# Cooperative Wireless Communications

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# Outline

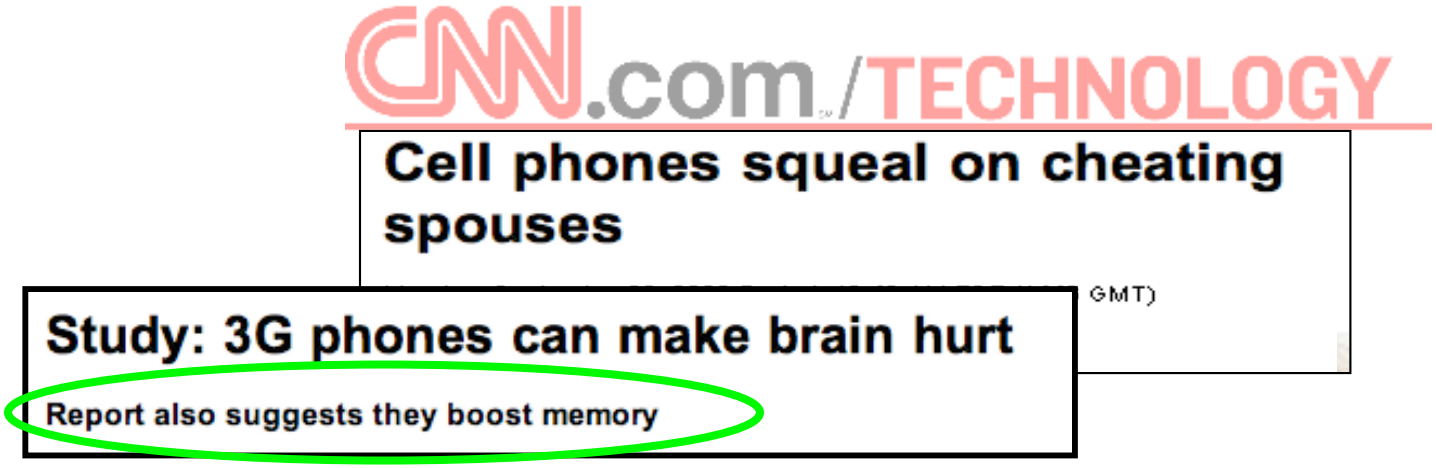
- Growing presence of wireless
- Why do we need a new paradigm
- Cooperative communication basics
- Future directions

# In Numbers

- Global cellular phone market
  - More than 1 billion cellular phone users !
  - $387 billion in 2002
  - Exists in almost all countries
- Emerging markets
  - 18.7 million WiFi cards shipped in 2002 ($1.5 billion)
  - 35 million bluetooth chipsets in 2002 (<$ 1 billion)
  - Camera phones outsold digital cameras in 1Q'03

# If Talking Wasn't Enough


**Boy's cell phone camera helps foil attempted abduction**

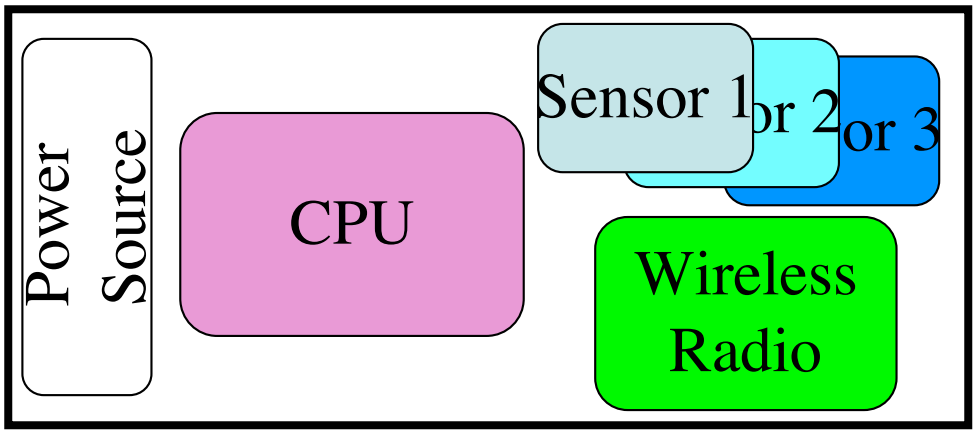


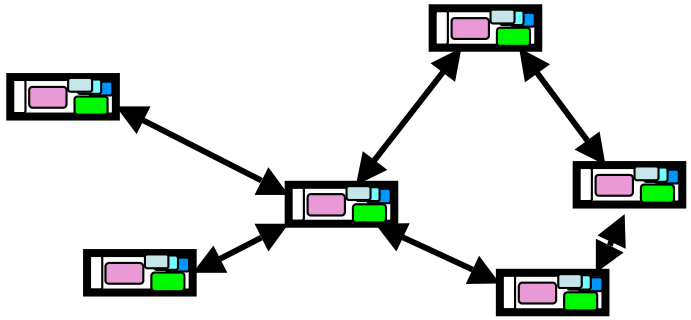
# As Common as Batteries

- Wireless becoming cheaper
  - Cellular phones comparable to landline phones
  - High speed 'Starbucks' wireless
  - Bluetooth (keyboard, mouses, headsets, remotes,…)

- 'Commodity' wireless
  - Wireless transceivers cheap - embed everywhere
  - Commodity wireless has to be intelligent

# Sensor Networks



- Devices to sense and interact with environment
- Data collection, decision making and altering the environment
- Distributed and wirelessly networked

# What's Different ?

- Extremely large number of devices
- Limited spectrum and power per device
- Higher data rates and better battery efficiencies
- A collaborative system, instead of competitive

