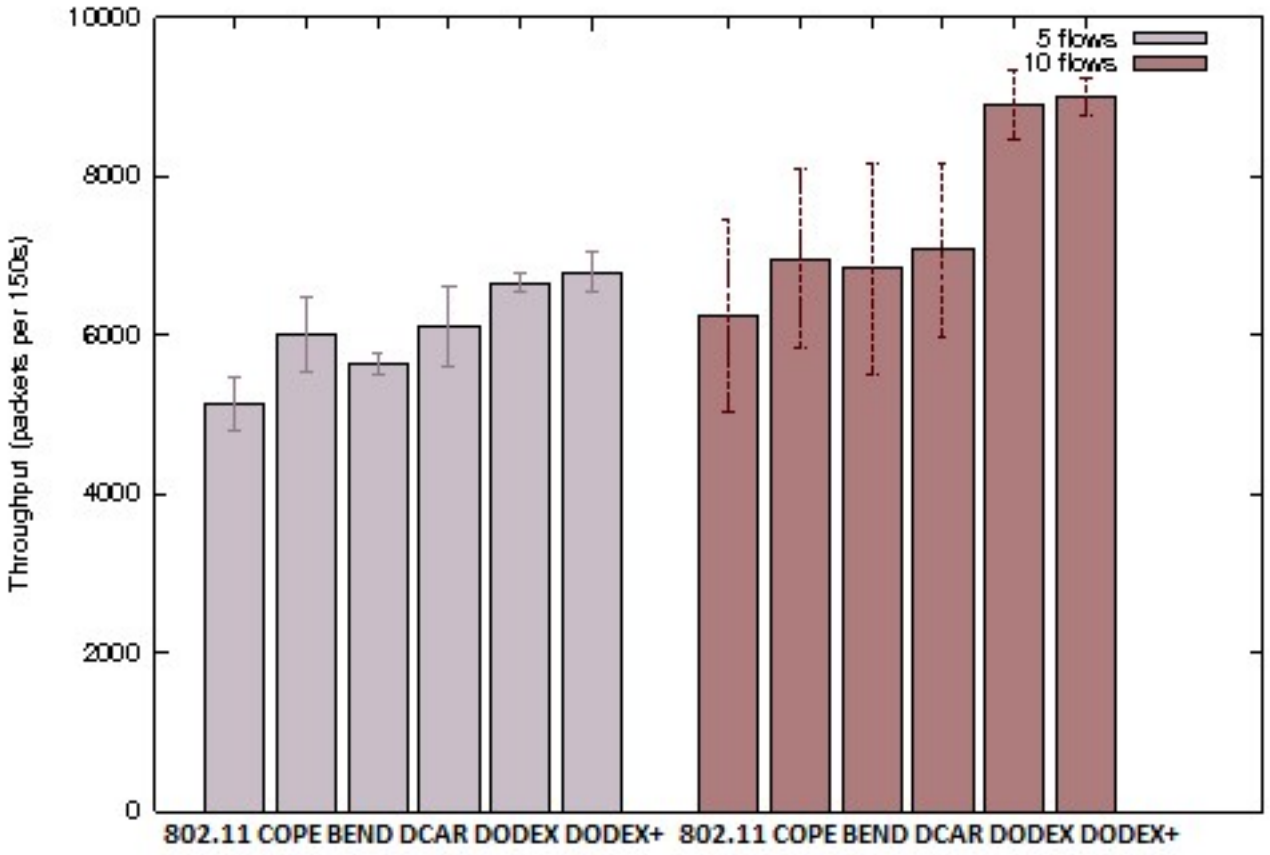


DODEX+

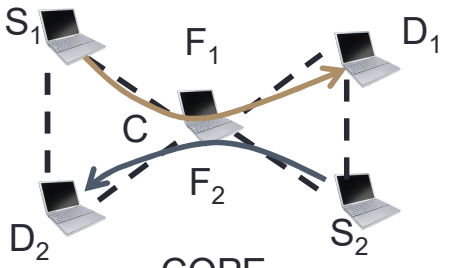
- Extension of DODEX
- Multiple encoders
- Allow re-encoding



