Network Coding for Resource-Efficient Operation of Mobile Clouds

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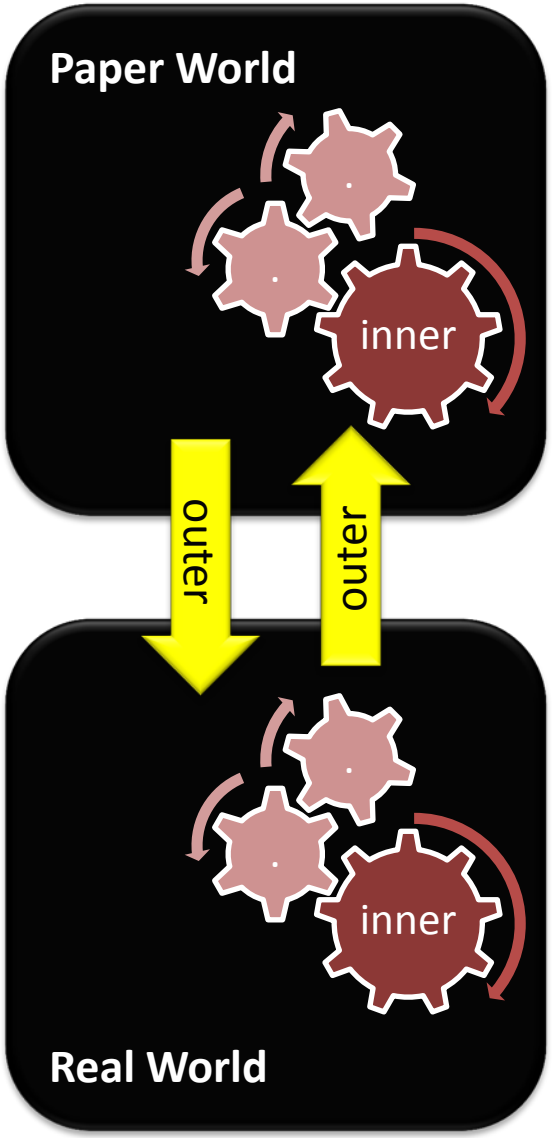
Short intro

- Aalborg University
- Research work on
  - Cooperative Wireless Networks
  - Cognitive Networks (not so much the radio part)
- Heading the mobile device group
  - Implementing “paper work” into “real world” AND feedback the output (evolution theory)
  - Mobile device it THE device
  - Nokia Innovation Network (NIN) member

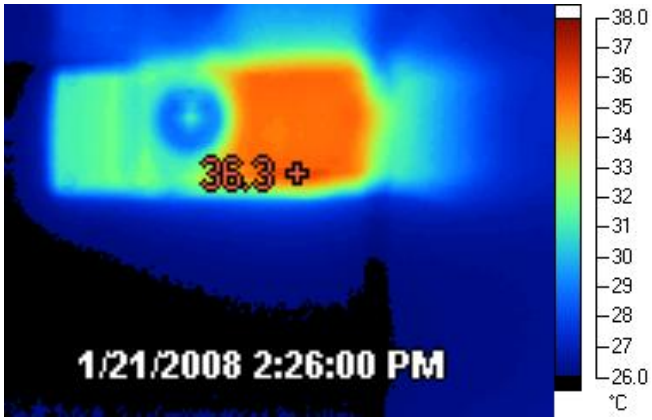
Rocket Science

- Bringing a rocket into space is simple – on paper
- Simple Newton laws are enough
- Real problem is the realization
- Year of testing needed to understand basic problem for rockets with liquid fuel



Problems for Mobile Devices

- Services (Apps)
  - Make the difference for the user
- High speed Internet Access
  - Monolithic approach is limited
  - Spectrum
- Energy and Power
  - Long operational times
  - Green aspects
  - Heating problems