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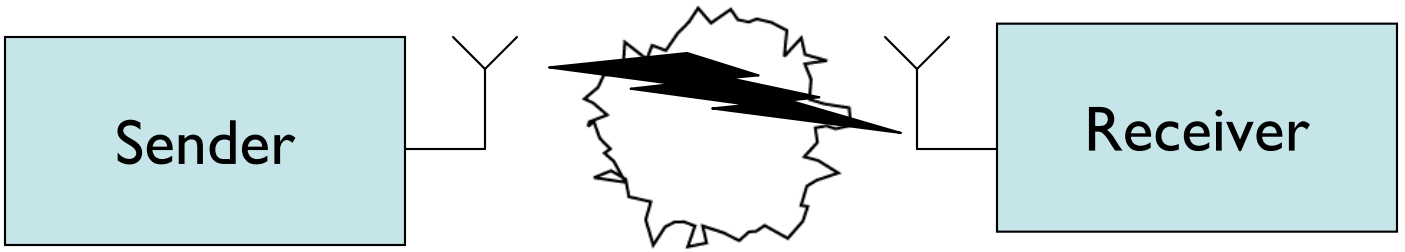
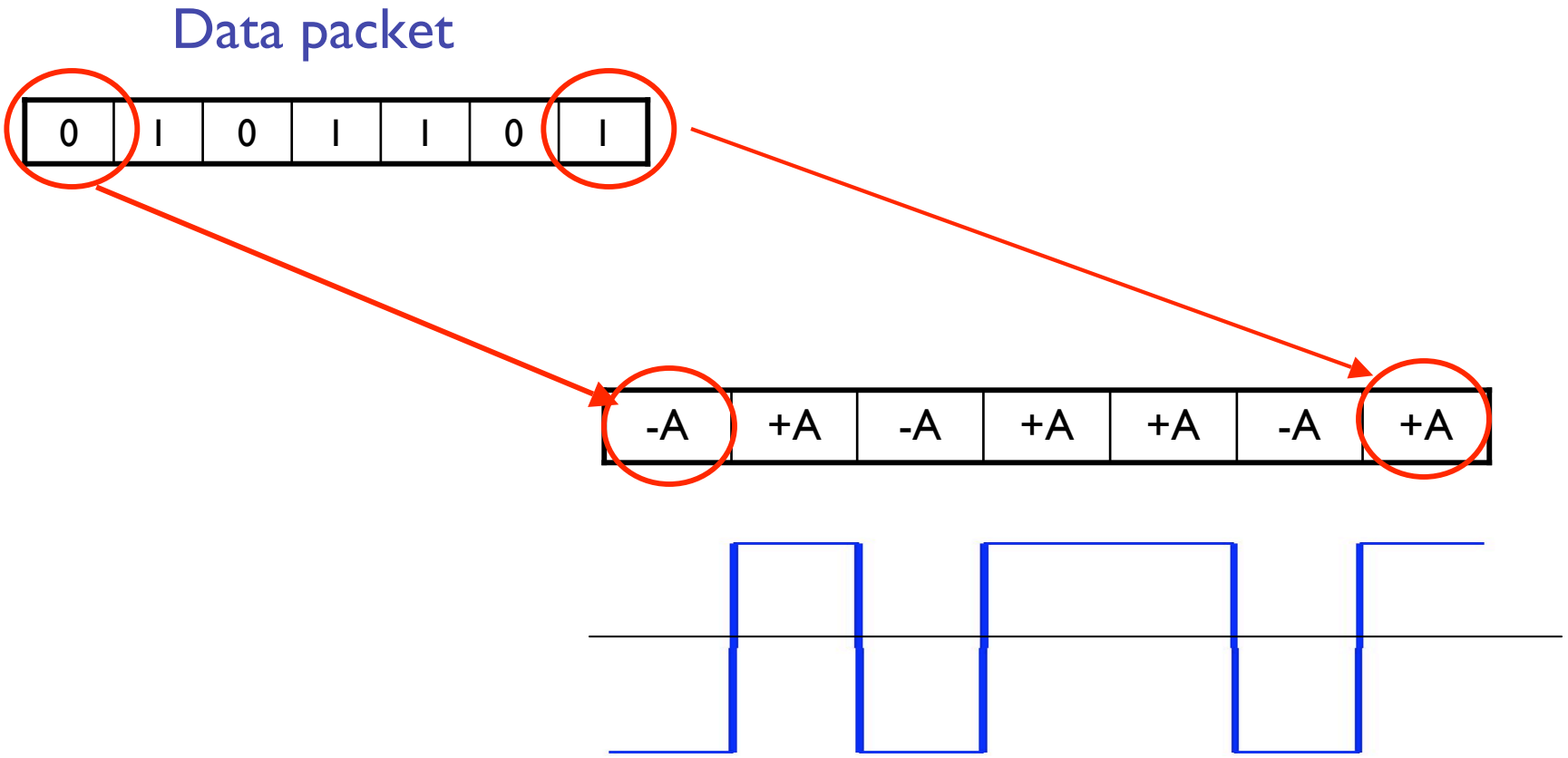
# Point-to-point System

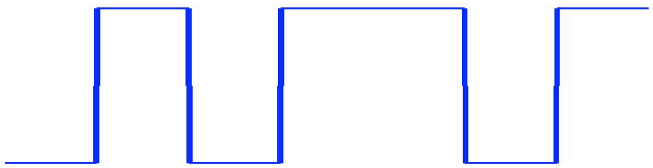


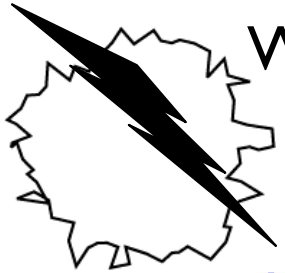

- One sender and one receiver
- Channel attenuates and distorts transmissions
- Objective : Send bits as fast as possible reliably