DODEX+ performances

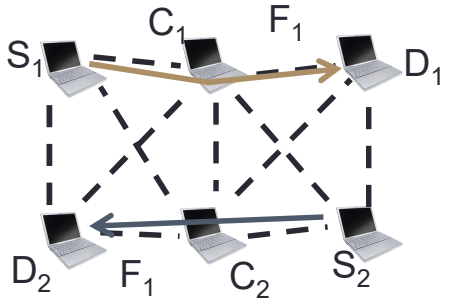


CODING STRUCTURES



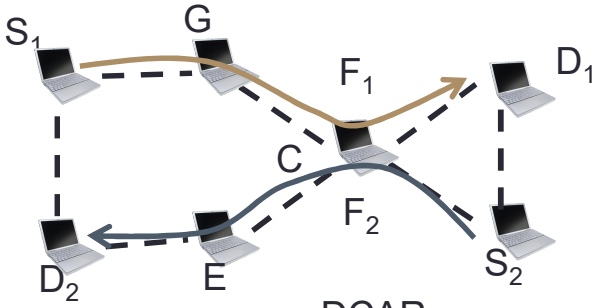
COPE

(Intersected 2-hop flows)



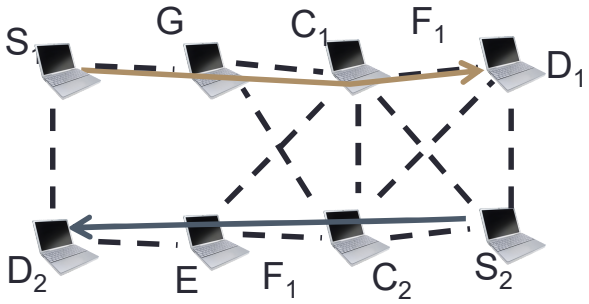
BEND

(Non-intersected 2-hop flows)



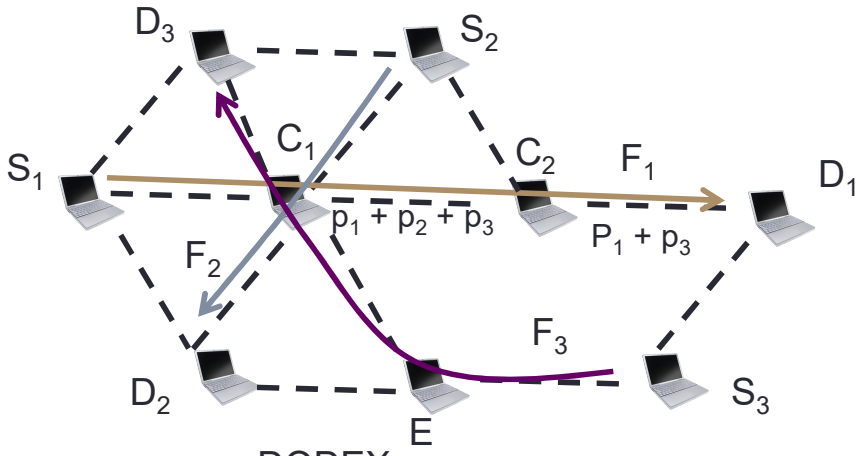
DCAR

(Intersected more-than-2-hop flows)