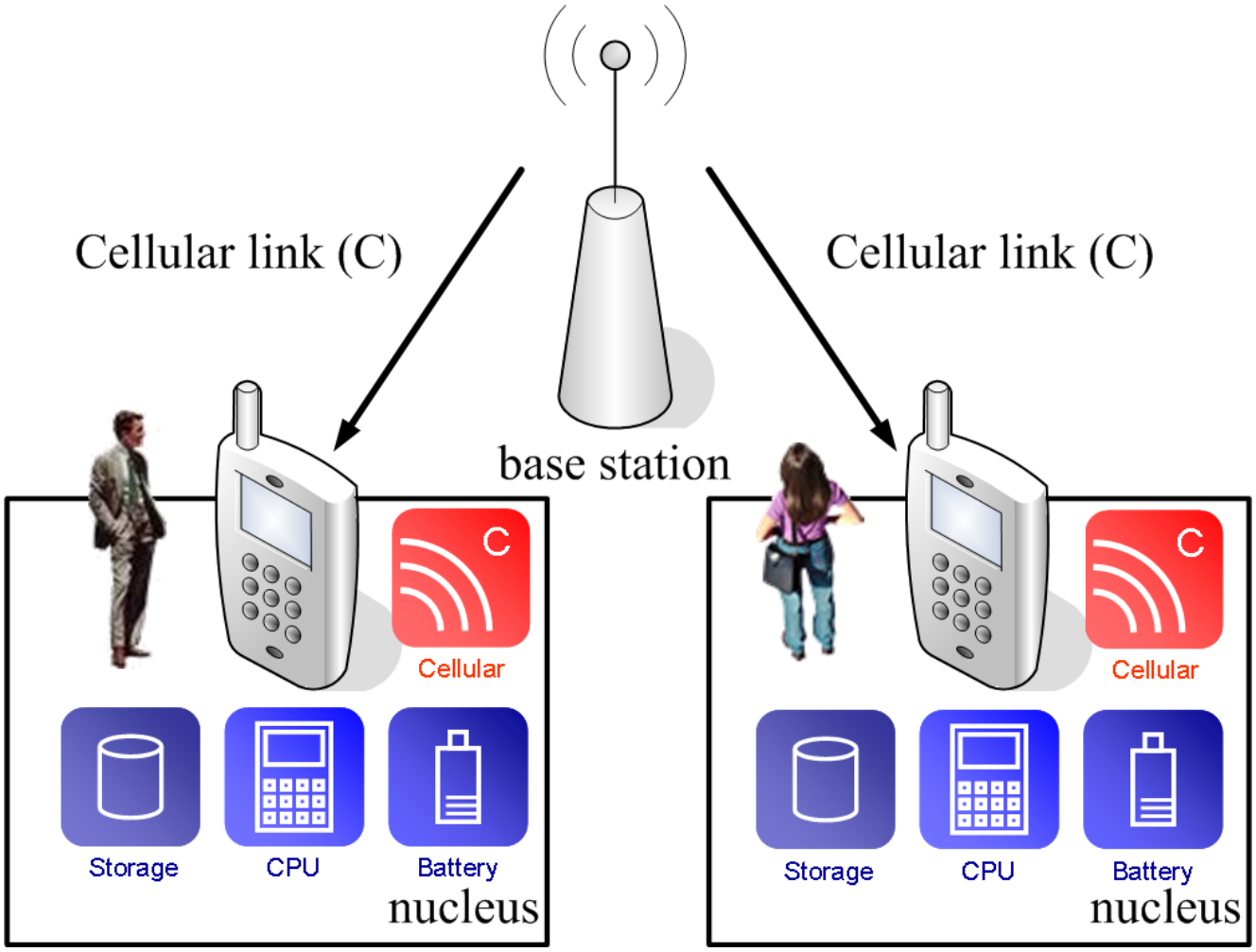


Today‘s Talk

Resource Sharing in Mobile Clouds

Communication within the Mobile Cloud

Monolithic Approach



Private Clouds

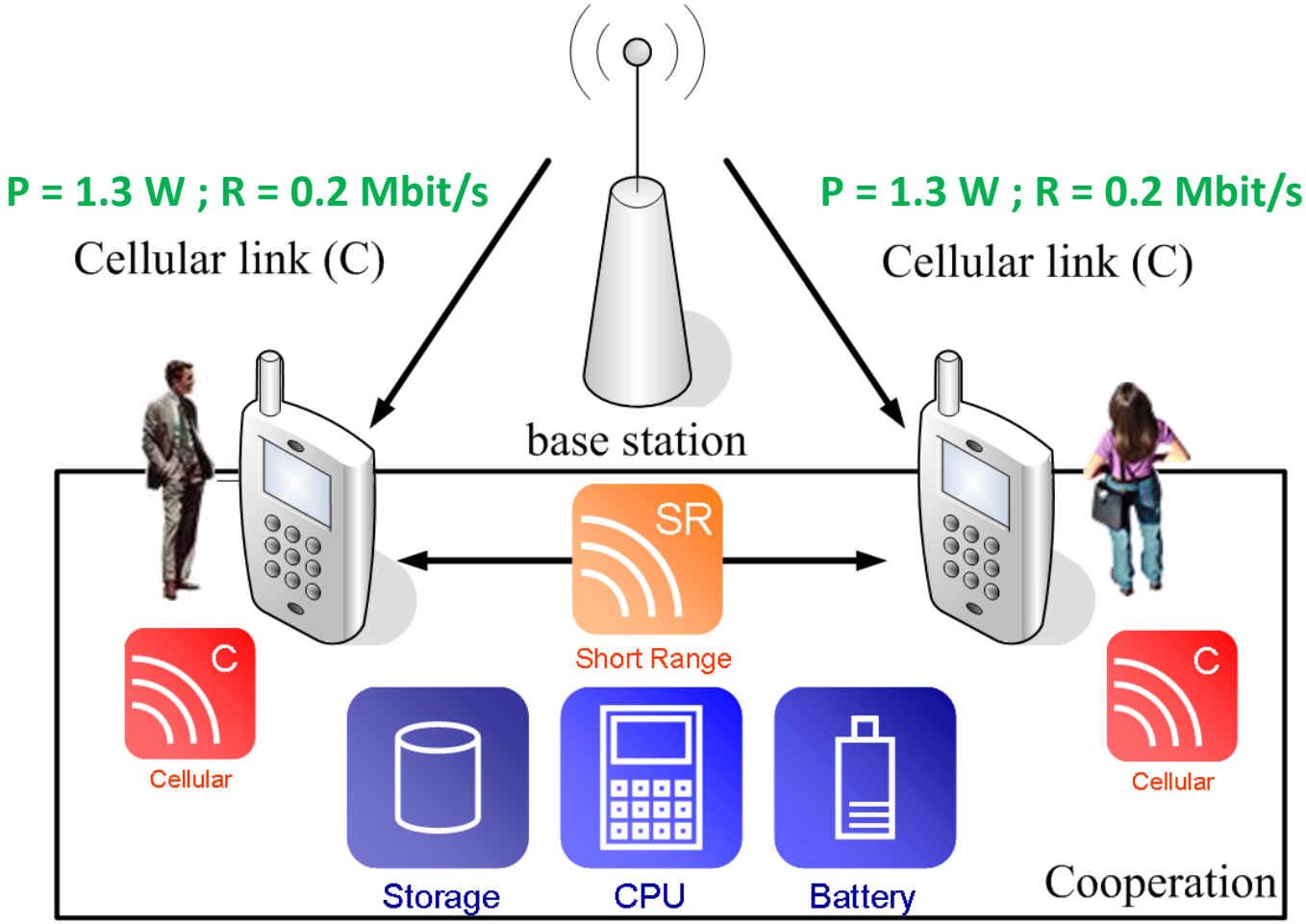
Private (Fixed) Cloud – Motorola

Private Mobile Cloud - phonedeck

Altruistic Sharing

- Mobile Hotspots
- Cellular connection is shared with others
  - Own devices
  - Friends
  - Others (?)

Public Mobile Clouds

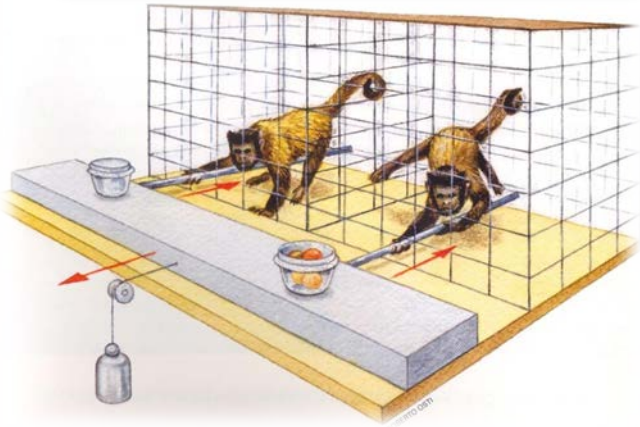


P = 1.6 / 1.3 W ; R = 5 Mbit/s

ENERGY PER BIT COUNTS

Basic rules of cooperation

1. Egoistic behavior rules!
   (No slavery, no altruism!)
2. Reciprocity (vampire bat)
3. Detection of cheaters (vampire bat)
4. Pay off tolerance (monkeys)



Two examples

Video services / Download

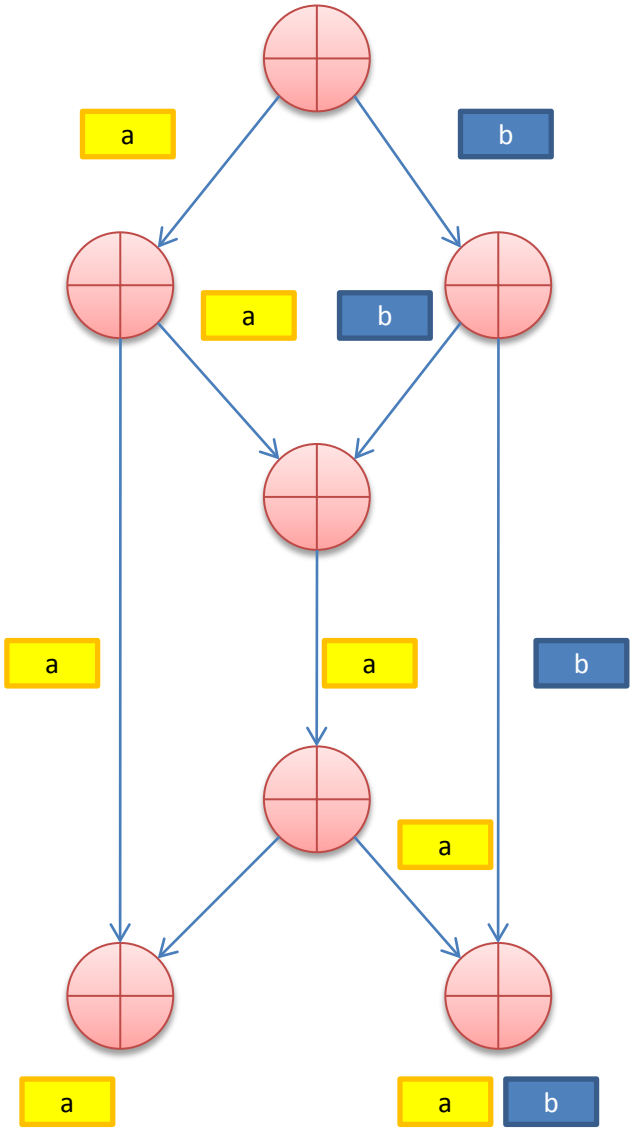
- All members of the cooperative cloud are interested in the SAME content
- Reduction of the cellular data rate but increased exchange of local short range
- Each cooperating entity gains in the very same moment.

Web Services

- Members of the cooperative cloud are interested in different content
- Cellular air interface activity versus reading phase 1:4
- Pay off tolerance becomes an issue
- Building up trust in short time is needed

