Radio Resource Management

WINLAB IAB Meeting
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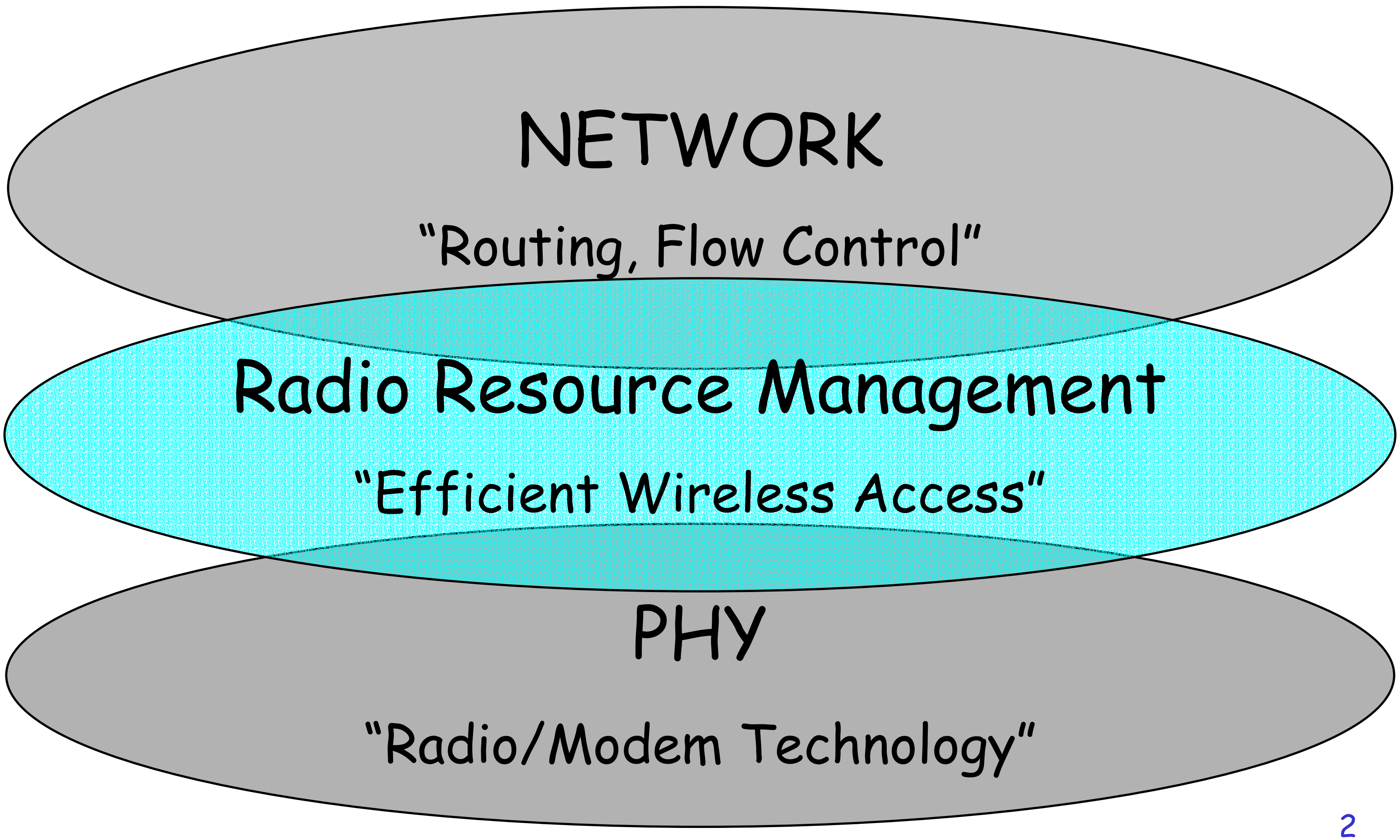
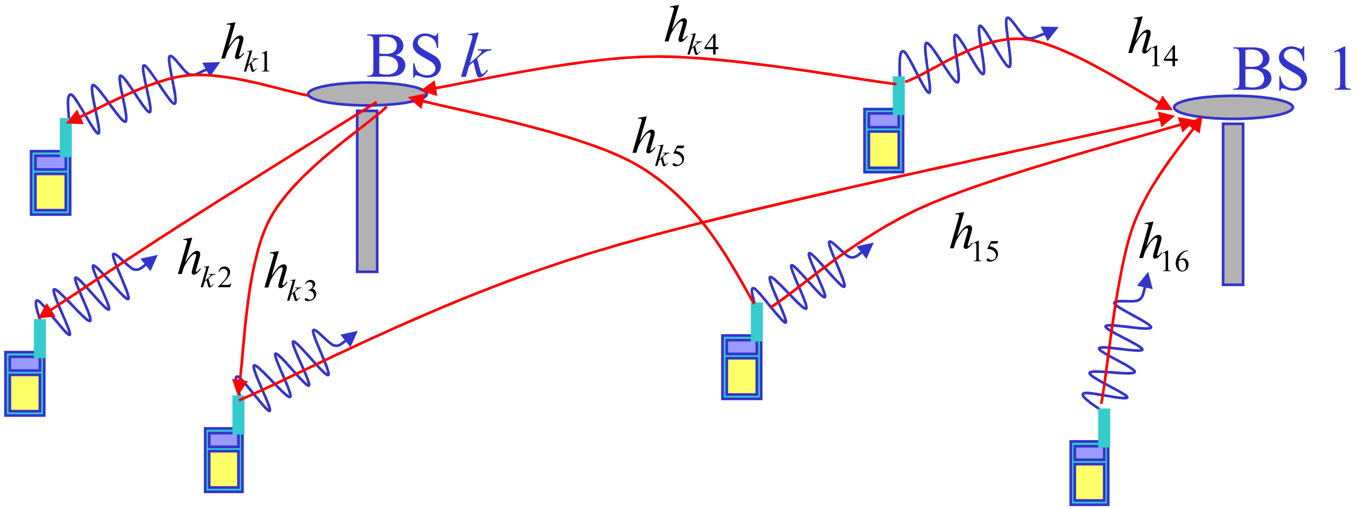
Roy Yates