DODE

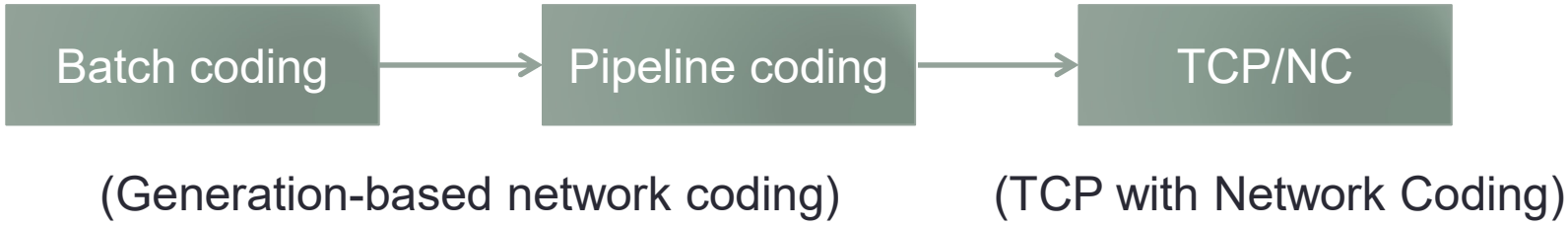
(Non-intersected more-than-2-hop flows)



DODEX

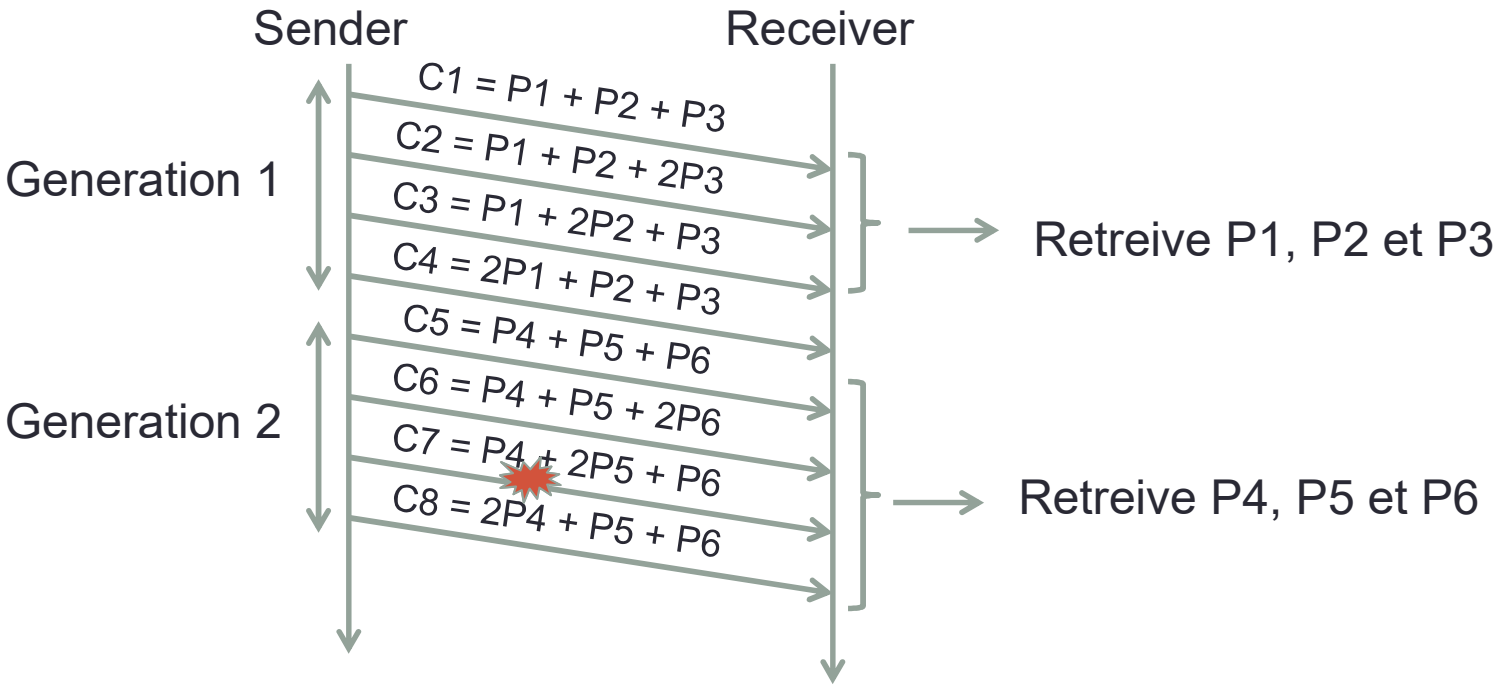
(DODE with multiple decoders)