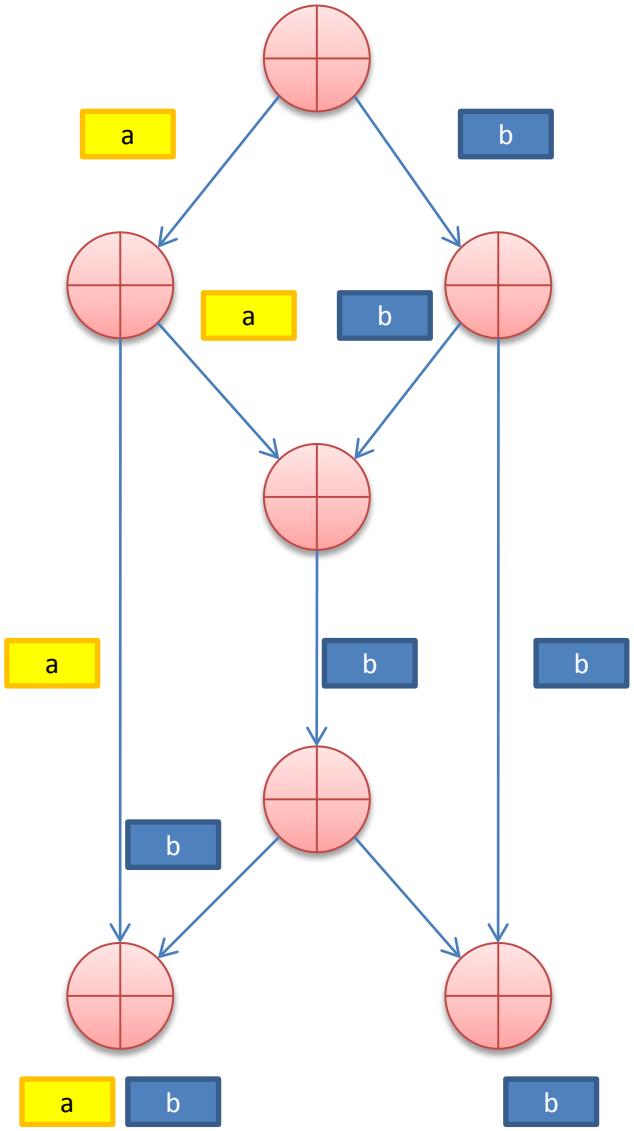
NETWORK CODING

Network Coding: The Butterfly



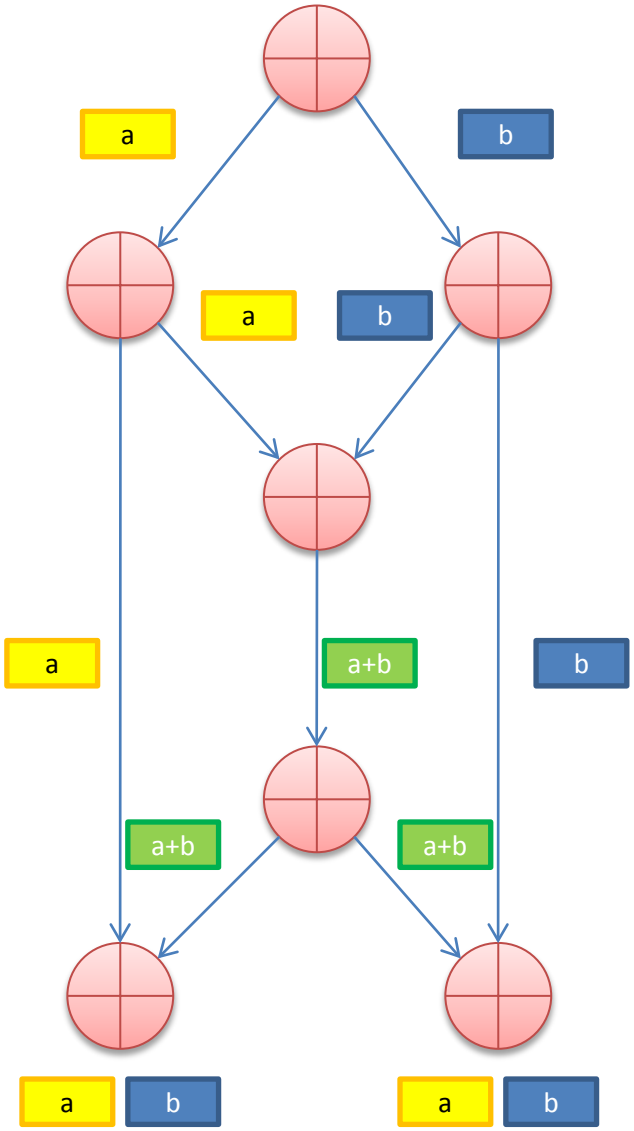
- Two packets a and b should be conveyed to two destinations
- Bottleneck in the middle
- Either packet a or b will path the bottleneck

Network Coding: The Butterfly

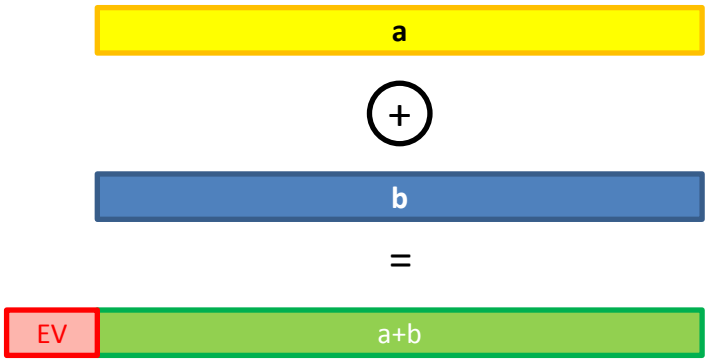


- Same old problem

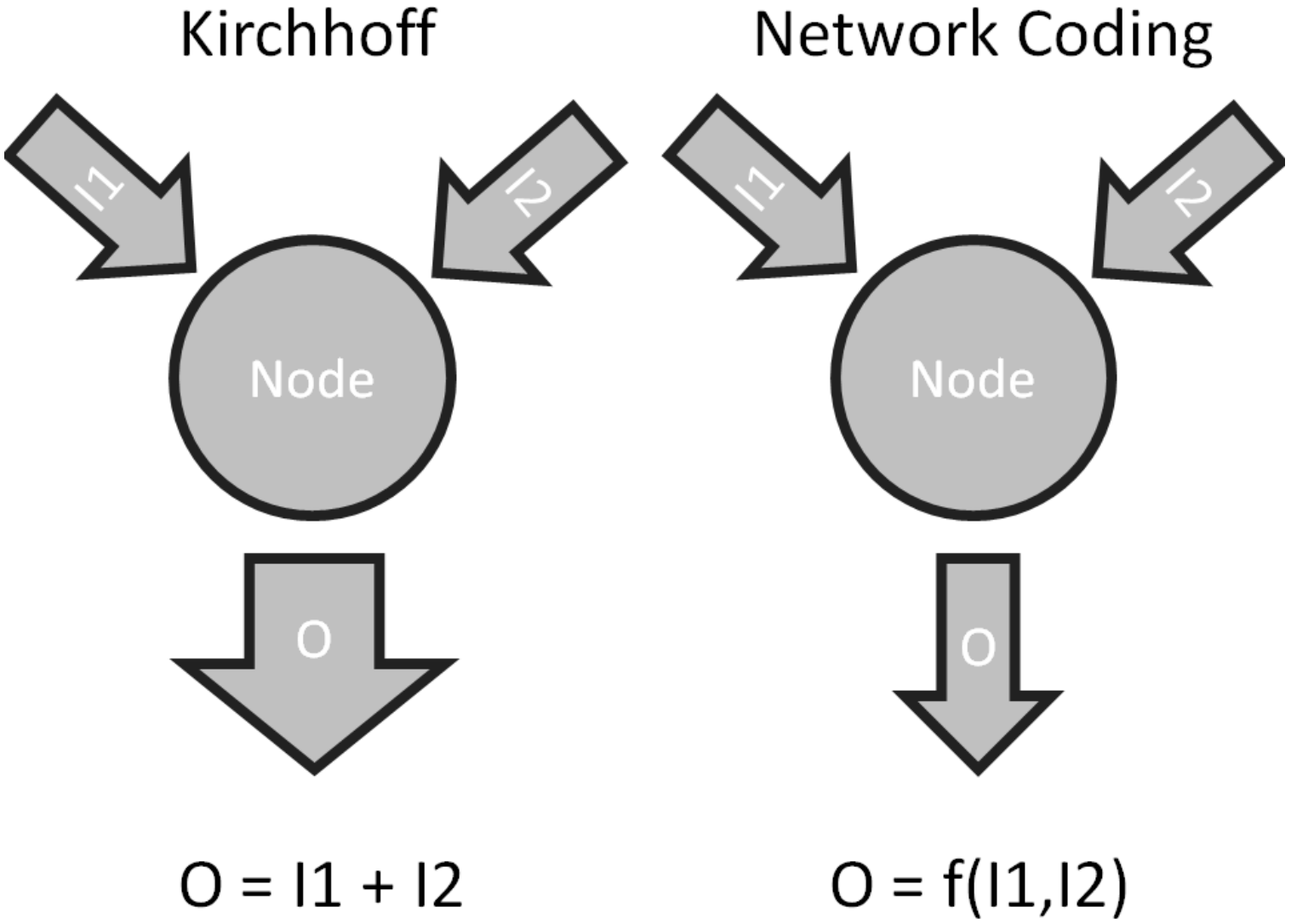
Network Coding: The Butterfly



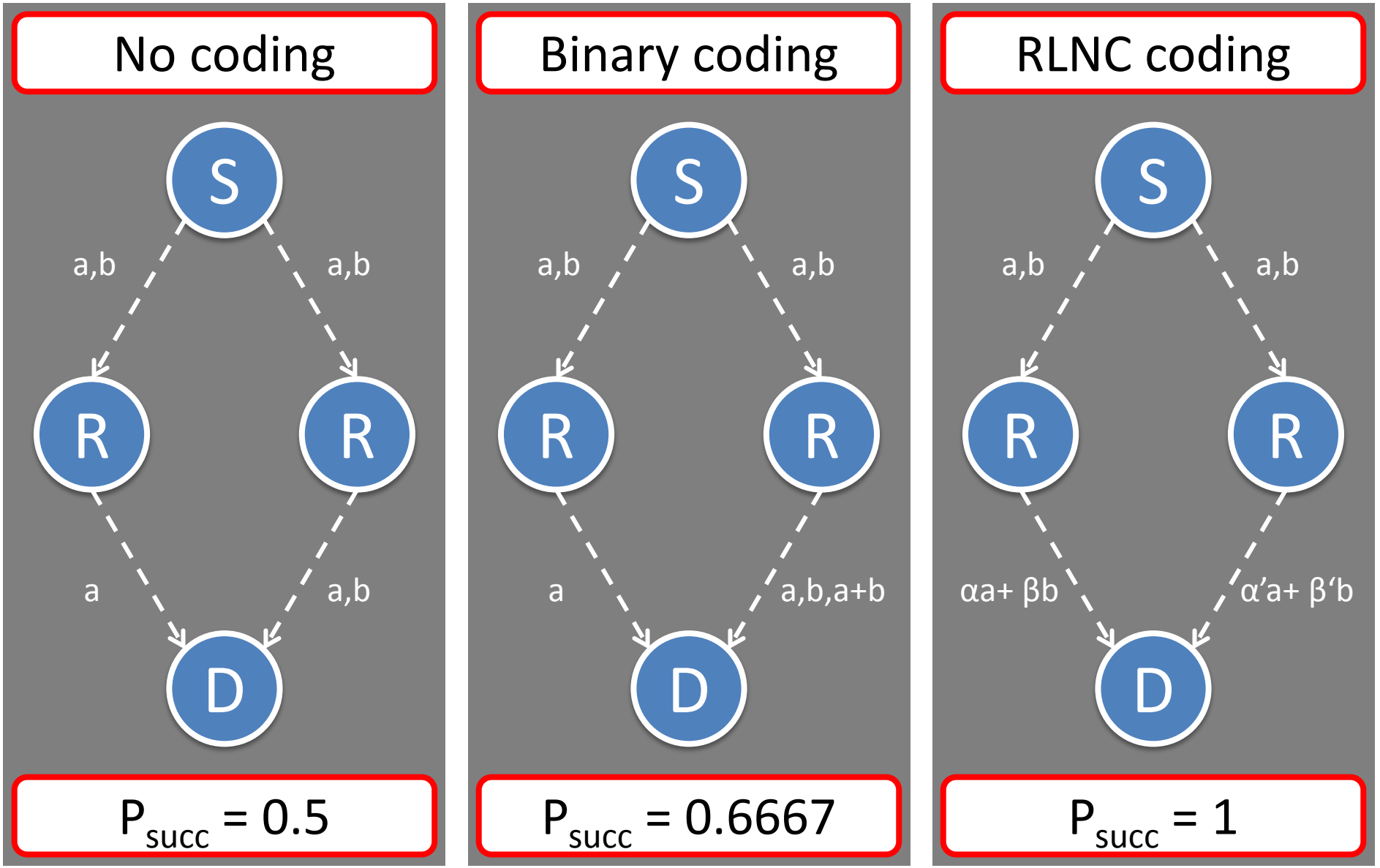
- Ahlswede et. al. In 2000
- Coding the packet
- Other ideas were around
- Max-flow min-cut theorem



