Wireless Network Coding: Opportunities & Challenges

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Characteristics of Wireless Networks .....in general

disadvantageous....

- High BER
- Low throughput
- Dead Spots
- Interference
- Unreliability

but also some to exploit....

- Broadcast Links
- Data Redundancy
- Spatial Diversity
- Mobility & Portability

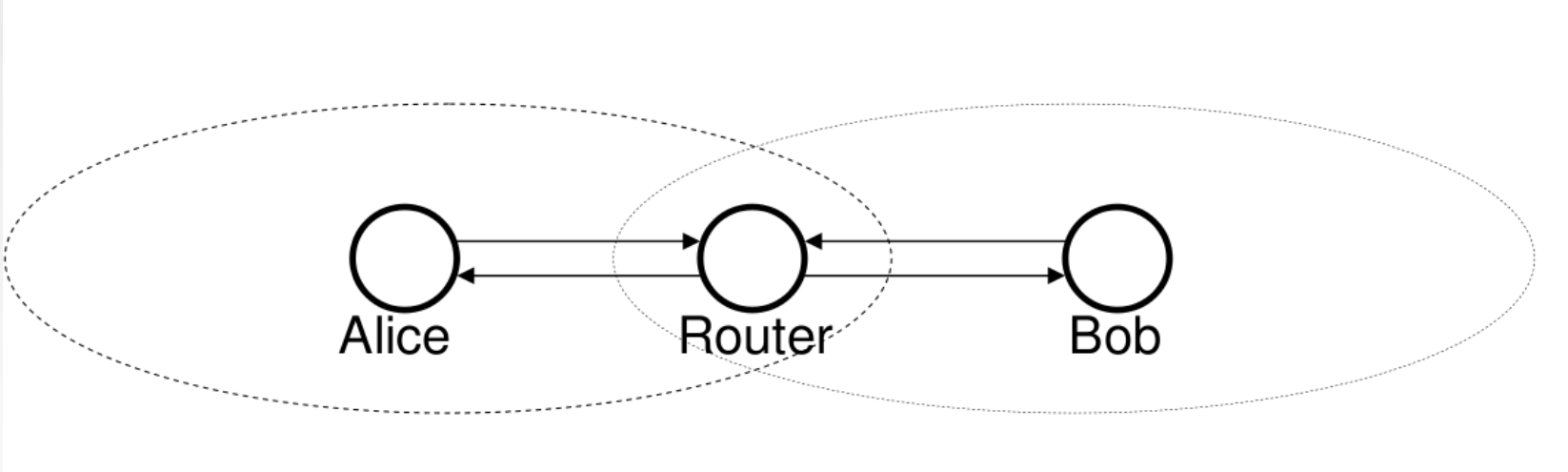
New Perspective!

- Alternate the design of Wireless Networks

- Exploit the Data Redundancy & Spatial Diversity

  and deal with all the disadvantageous characteristics....

- Network Coding
  - in general, routers mix the content of different packets and broadcast the coded result



Coding leads to 3 transmissions instead of 4---throughput increasement

Opportunities

- Throughput
- Reliability
- Fairness
- Mobility
- Monitoring

Challenges

- Broadcast Network Challenges
  - MAC
  - Routing
  - Transport
- Coding Challenges
  - Fast Coding
  - Forced Reliability
  - Realtime Traffic

Opportunities: Throughput (1/2)

Network Coding increases wireless throughput: Coding allows routers to compress the transmitted information given the already known information at various nodes

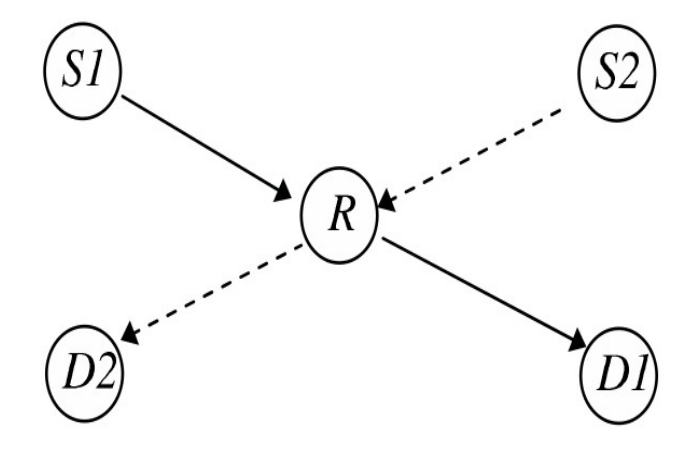
Coding Style----Inter-flow Coding: Coding over packets that differ in the next hop (different flows)