Intra-flow network coding



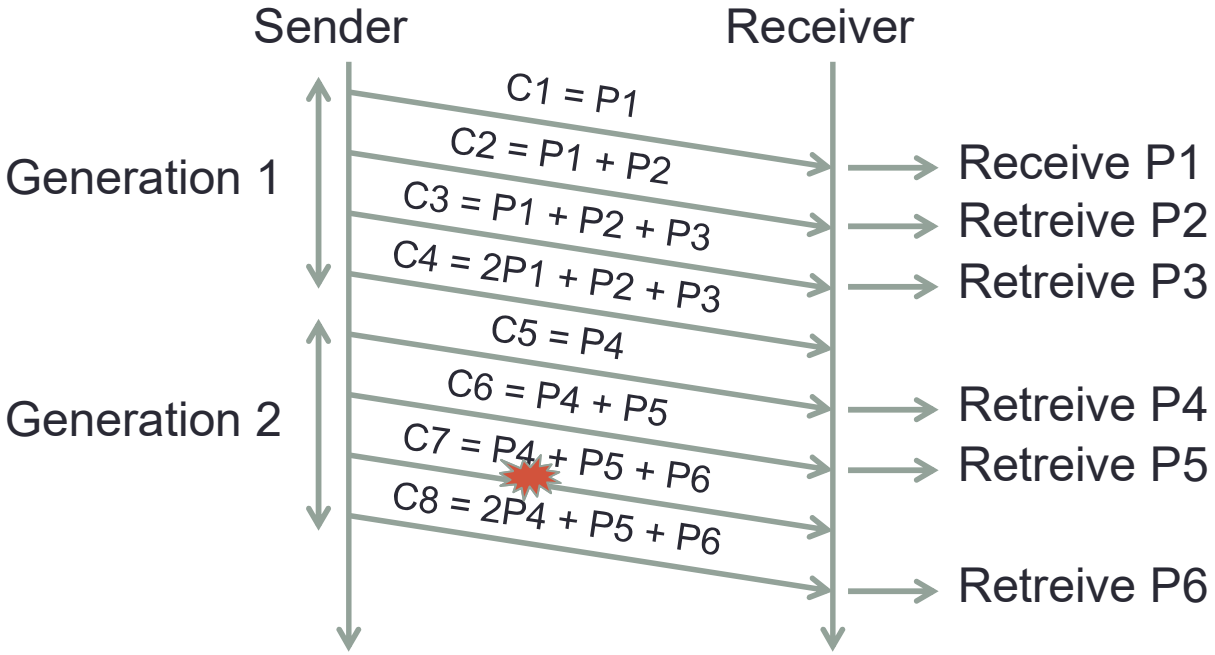
Batch coding

- Packets are grouped into **generation** of size n
- Fixe redundancy level
- Provide transmission reliability against packet loss