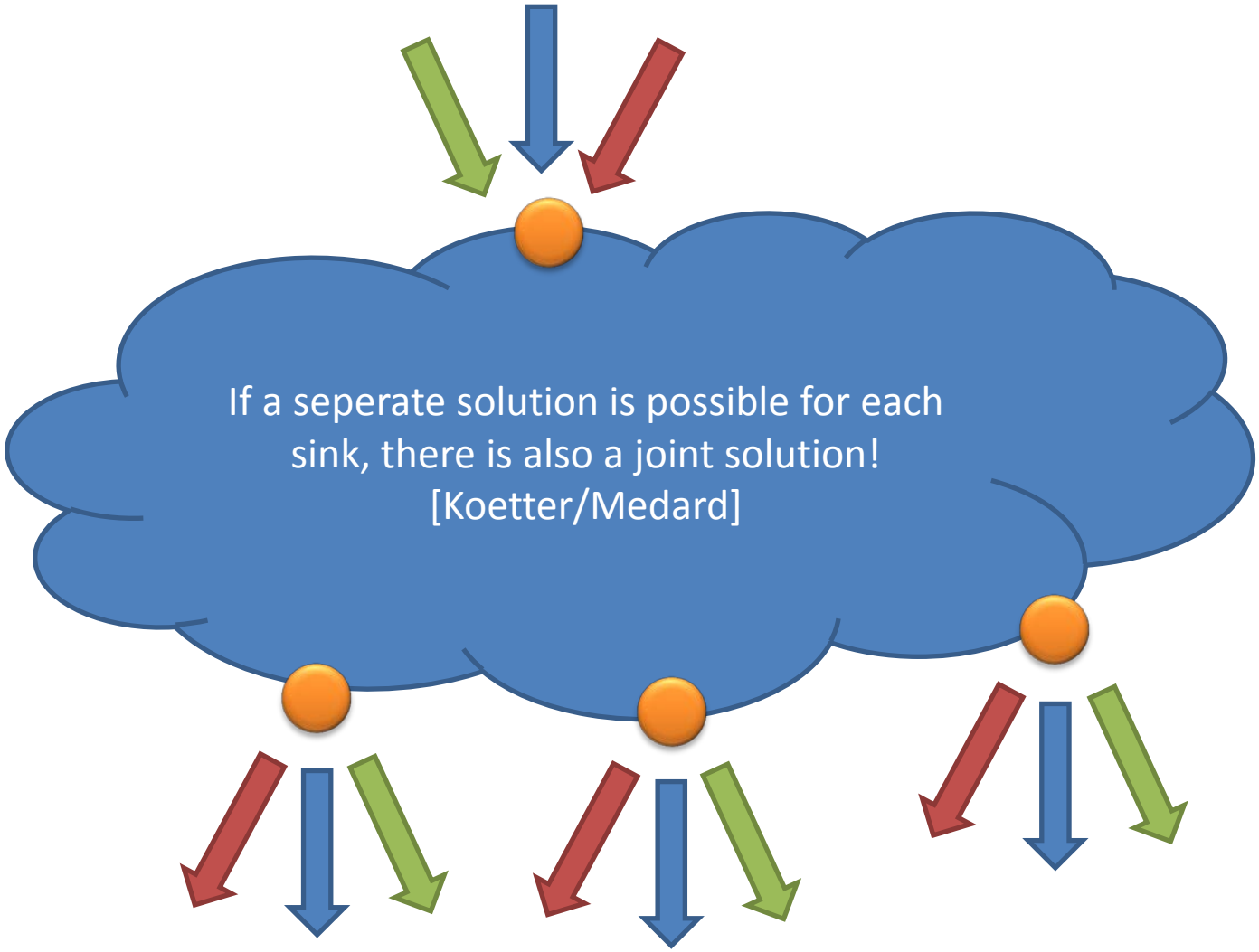
Kirchhoff versus Network Coding



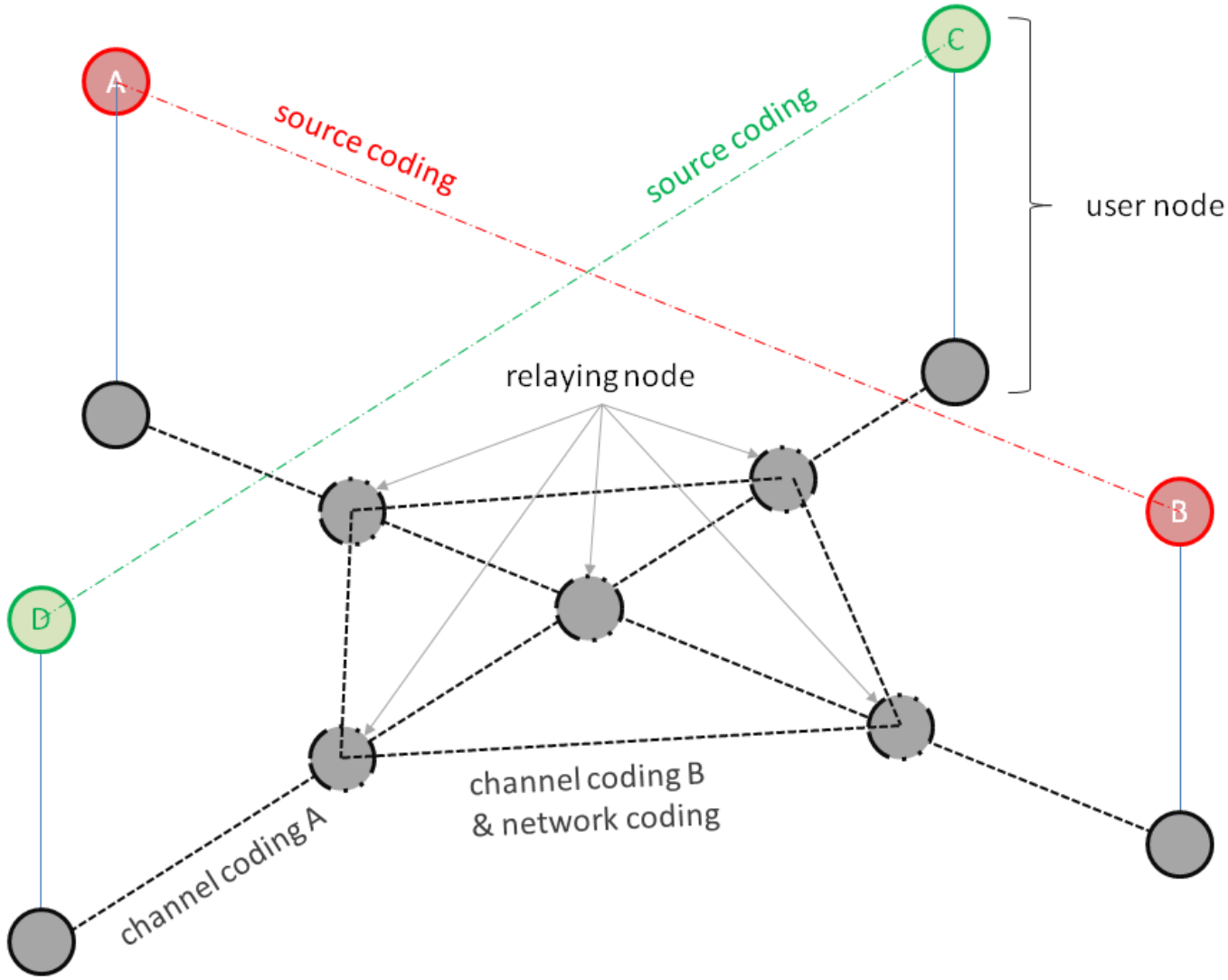
Coding


No coding
S
a,b
a,b
R
R
a
a,b
D
P_{succ} = 0.5
Binary coding
S
a,b
a,b
R
R
a
a,b,a+b
D
P_{succ} = 0.6667
RLNC coding
S
a,b
a,b
R
R
αa+ βb
α'a+ β'b
D
P_{succ} = 1