COPE "Coding Opportunistically"

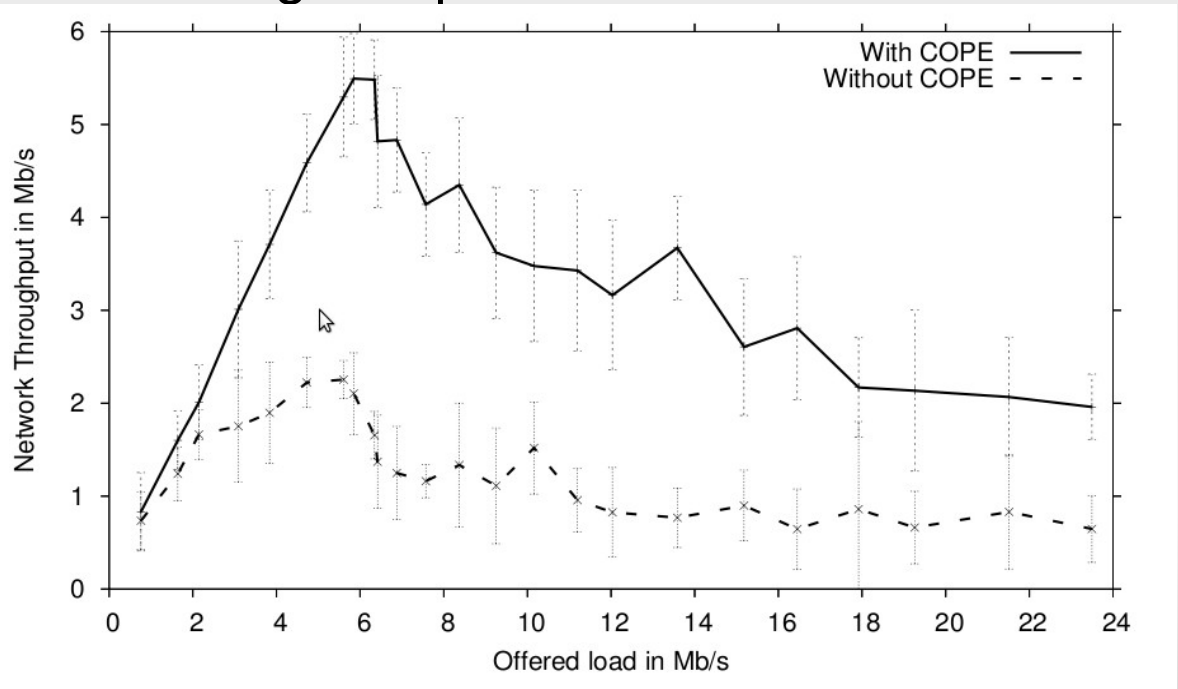
data redundancy at the network level

Cope is a MAC extension with the following components:

- Opportunistic Listening
- Opportunistic Coding



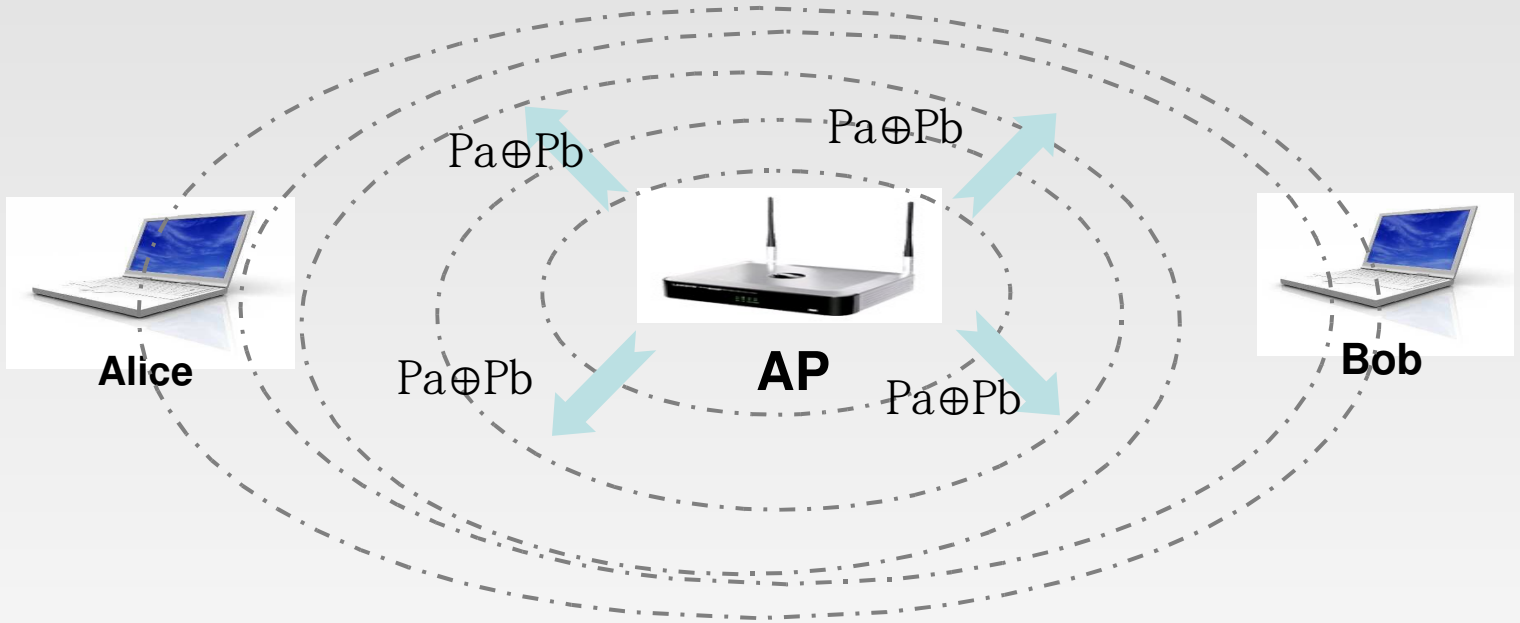
Inter-flow coding



Opportunities: Throughput (2/2)

Content Distribution:

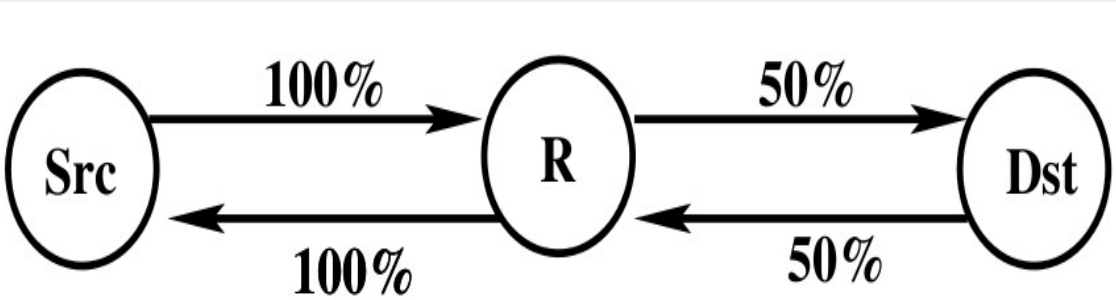
data redundancy at the application level