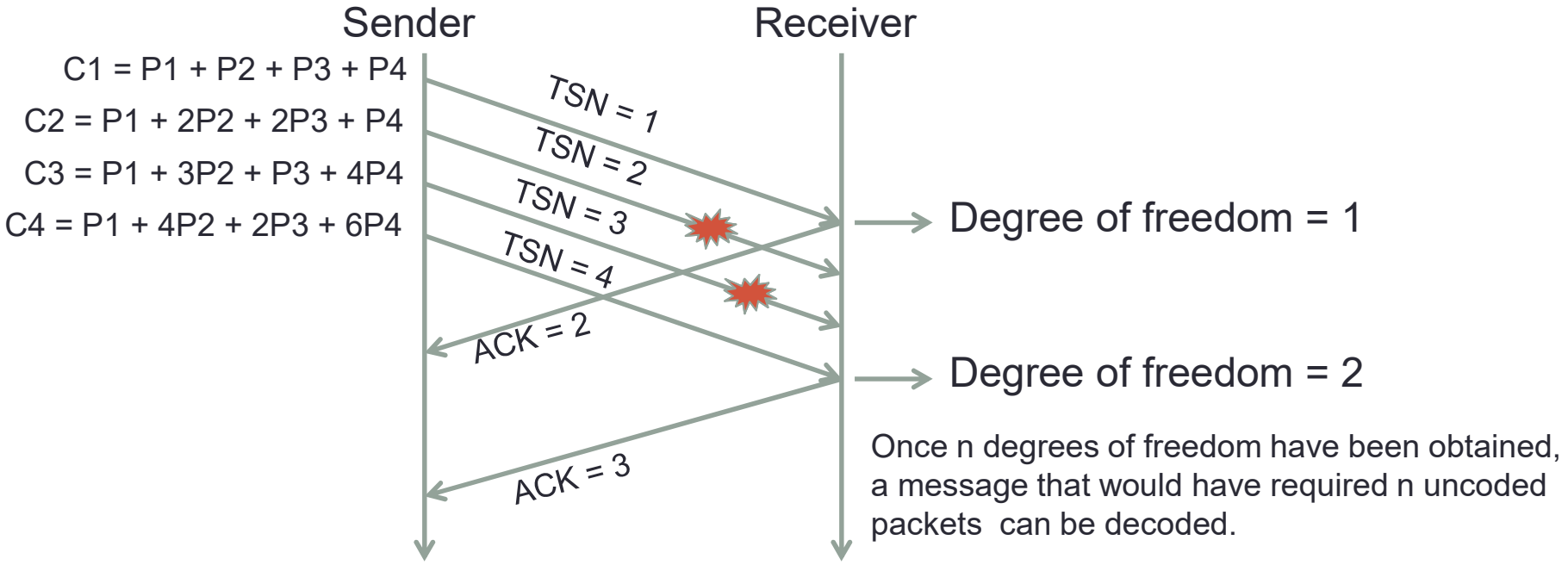
Pipeline coding

- Variation of batch coding
- Packets of a generation are added one by one into the encoding process
- The decoding does not need to wait for the arrivals of n coded packets → reduce the decoding time