Network Coding

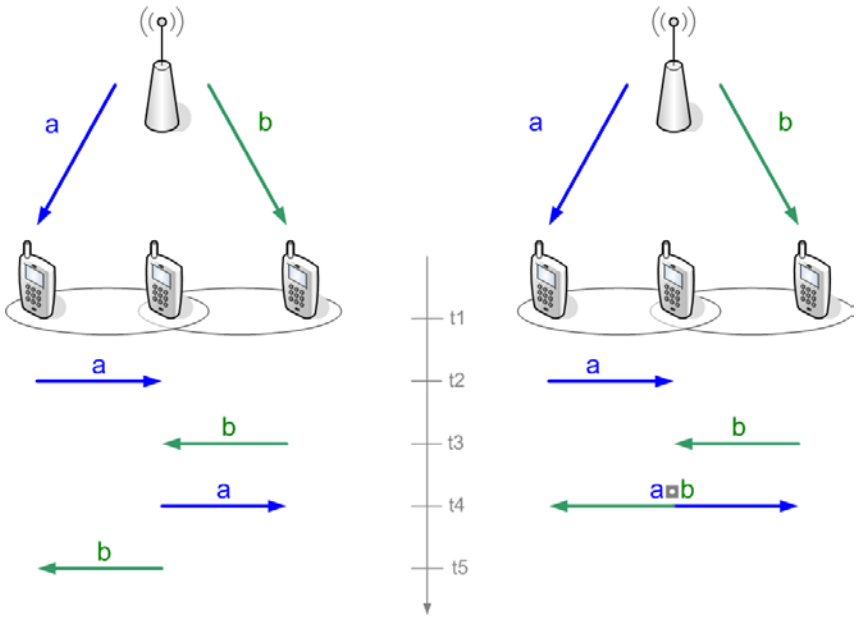


Different forms of coding

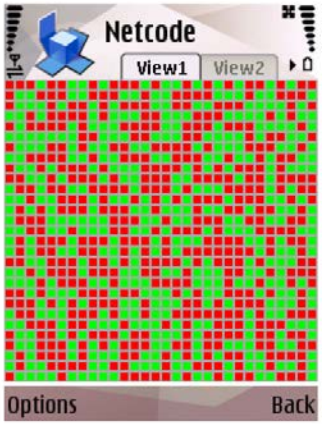


Network Coding for Cooperative Wireless Networks

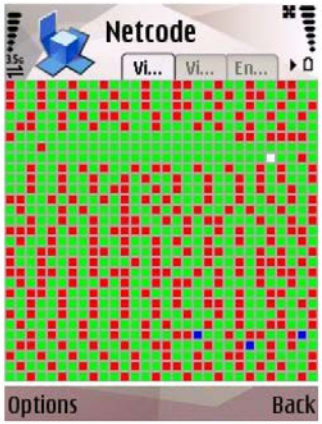
- Our starting point
- Simple scenario
- Seeding of packet a and b is crucial
  - Fairness
  - Performance
- Forms of NC
  - XOR in the air (COPE)
  - RLNC



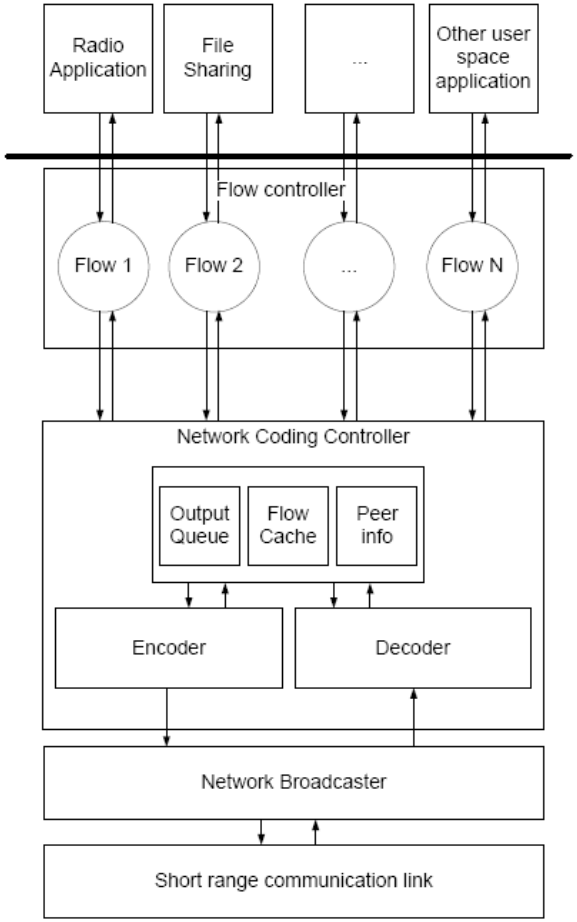
XOR


Netcode
View1
View2
Options
Back

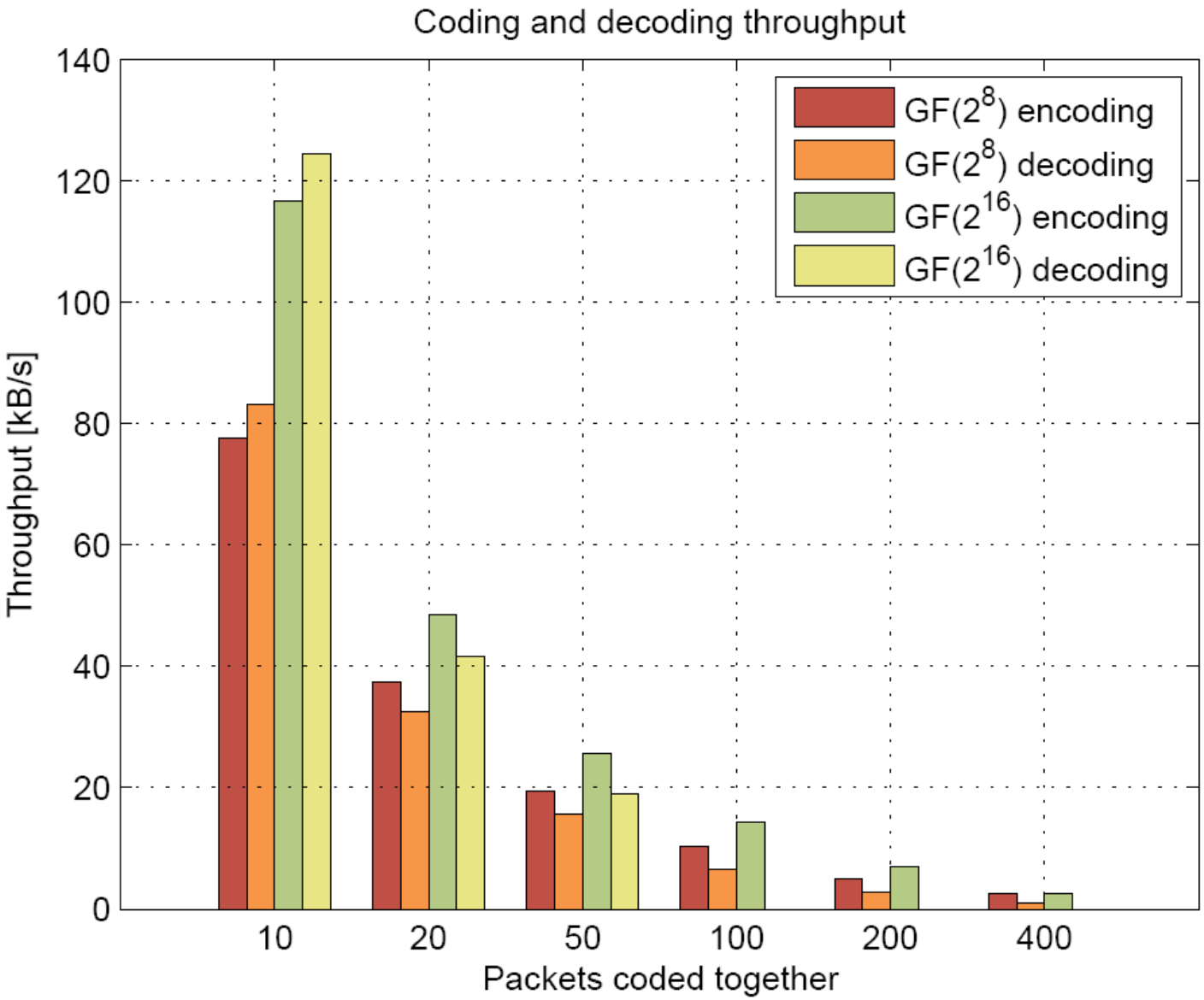
(a)


Netcode
Vi...
Vi...
En...
Options
Back

(b)


Radio Application
File Sharing
...
Other user space application
Flow controller
Flow 1
Flow 2
...
Flow N
Network Coding Controller
Output Queue
Flow Cache
Peer info
Encoder
Decoder
Network Broadcaster
Short range communication link