WINLAB
WIRELESS INFORMATION NETWORK LABORATORY

What is RRM?


NETWORK
“Routing, Flow Control”
Radio Resource Management
“Efficient Wireless Access”
PHY
“Radio/Modem Technology”

RRM Ancient History (pre 1996)



Anytime Anywhere cellular voice service

Each user needs an acceptable connection:

Channel, Base station, Transmit Power

Cellular Wireless Today

- Optimized for Anytime/Anywhere voice
  - Strict Network Control
  - Licensed Bandwidth
- Limited Wireless Data
  - Low to Moderate Rates
    9.6 - 14.4 kb/s → 144 –384kb/s
- High Cost per bit
  - 10 kb/s, 10 cents/min = $1.30/MB

Cellular = Expensive Bits

1 cent/min = 13 cents/MB

Fill an MP3 player	30 MB	$3.90
Upload camera photos	32 MB	$4.16
Sync laptop disk	50 MB	$6.50

1 cent/min voice is still 100x too high for data

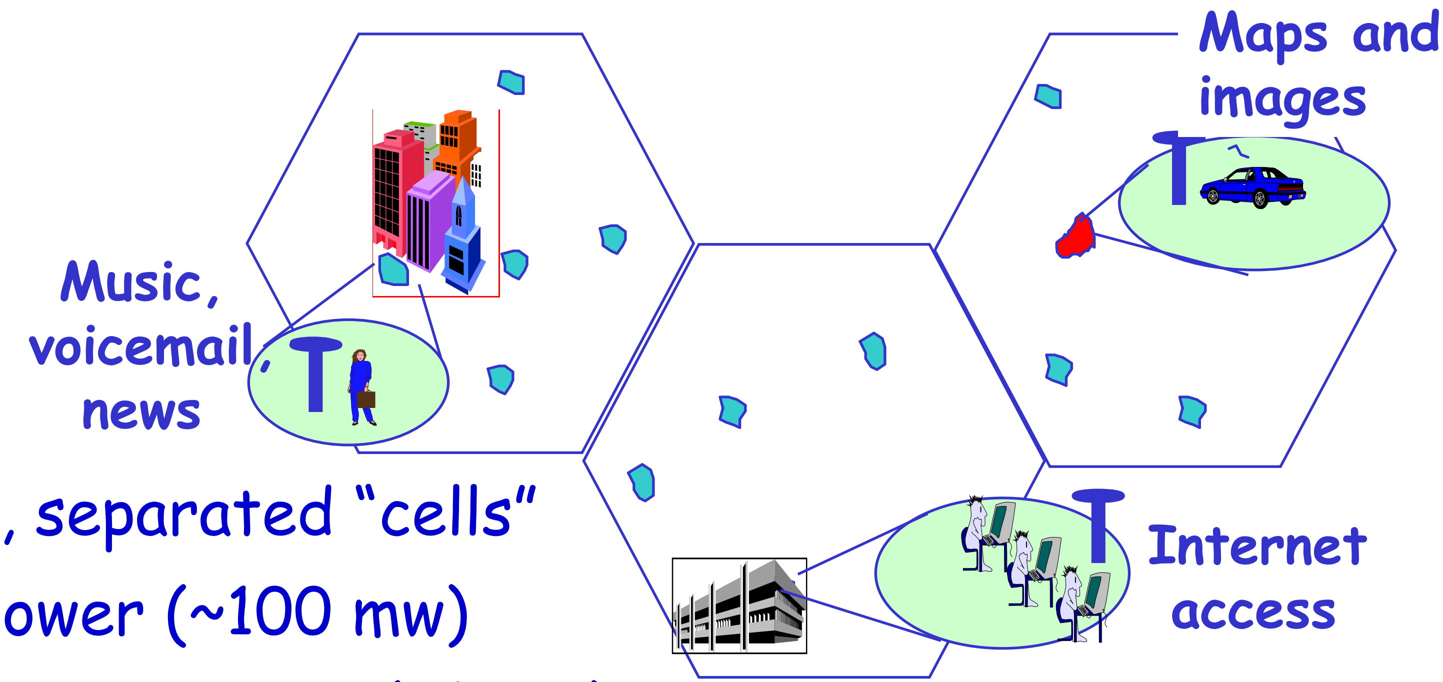
Internet Access = Free Bits

- Internet: Applications and attitudes are based on "free" bits
  - Fill an MP3 player: 30 MB = FREE
  - To get a lot of bits, you wait more but not pay more

- Cellular access is a toll booth
- Radio bits need to be "free"

Infostations

A system of sweet spots for free bits



- ❑Small, separated "cells"
- ❑Low power (~100 mw)
- ❑Brief connections (~1 sec)
- ❑Very high bit rate (~1 G bps)
- ❑Simple infrastructure (LAN on a pole, IP access)
- ❑Unlimited capacity for a flat rate?

Free Bits

- NSF ITR Multi-university Project
  - WINLAB, Princeton, NJIT
- Research Areas
  - Radio Channel Modeling
  - Transceiver Design
  - Radio Resource Management
  - Algorithm Development Testbed

RRM Research at WINLAB

- About 15 student projects
- Investigators
  - Evans, Frenkiel, Gajic, Mandayam, Mau, Raychaudhuri, Rose, Spasojevic, Yates
- Range of Systems:
  - 3G cellular, infostations, ad hoc data networks

Common Theme

Methods for Efficient Transmission

- Opportunistic Transmission
  - Transmit when/where the channel is good
  - Exploit sweet spots, delay insensitivity
- Conserve battery power
- Mechanisms for Distributed Control
  - Power Control, Interference avoidance
  - Utility functions to unify mixed objectives

15 RRM Projects

1. Interference Avoidance and Fading Channels
2. Interference Avoidance for Multiple Basestation Systems
3. Using Mobility for Delay-Tolerant Data Transmission in Ad-Hoc Networks
4. Energy and Delay Constrained Dynamic Transmission Control in Wireless Data Communications Systems