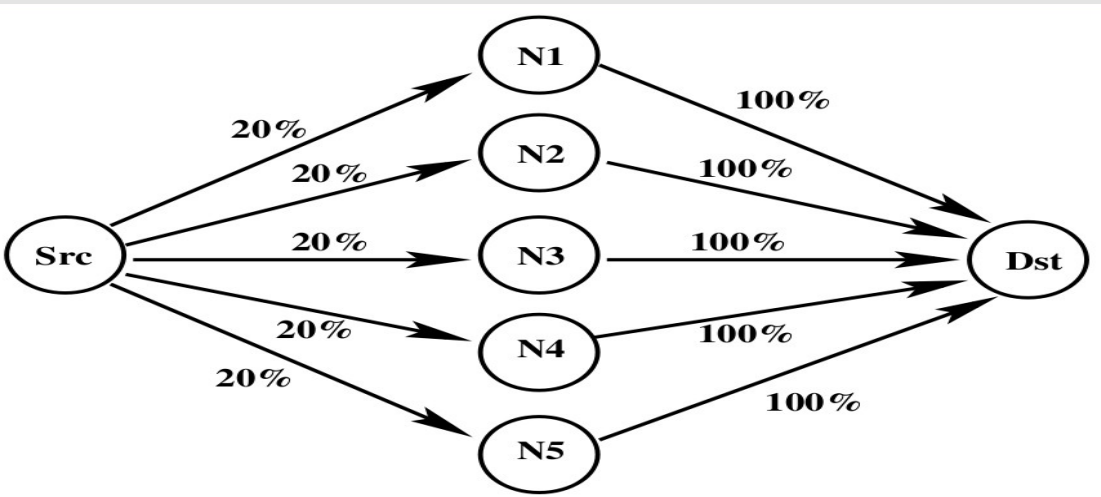
Alice wants song Pa and has song Pb. Bob wants song Pb and has song Pa. The AP sents the XORed packet and with one transmission both clients get what they want

Opportunities: Reliability

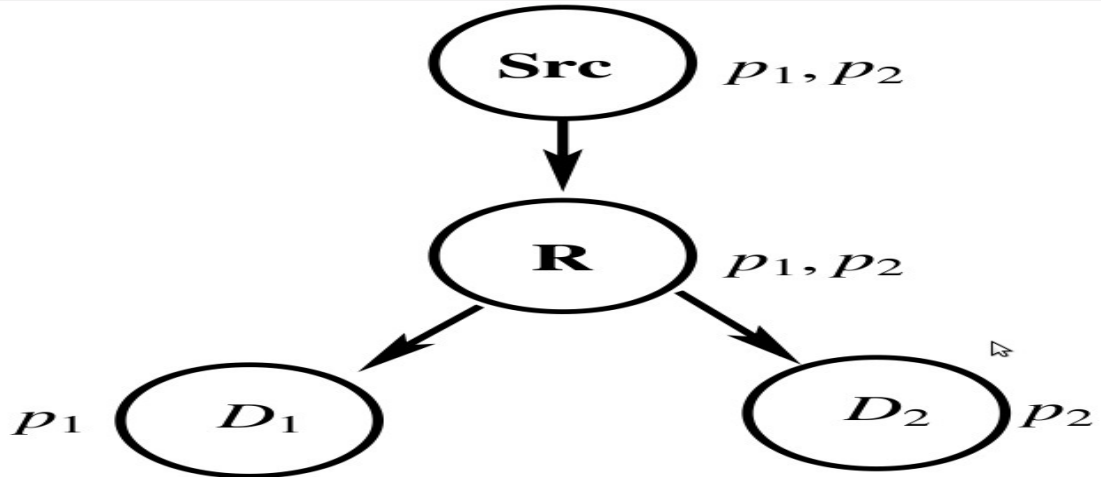
Single Path:
for a file of n packets
without coding E(T)=4n
with coding E(T)=2n+2



Dead Spots:
Combine Spatial Diversity and Network Coding to face the dead spot ineffective use of the medium



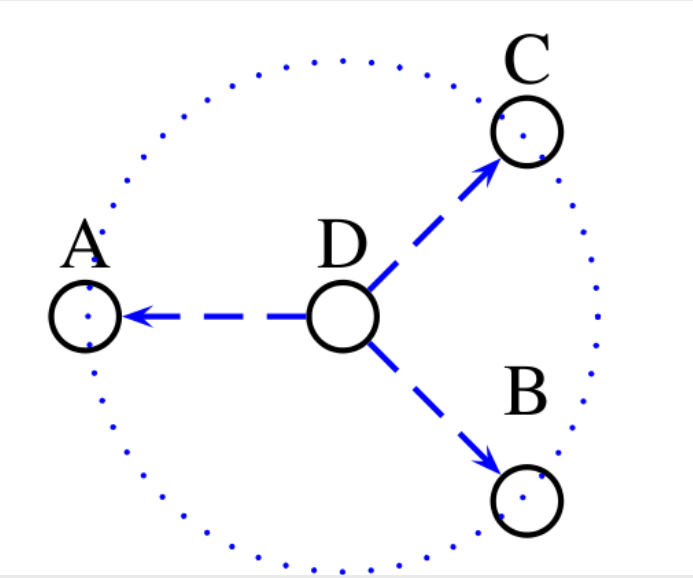
Multicast:
R codes the multicast session packets, D1 & D2 get any lost packets