S60 Implementation RLNC



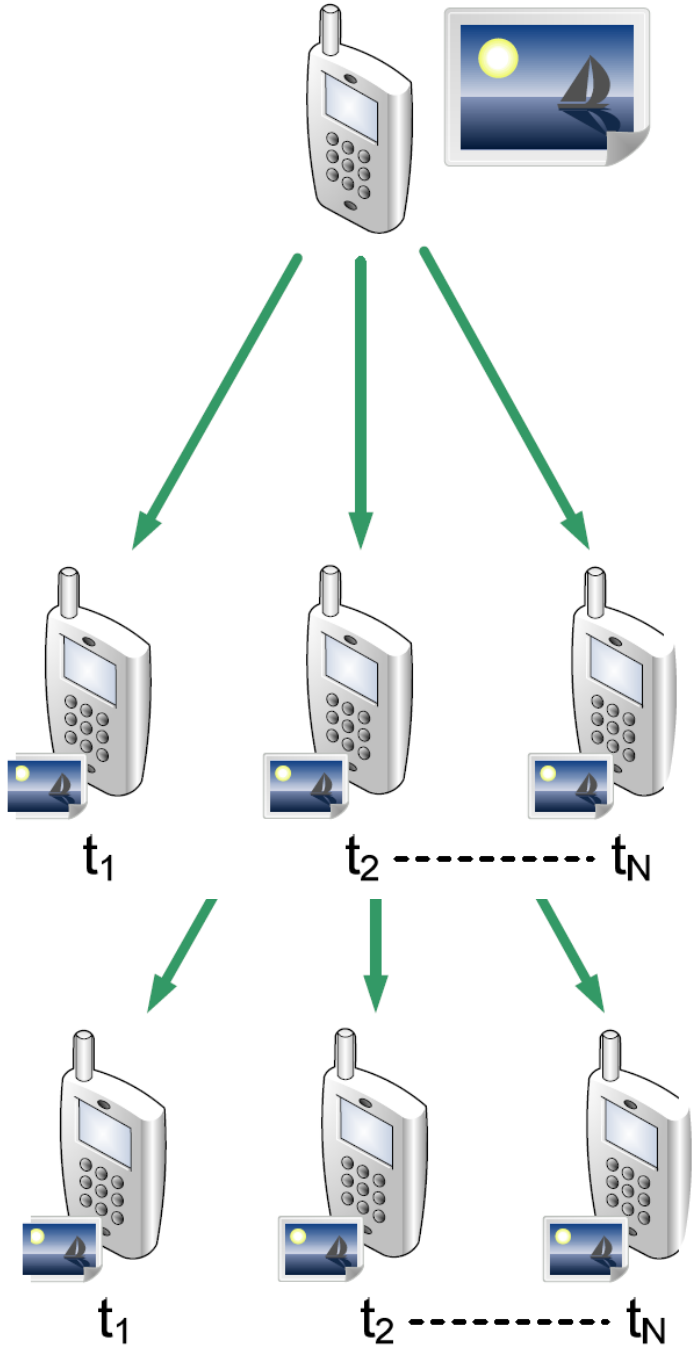
Not for free …

- Overhead due to encoding vector (↑GF++ GS++)
  - Additional bits to indicate which packets are coded together
  - Seed trick reduces this to zero
  - “Intrinsic information exchange”
- Computational overhead (↑GF++ GS++)
  - Coding/Decoding is not for free
- Network Overhead (↓GF++ GS++)

- GF size and the generation size (GS) determine the performance

PictureViewer

- Convey information of your mobile phone to your neighbors.
- How to do this?
- What about multi-hop?



Results of Preanalysis (g=64) 1/2

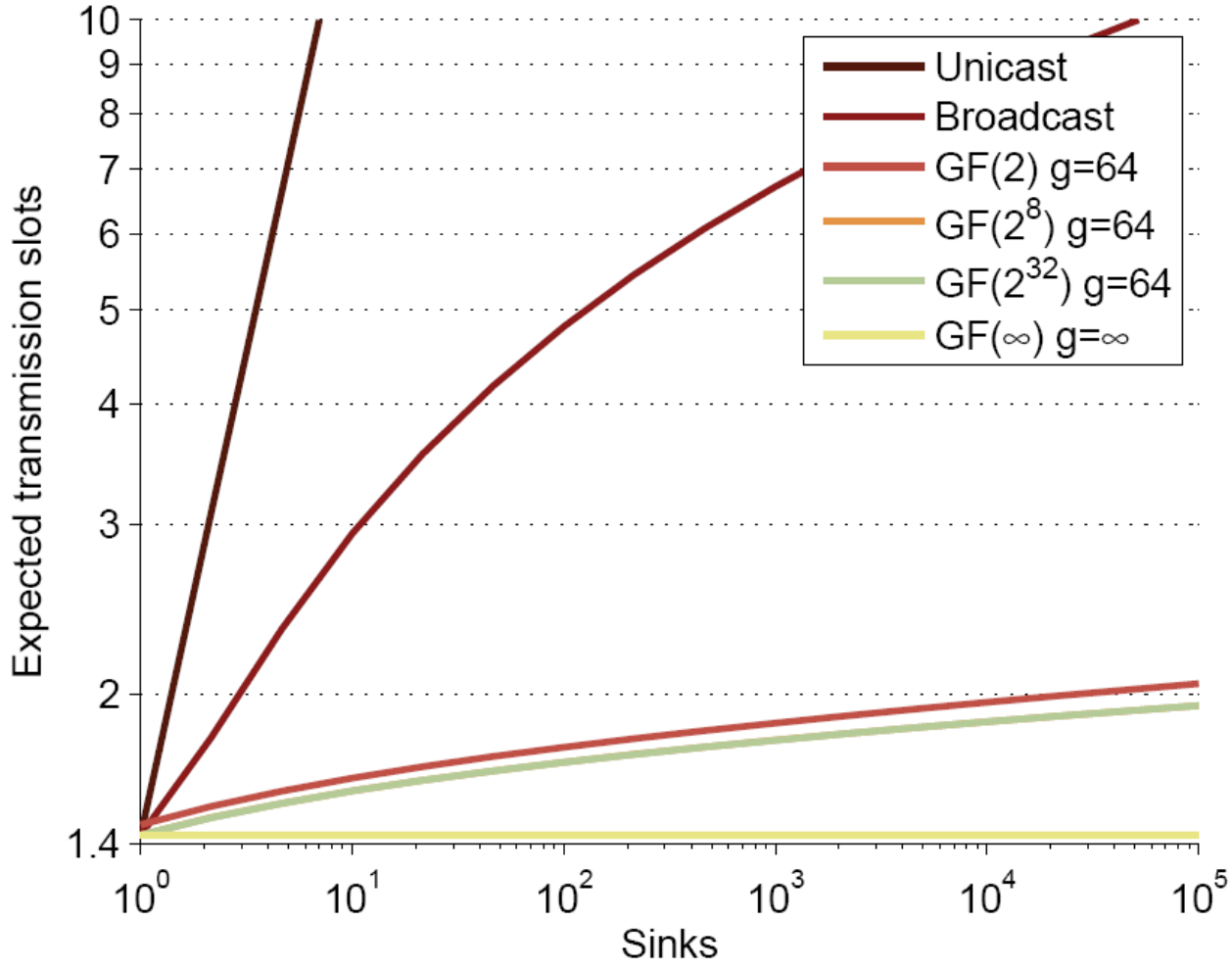


Fig. 4: Expected number of transmission per packet, $p = 0.3$.

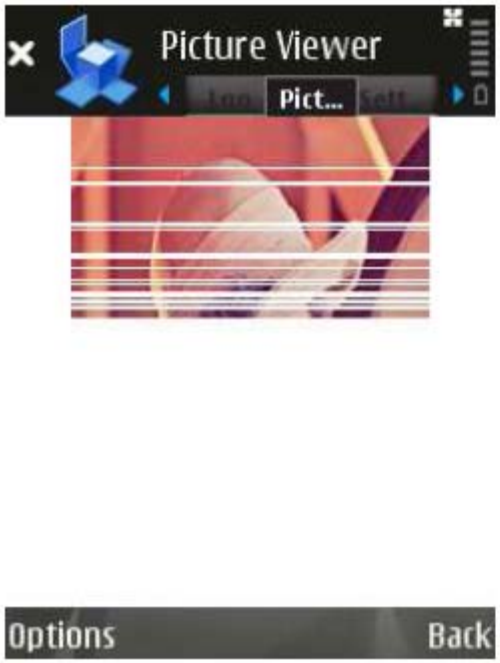
Network Coding GF(2)

(a)

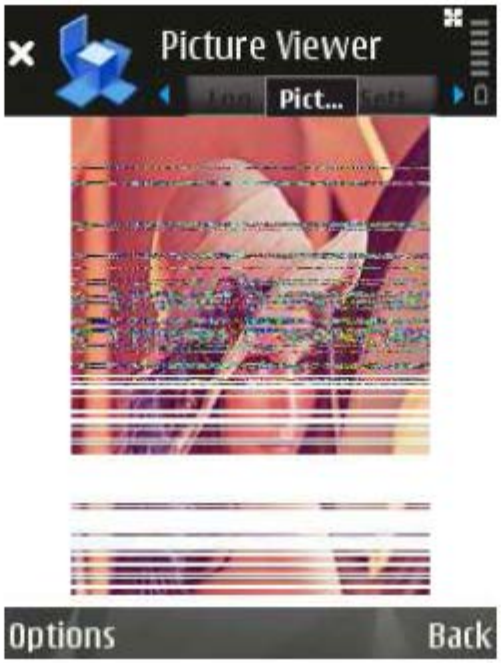
(b)

(c)