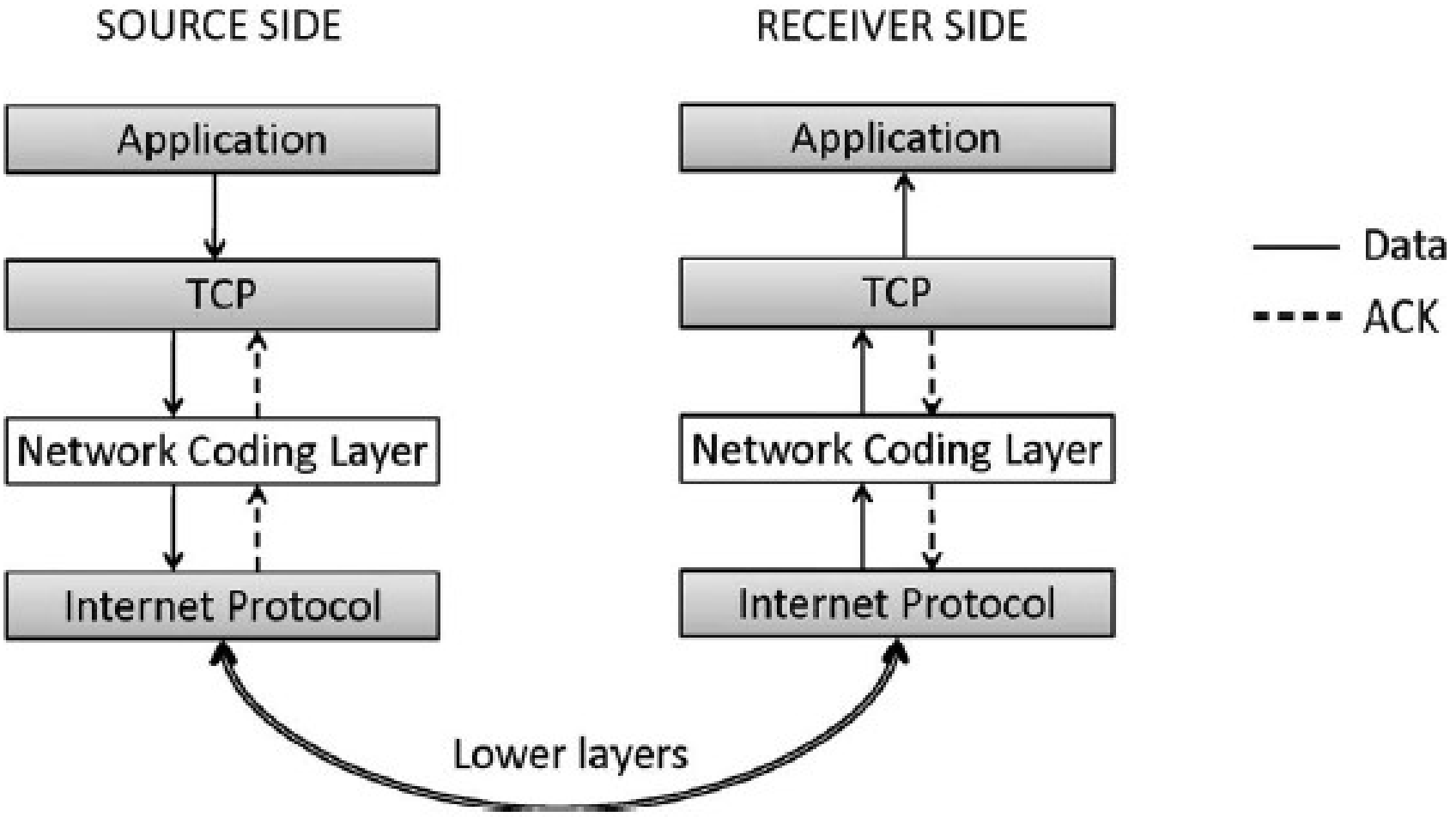


TCP/NC

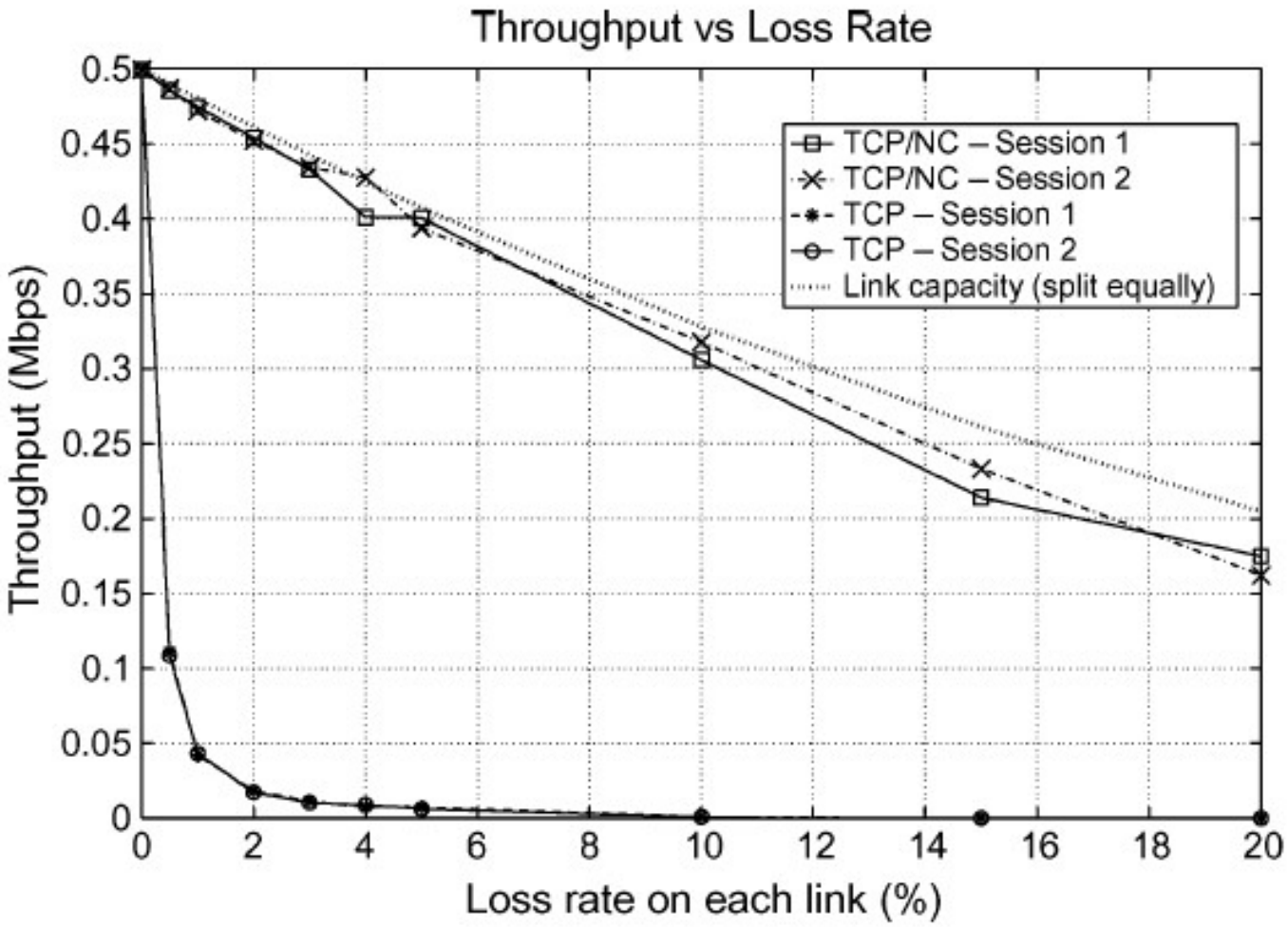
- Transmission Control Protocol with Network Coding
- No generation
- All packets in the congestion window are encoded together
- Acknowledge a degree of fredom (a linear combination that reveals one unit of new information)
- Mask packet loss from TCP congestion control→ better throughput