Opportunities: Fairness

Base Station D has three indepentent packet streams to nodes A, B, C.

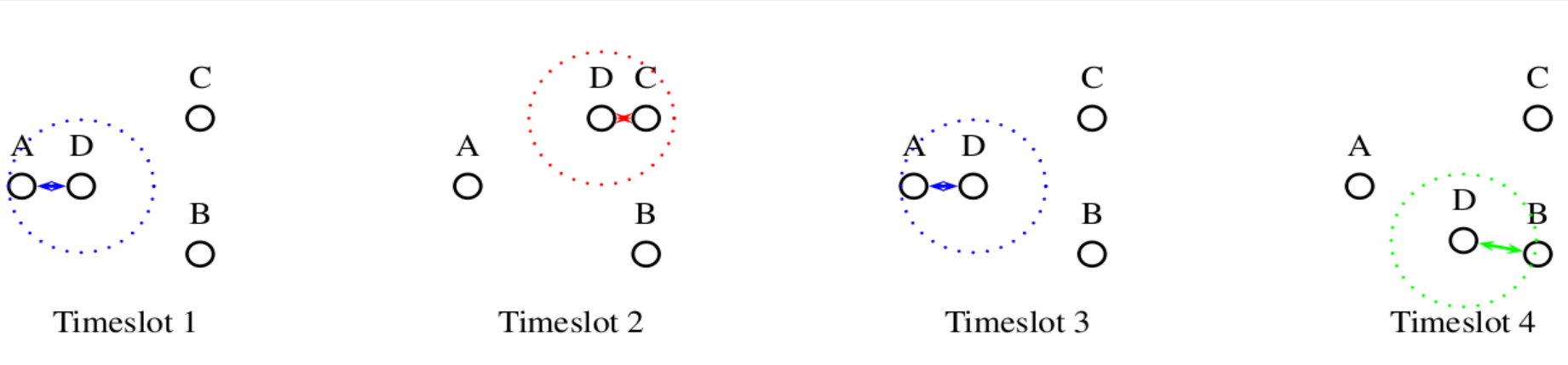
The network coding solution leads to the same aggregate throughput, but more evenly divided among receivers compared to a TDMA scheme with the fair transmission strategy of Round-Robin algorithm



Round Robin Routing						
time	1	2	3	4	5	6
D tx	x_A^1	x_B^1	x_C^1	x_A^1	x_B^2	x_C^2
A rx	-	-	x_C^1	-	x_B^2	x_C^2
B rx	x_A^1	-	x_C^1	-	x_B^2	x_C^2
C rx	-	x_B^1	x_C^1	x_A^1	-	x_C^2
Network Coding Solution						
time	1	2	3	4	5	6
D tx	x_A^1	x_B^1	x_C^1	$x_A^1+x_B^1+x_C^1$	$x_A^1+2x_B^1+3x_C^1$	$x_A^1+4x_B^1+5x_C^1$
A rx	-	-	x_C^1	-	$x_A^1+2x_B^1+3x_C^1$	$x_A^1+4x_B^1+5x_C^1$
B rx	x_A^1	-	x_C^1	-	$x_A^1+2x_B^1+3x_C^1$	$x_A^1+4x_B^1+5x_C^1$
C rx	-	x_B^1	x_C^1	$x_A^1+x_B^1+x_C^1$	-	$x_A^1+4x_B^1+5x_C^1$