# Encoding

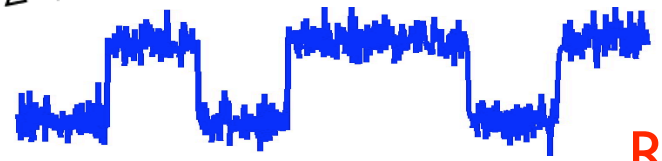


# Received Signal



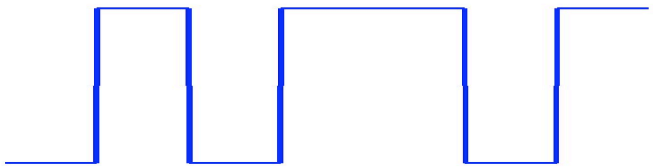


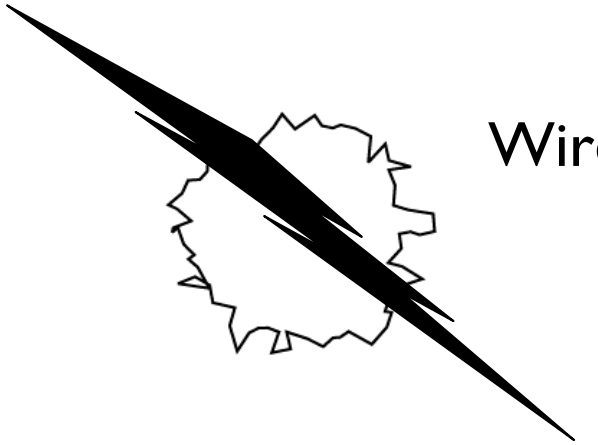
Wireless channel



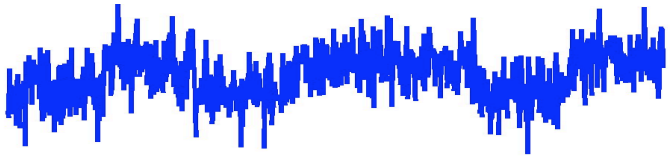
Received signal
after short distance

# Received Signal



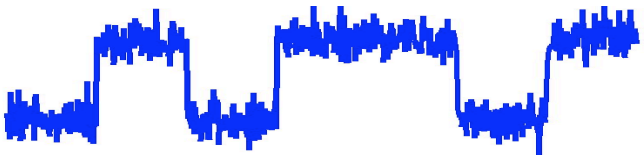


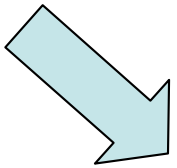
Wireless channel



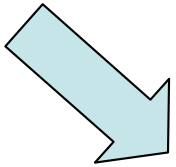
Received signal
after long distance

# Decoding After Short Distance





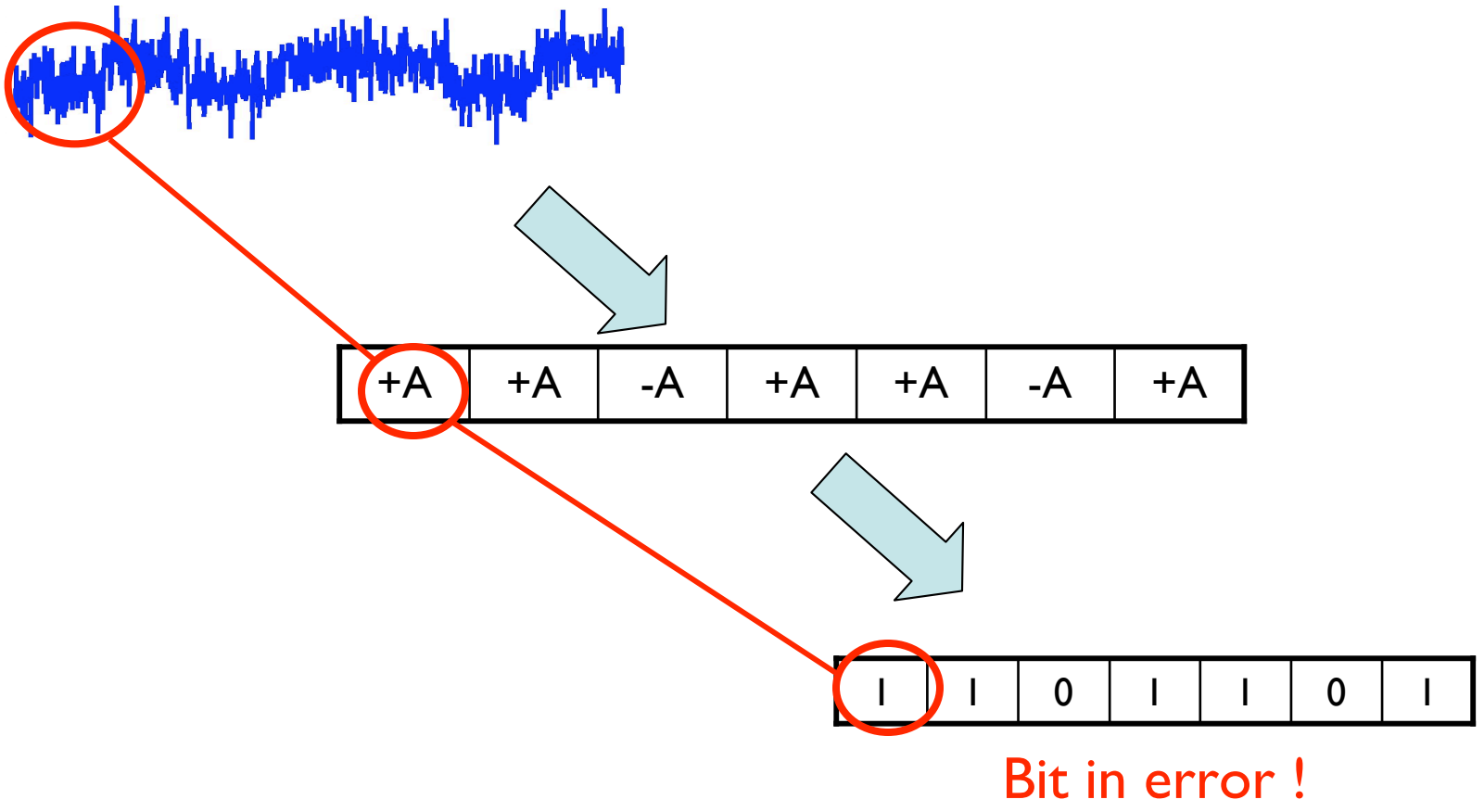
| -A | +A | -A | +A | +A | -A | +A |
|---|---|---|---|---|---|---|



