Cooperative Wireless Communications

Ashutosh Sabharwal
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

Cell phones squeal on cheating spouses

Study: 3G phones can make brain hurt
Report also suggests they boost memory
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

Data packet

0 1 0 1 1 0 1

-A +A -A +A +A -A +A

-
Received Signal

Wireless channel

Received signal after short distance
Received Signal

Wireless channel

Received signal after long distance
Decoding After Short Distance

Correctly decoded packet
Decoding After Long Distance

Bit in error!
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

Sender

Relay

Receiver

time n-1
Cooperative Encoding

 Sender \rightarrow Relay \rightarrow Receiver

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<th>Relay</th>
<th>Receiver</th>
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Cooperative Encoding

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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

Throughput vs Number of relays

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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
Thank you!