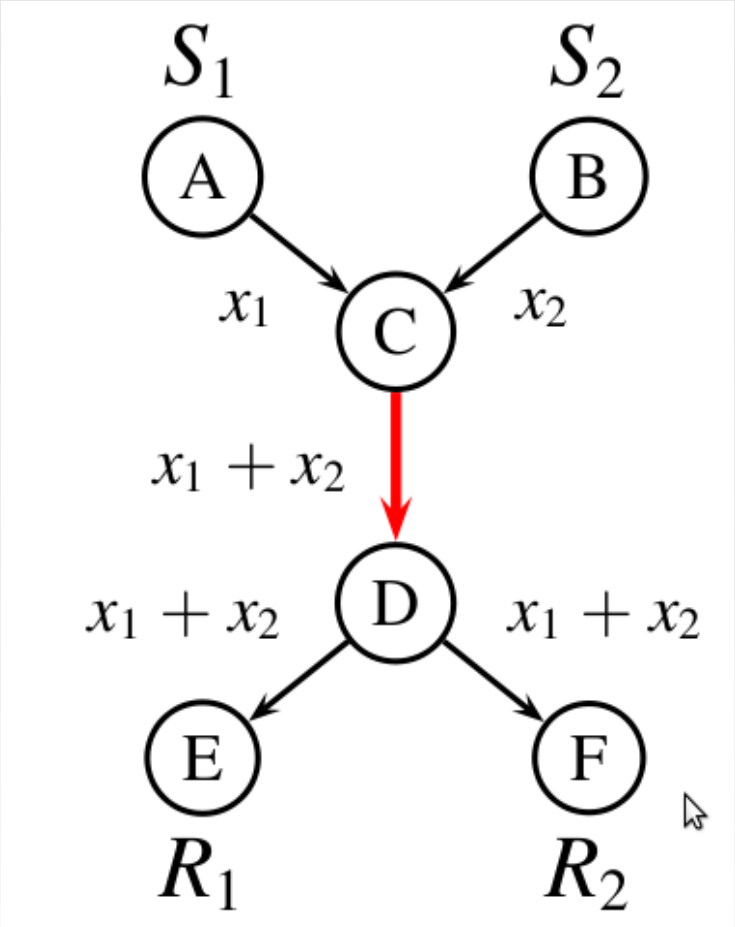
Opportunities: Mobility

- Nodes A, B, C are interested in receiving information from node D
- Node D is mobile and not aware of which node is in its range
- With Coding, D doesn't need any information about the network topology or the history of successful transmissions
- D just transmits a linear combination of the packets it has: $\sum c_i p_i$
- Each node in D's range receives this information and as far as there is innovative information in the transmittion, it's useful for the nodes.



Opportunities: Monitoring

- nodes A, B, C, D are sensors while nodes E, F are sinks
- Sensors A, B send probes x1, x2 to C, which XORes the probes, while D broadcasts the XORed information to E, F
- With several rounds of probes we infer the link loss rate on all links
- advantages:
  - each round of probes observes more paths
  - One probe per link
  - Scan the entire network in one pass
  - !!Reducing the number of probes translates into bandwidth and energy savings!!



Challenges: ...of a Broadcast Network

MAC

- no acknowledgment for broadcast packets
- no congestion avoidance function for broadcasting
- not clear how to add this functionality without complextiy or potential ack implosion

Routing

- Changes on the notion of routing from a single shortest path to a multipath problem
- Decisions are made after reception, not at the time of transmission

Transport

- Interflow coding: High loss rate is a sign of congestion by transport protocols, causing them to reduce their rate unnecessarily
- Intraflow coding: Coding and Decoding involve linear operations over batches of packets
- Window-based protocols don't cope nicely with batching
- Redesign of transport protocols

Challenges: ...of Coding

Fast Coding

- Intra-flow coding is computationally expensive
- Examining innovation adds complextiy
- Decoding involves solving a system of linear equations, a fact that increases complexity

Forced Reliability

- Intra-flow coding requires n linear combinations for n packets. Anything less is useless
- Stringent requirements for reliable delivery

Reatime-Traffic

- Requirement for low or no delay on receiving n linearly combined packets, regarding intra-flow coding
- Requirement of n sufficient enough to optimally mix the information

Conclusion

- Network Coding promises new opportunities for improvement regarding throughput, monitoring, mobility, reliability etc
- Need for rethinking and redesigning the Wireless Network stack: MAC, Routing, Transport