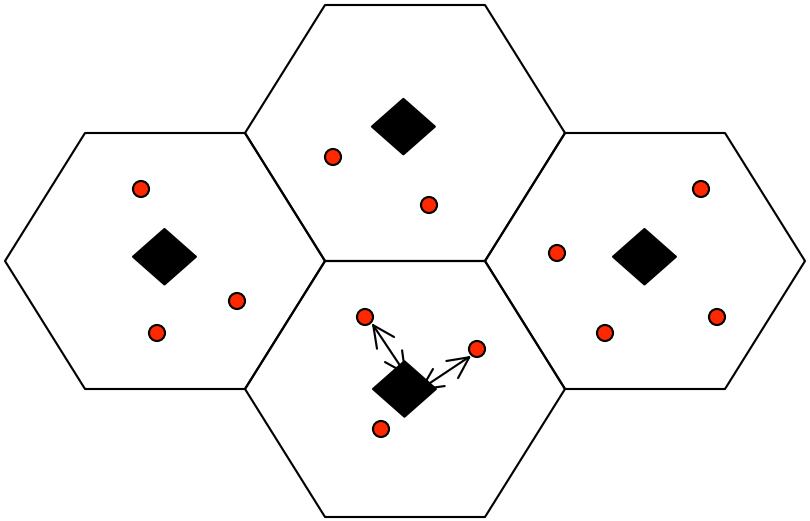
| 0 | 1 | 0 | 1 | 1 | 0 | 1 |
|---|---|---|---|---|---|---|