TCP/NC implementation



TCP/NC throughput

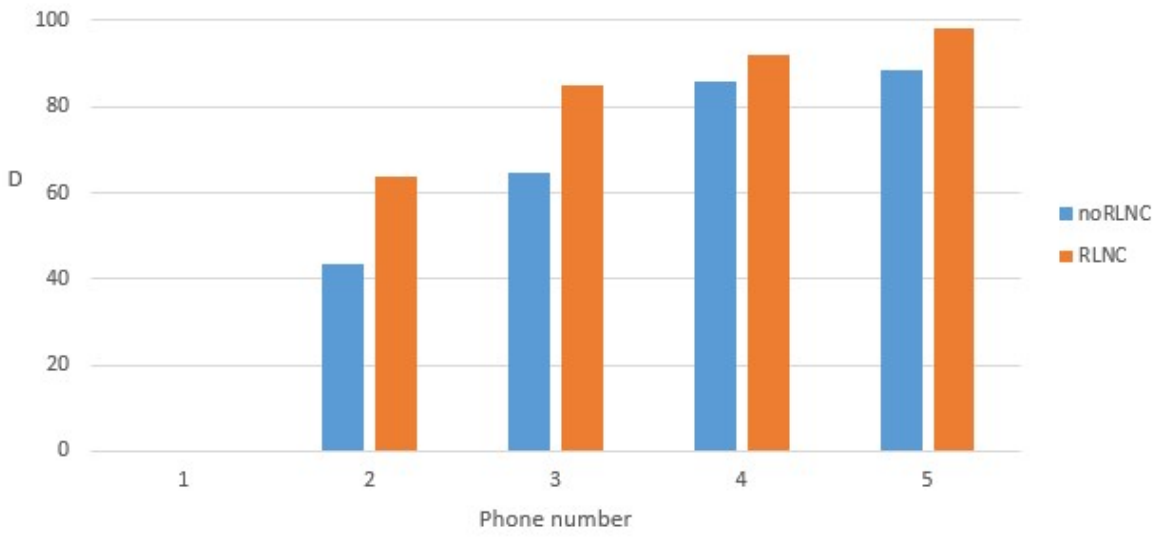


NETWORK CODING FOR D2D-BASED COOPERATIVE STREAMING

- A real test-bed of cooperative streaming with network coding at Nanjing University (NJU)
- The smart phones try to get video segments by D2D first
- The cellular interface is used when the waiting time is greater than a threshold
- Terminal 1 starts the video first
- Terminals 2-5 follow one after another every 20s

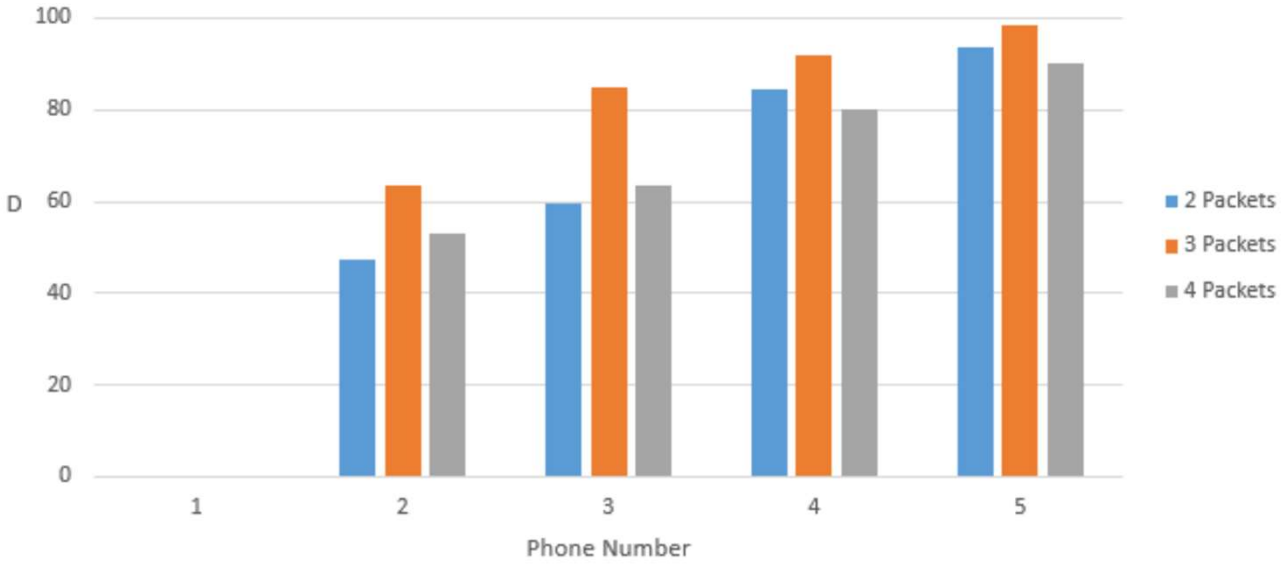
OFFLOADING GAIN WITH VS. WITHOUT USING NETWORK CODING

- Offloading gain D = W/(W+C) * 100%
  - W : the amount of data obtained by video sharing using D2D communications
  - C : the amount of data obtained by directly downloading from the server using the cellular interface



OFFLOADING GAIN UNDER DIFFERENT GENERATION SIZES

- Generation sizes
  - 2 packets of 24 KB
  - 3 packets of 16 KB
  - 4 packets of 12 KB



Conclusion

- Network coding is a very promising solution to future networks
  - Increase network capacity by detecting coding opportunities and reduce the number of wireless transmissions
  - Provide transmission reliability by combining packets belonging to the same flow
- Changes in current network device behavior is needed to support network coding
  - Routers can combine incoming packets
  - Wireless interfaces need to enable overhearing
  - Transport protocols exchange packet combinations instead of native packets
- Network coding should be considered and integrated in the first step of future network architecture and protocol design