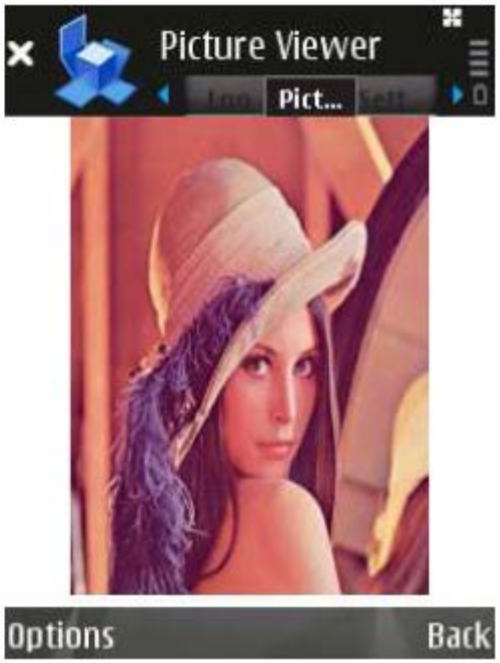
Systematic Network Coding GF(2)



(d)



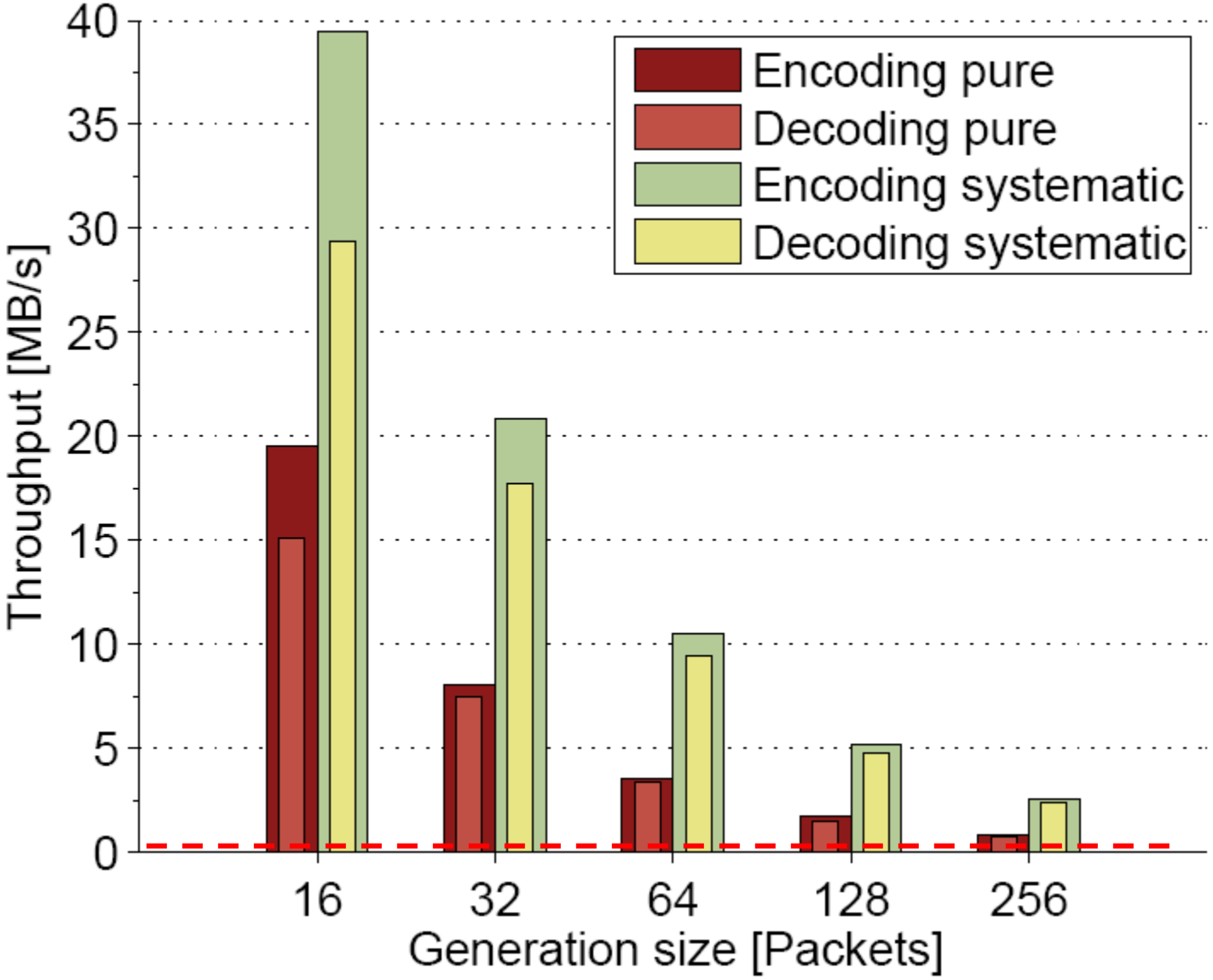
(e)



(f)

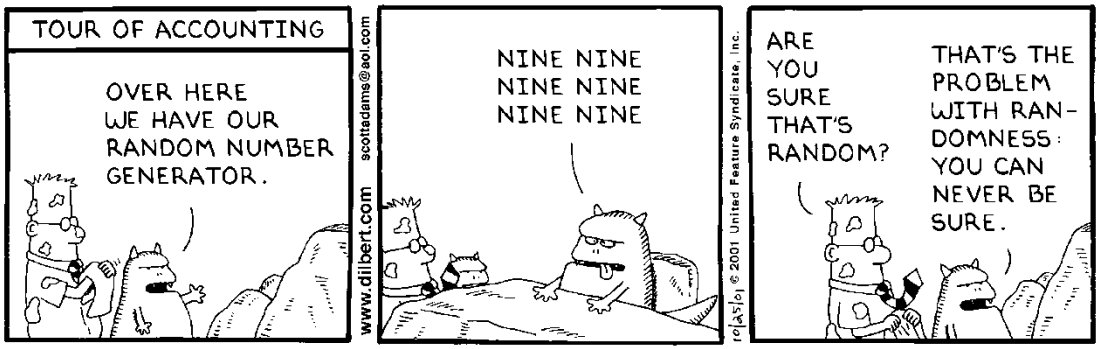
Coding throughput on Nokia N95

Nokia N95-8GB, ARM 11 332 MHz CPU, 128 MB ram, Symbian OS 9.2



NC is real …

- We implemented COPE and RLNC
  - Mobile phones
    - Nokia
    - Android
    - iPhone
  - Laptops
  - Sensor board
- Problems
  - Coding potential is missing
  - Random generator !!
  - Coding performance too bad

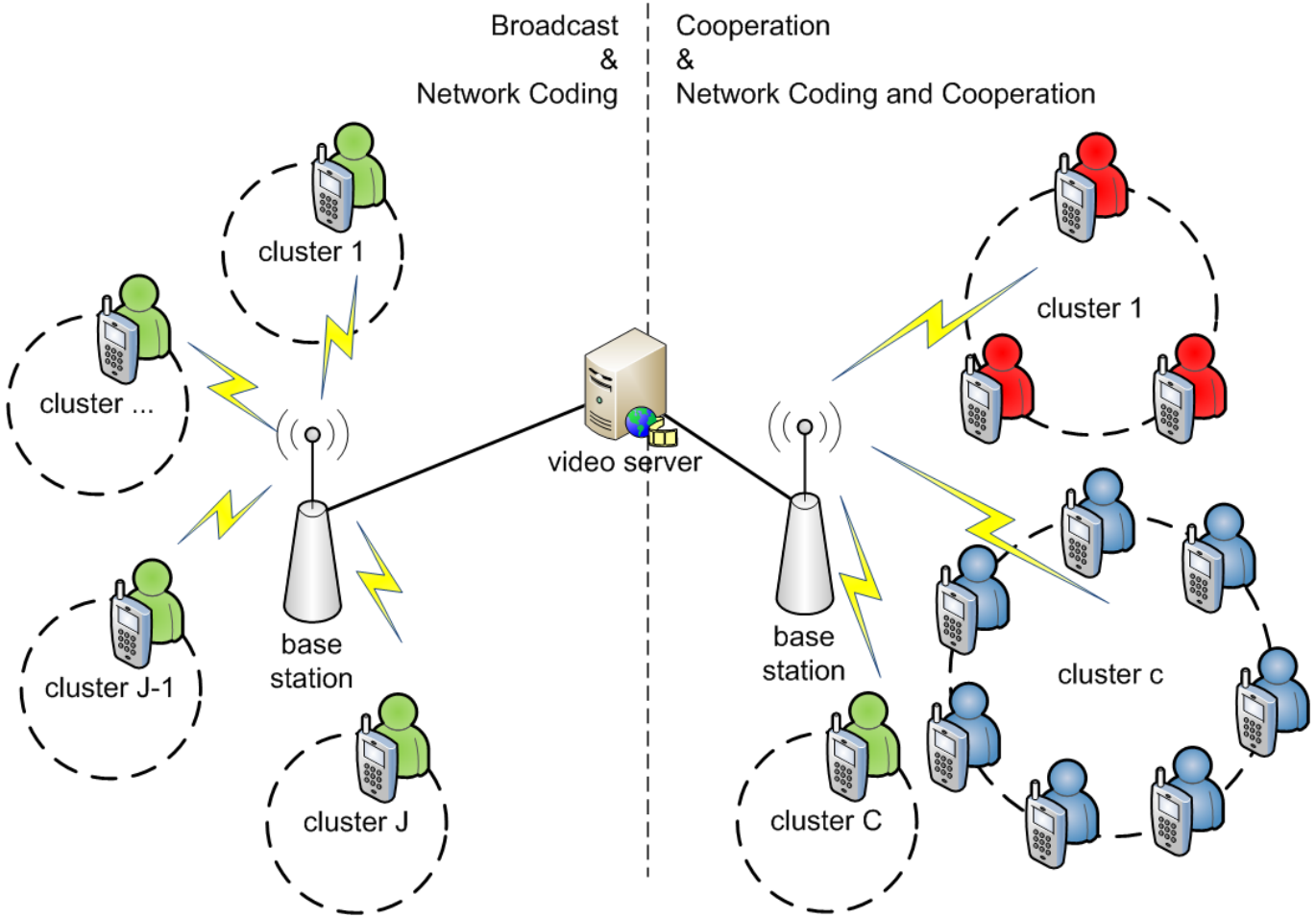


ENOC

ENOC

- Nokia project
- IPTV services over LTE networks
  - RAPTOR codes are used to deliver the content
- New approach
  - Cooperation among devices
  - Network Coding for cluster communication