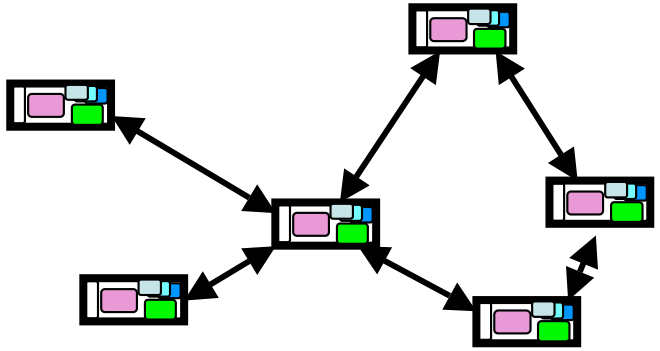
Correctly decoded packet

# Decoding After Long Distance



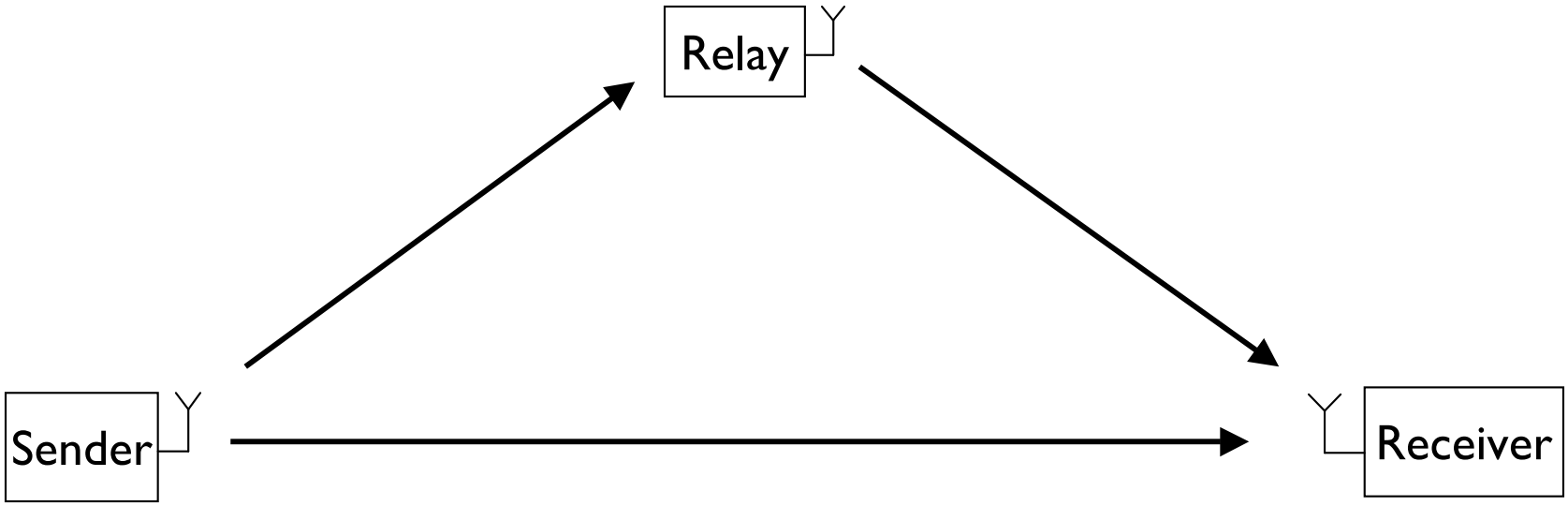
# Building Block: Point-to-Point





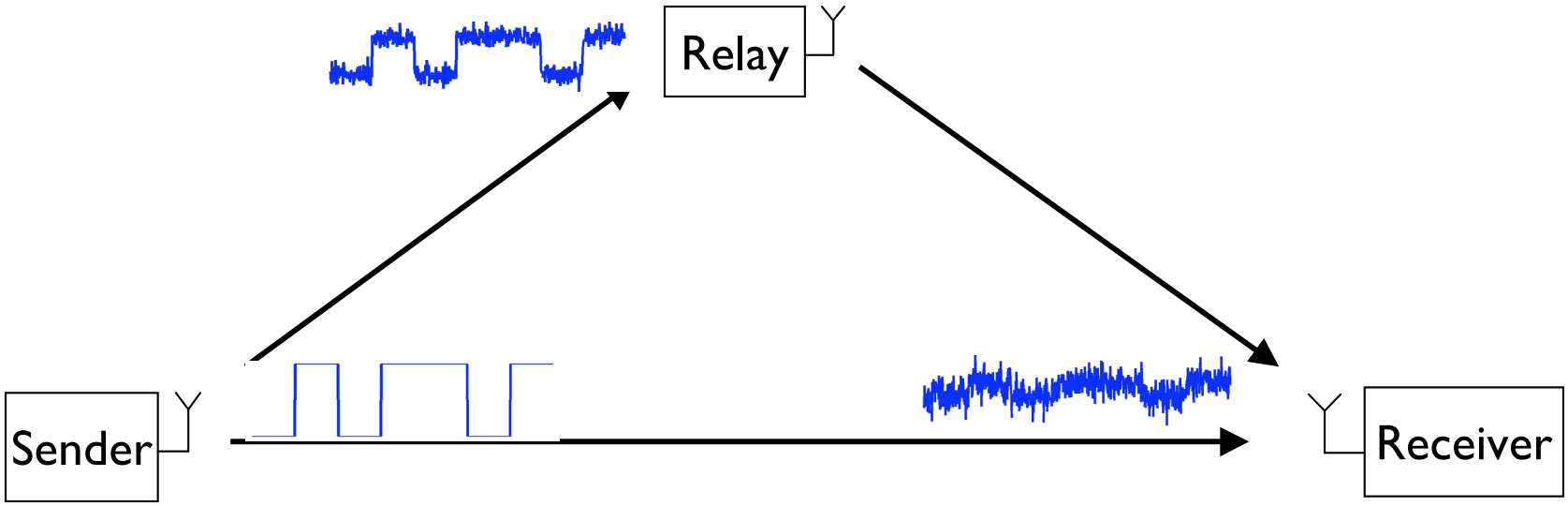
- Point-to-point forms building block for most systems
- Network protocols enable multiple users to co-exist

# Fine-grained Cooperation




- Another node acts as a relay
- Two channels : Direct and via relay
- Key to our gain : cooperation

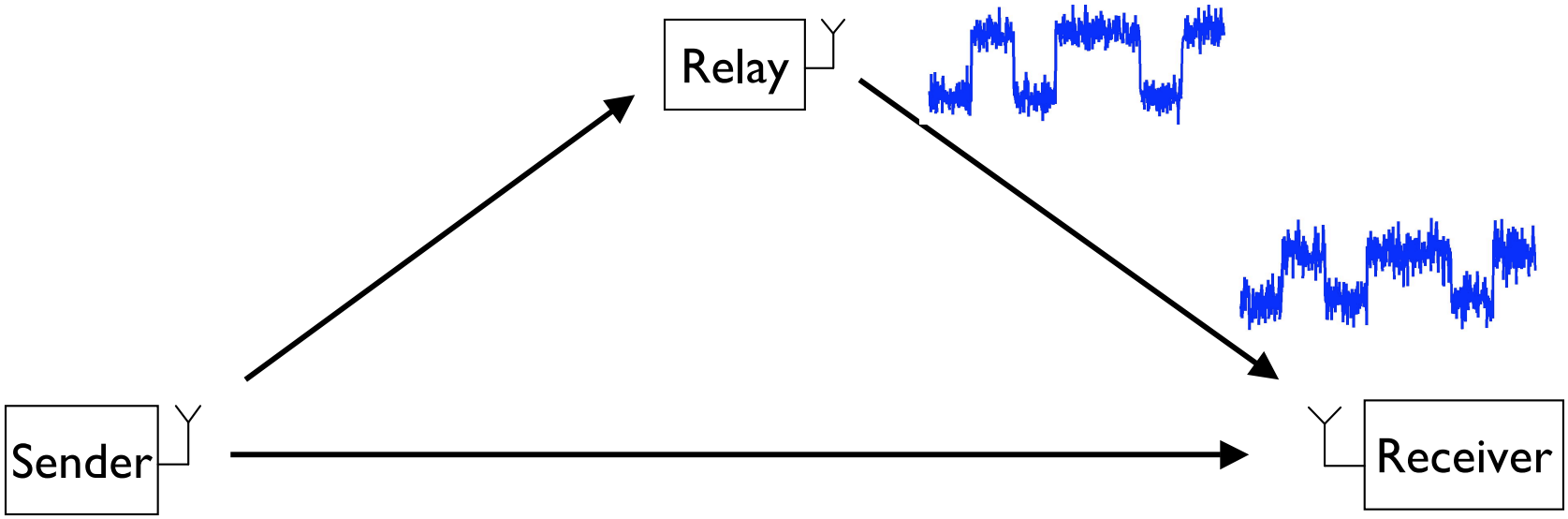
# Cooperative Encoding

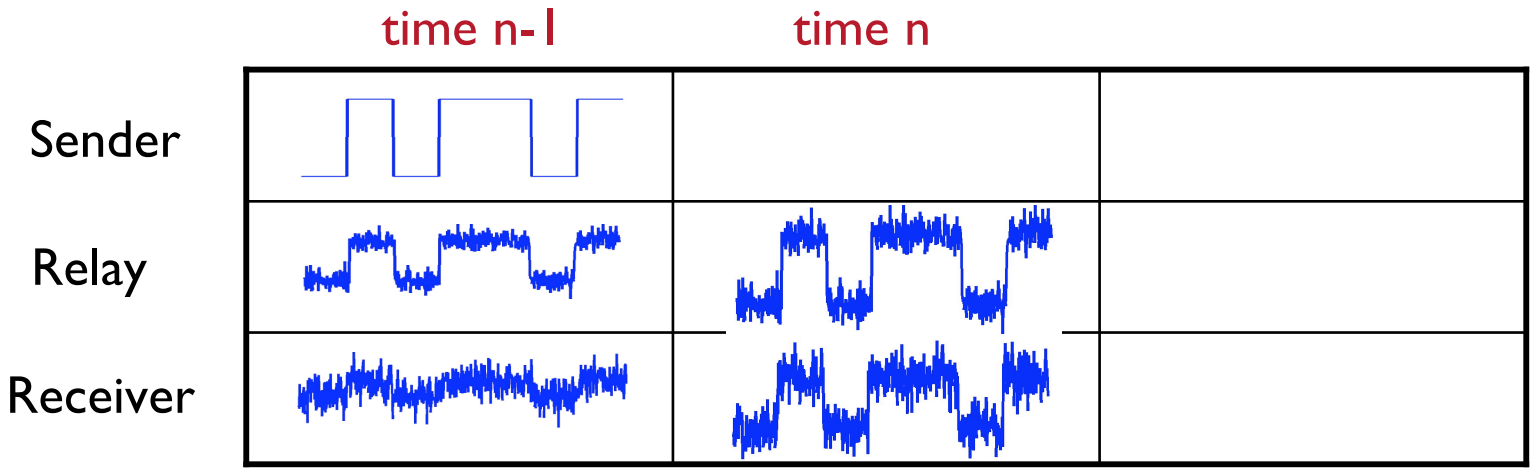



time n-1

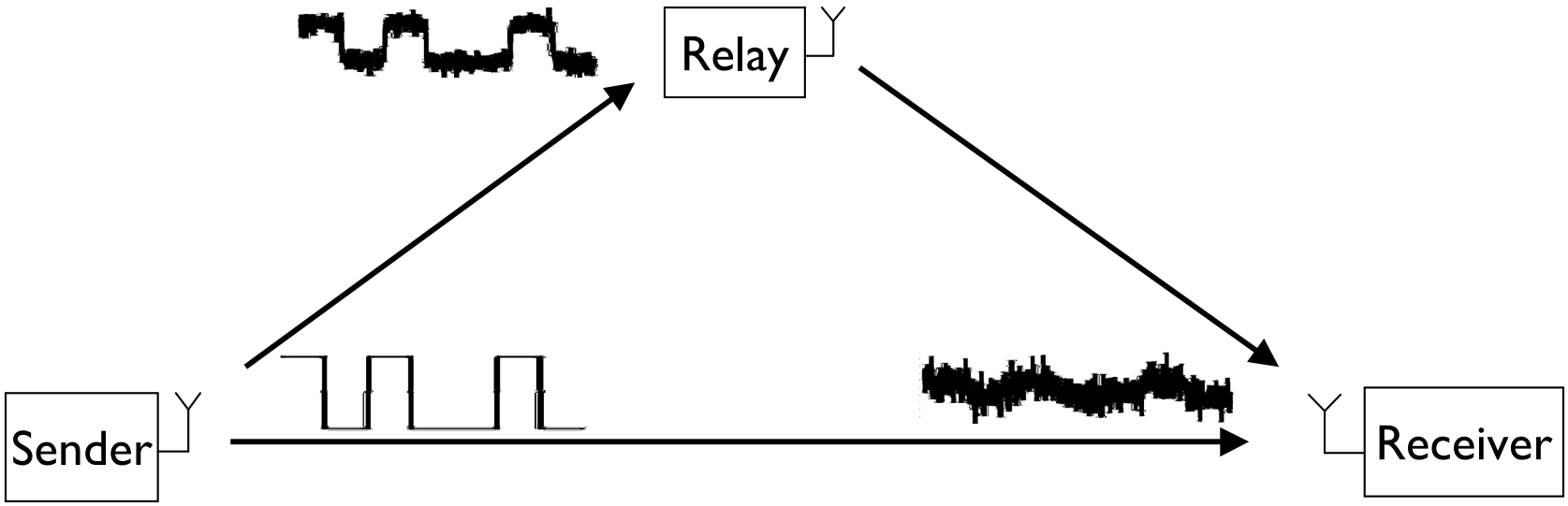
| | | | |
|---|---|---|---|
| Sender | | | |
| Relay | | | |
| Receiver | | | |