Scenario under Investigation



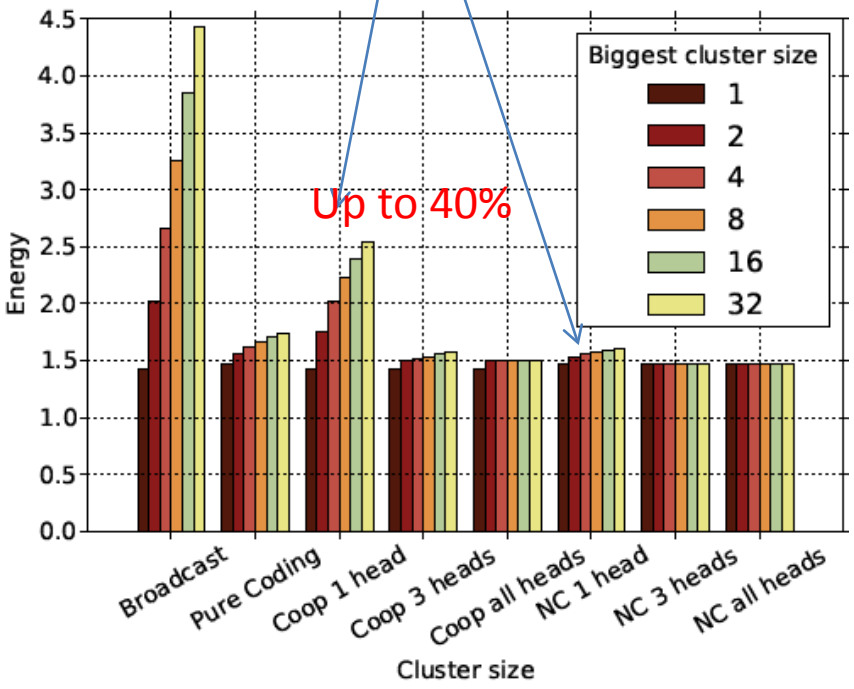
- four scenarios
- 10% error rate
- Generation size inf

Hetero

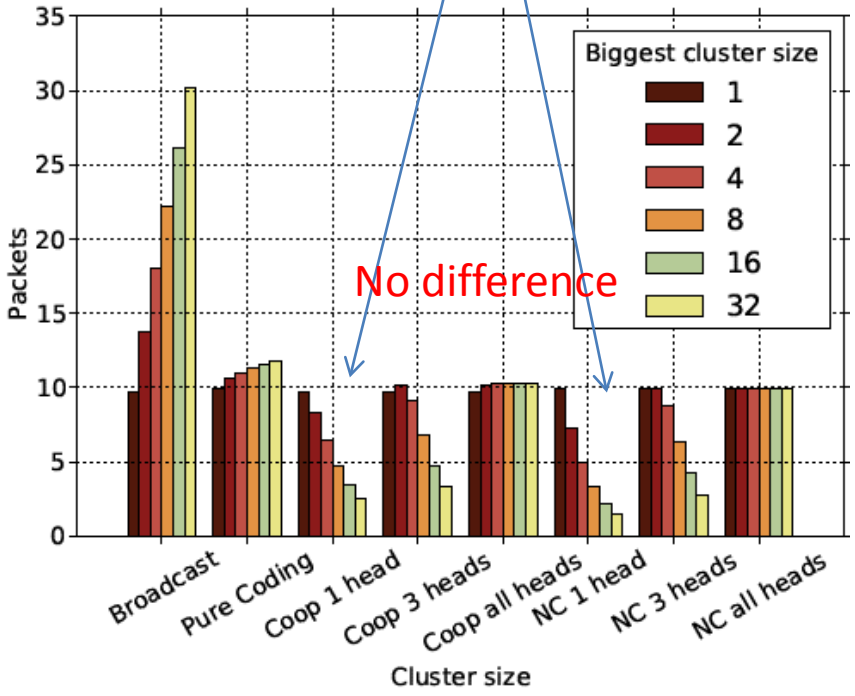
Network Operator will ask for NC!!!!

Nodes might go for Coop or NC coop

BS sends



Energy per node



CATWOMAN

- Multihop network based on BATMAN routing (draft RFC)
- Implementation of network coding on real WiFi access points
- Multi hop

Work by Martin Hundeboll and Jeppe Ledet-Pedersen

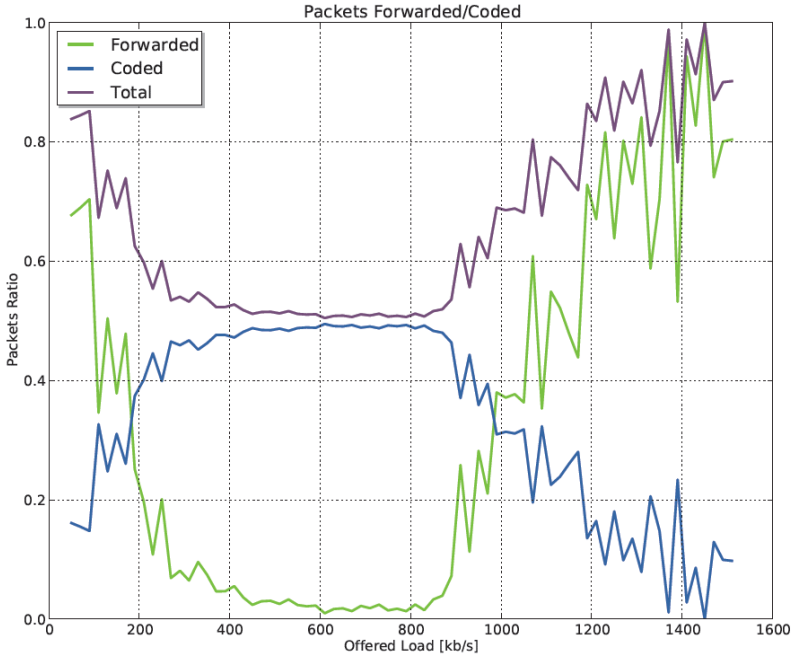
Catwoman

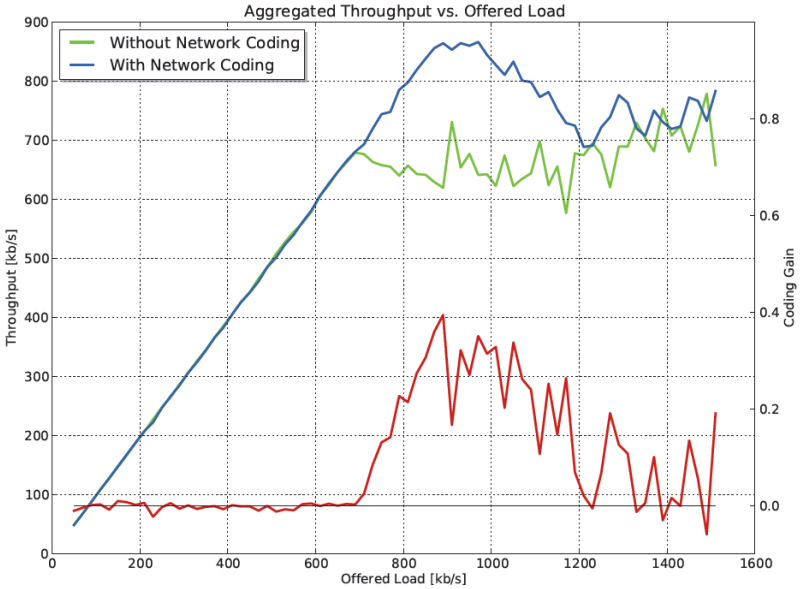
Scenarios under Investigation

- First Alice & Bob
- Later arbitrary networks

Catwoman

Results





Conclusion and Outlook

- Network coding is the missing piece for cooperative wireless networks.
- NC will improve the performance of CWN in terms of throughput and energy consumption.
- NC is not just paperwork. It runs on any device. But care is needed to do it the right way.
- NC offers inherent security

- Seeding packets into cooperative cluster → GA
- Low complexity for higher GF (multi hop)
- Multi hop challenge
- First products will be launched end 2011

Tutorial on Cooperative Wireless Networks

- Free Online Tutorial
- IEEE Tutorial NOW
- Fitzek/Katz
- Recorded at GC 09

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