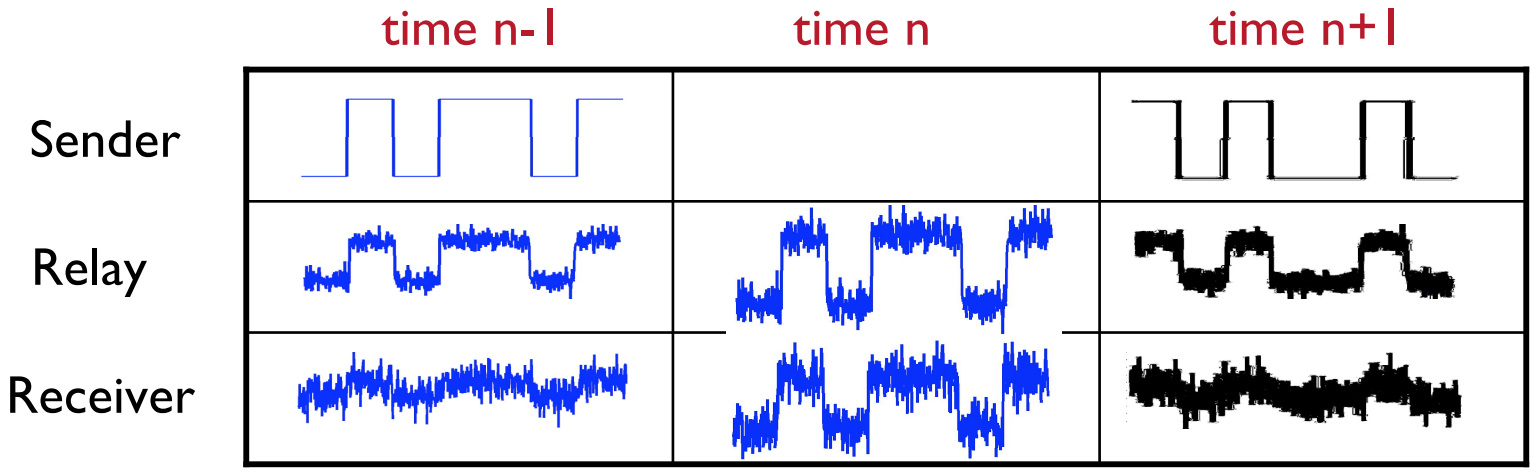
# Cooperative Encoding



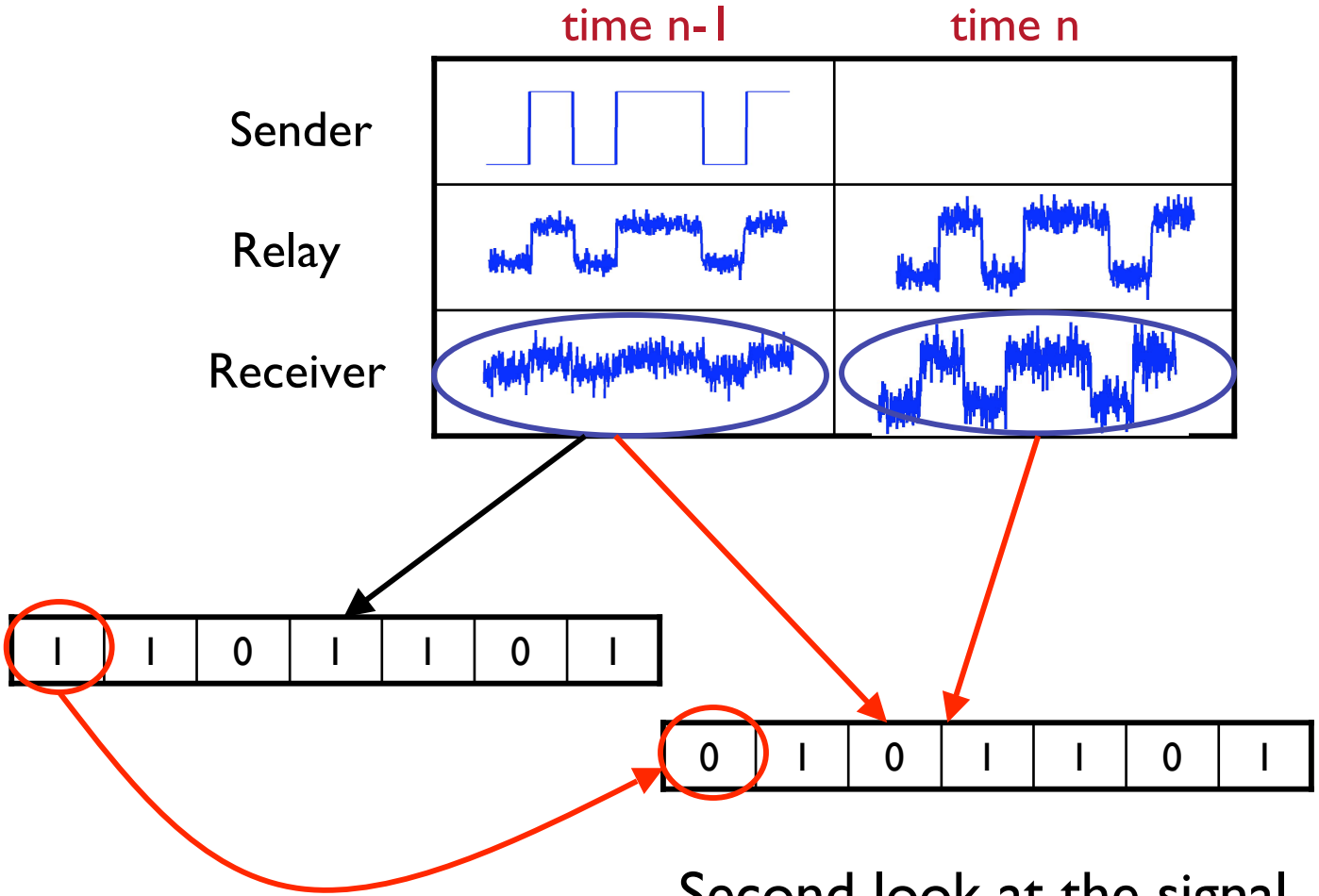



# Cooperative Encoding



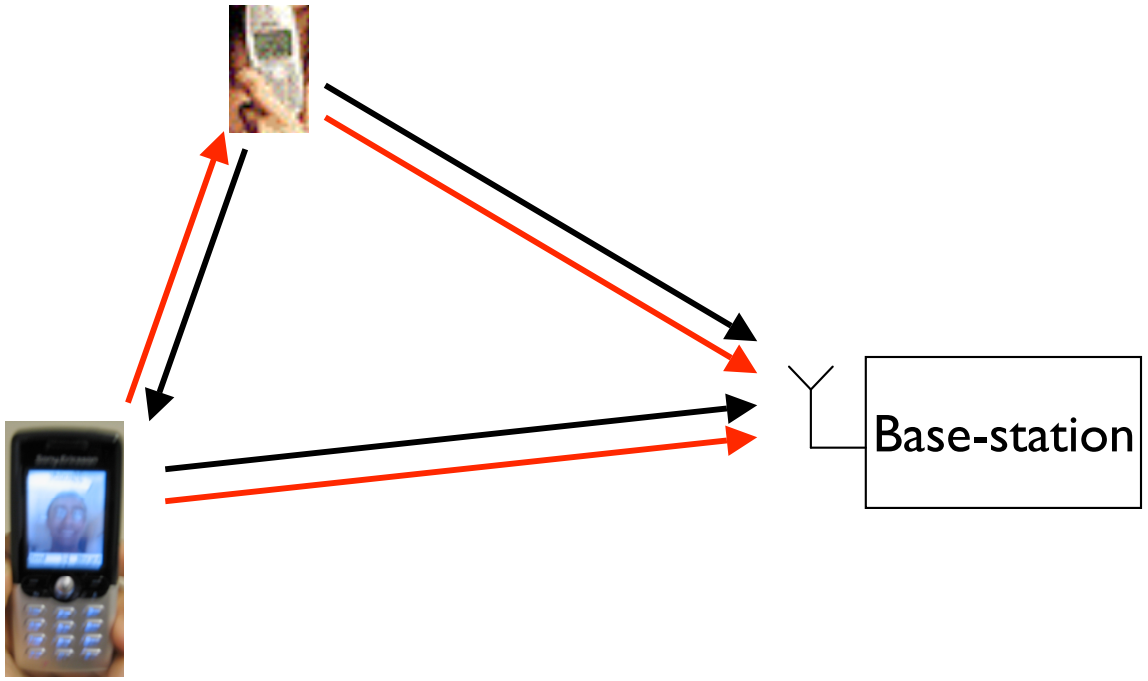



# Decoding



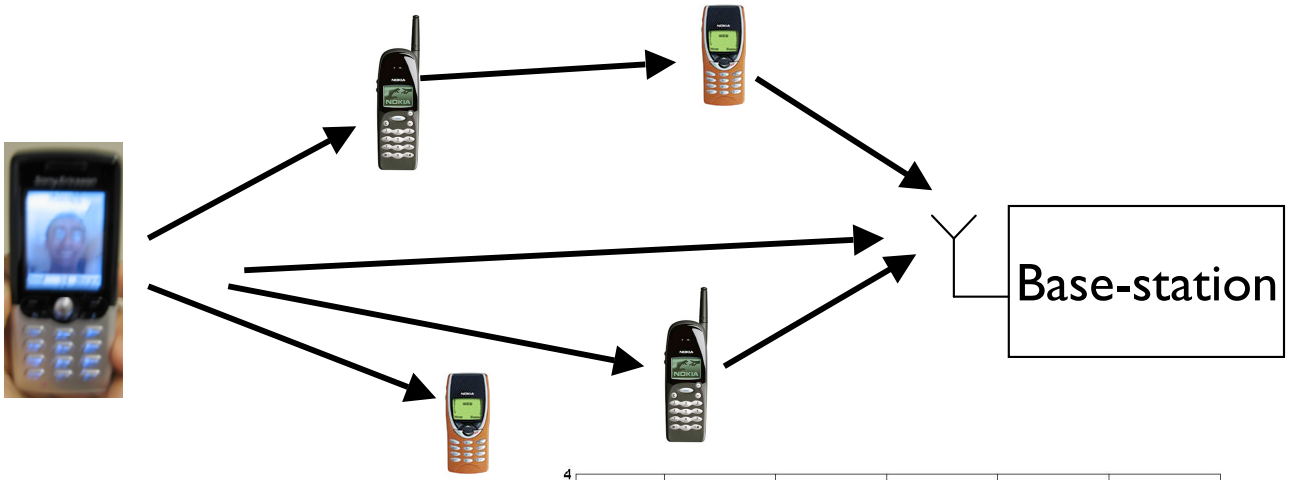

Second look at the signal helps reduce errors

# Two Can Play The Game

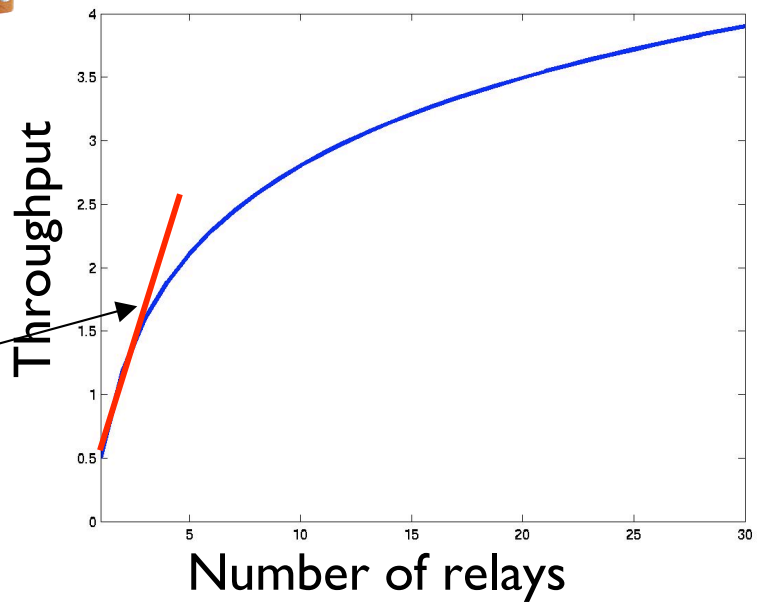



- Two senders and one receiver
- Each helps the other to improve performance

# Add More Relays




Biggest gains need very few nodes



# Recap

- Cooperation performed at symbol level
- Takes a system perspective, not a per link perspective
- Adding more nodes can help
- Significant gains available

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# Challenge 1: Establishing Cooperation

- Discovering cooperation
  - Nodes move, changing the neighbours
  - New cooperating partners have to be discovered
- Establishing cooperation
  - Higher overhead to establish cooperation with more nodes
  - Select the right number of nodes
  - Select the cooperative encoding strategy
  - How do we do it in scalable manner ?

# Challenge 2: Encoder Design

- Encoding has to be robust
  - Cooperative nodes may quit in the middle
  - Channel conditions may change
- Encoding should be scalable
  - Easily adapts to any number of relay nodes
  - Decoding complexity scales gracefully

# Challenge 3: Analytical Foundations

- System viewpoint
  - Protocols to establish cooperation important part
  - No theory to integrate with communication theory
  - Joint analysis impossible today
- A cohesive theory
  - Key to predicting performance
  - Key to design of efficient method
  - Many years away

# Summary

- Wireless has made great strides
- New paradigm driven by
  - High node density
  - New application domains
- We have a long way to go
  - Before we reach the limits (limits unknown)
  - Future promising for both wireless economy and research

# Wireless Future is in Good Hands

Ashu Sabharwal

RICE

Thank you !