5. Access Control for Mixed Receivers, Integrated Voice/Data CDMA Systems
6. Pricing and Power Control for Joint Network-Centric and User-Centric Radio Resource Management
7. Routing in Ad Hoc Networks
8. Service Outage Based Adaptive Transmission in Fading Channels
9. Discrete Adaptive Transmission for Fading Channels
10. Downlink Interference Analysis
11. Multicast Transmission in the Downlink of Wireless System
12. Effects of Channel Models on Performance of MobileAd Hoc Networks
13. Power Control in Ad Hoc Networks Using Hello and Data Packets
14. OFDM Based Multiple Access Systems
15. Dynamic Nash Games for Power Control in 3-G Wireless CDMA Networks

Access Control
Sharing for Heterogeneous Services

- Access Control for Mixed Receivers, Integrated Voice/Data CDMA
  - *Narayan Mandayam and Cristina Comaniciu*
- Pricing and Power Control for Joint Network-Centric and User-Centric Radio Resource Management
  - *Narayan Mandayam, Siun-Chuon Mau and Nan Feng*
- Downlink Interference Analysis
  - *Roy Yates and Mehmet Kemal Karakayali*
- Multicast Transmission in the Downlink of Wireless System
  - *Roy Yates and Nanyan Jiang*
- OFDM Based Multiple Access Systems
  - *Roy Yates and Rajnish Sinha*
- Dynamic Nash Games for Power Control in 3-G Wireless CDMA
  - *Zoran Gajic and Sarah Koskie*

Access Control
Sharing for Heterogeneous Services

- Closely tied to receiver technology
  - WCDMA, Multiuser Detection, OFDM
- Multiple Services
  - Voice, Web, Video
- Utility Functions to unify mixed objectives
- Pricing Mechanisms to improve user's utilities

Adaptive Transmission
Transmit When the Channel is Good

- Energy and Delay Constrained Dynamic Transmission Control in Wireless Data Communications Systems
  - *Narayan Mandayam and Henry Wang*
- Service Outage Based Adaptive Transmission in Fading Channels
  - *Roy Yates and Jianghong Luo*
- Discrete Adaptive Transmission for Fading Channels
  - *Roy Yates and Lang Lin*

- Goal: Reduce the Energy per bit
  - Increase power and rate as channel improves
  - Turn the transmitter off if channel is bad.
- Result: Transmit in sweet spots $\Rightarrow$ Infostations

Interference Avoidance
Transmit Where the Channel is Good

Interference Avoidance and Fading Channels

- *Christopher Rose and Dimitrie C. Popescu*

- Interference Avoidance for Multiple Basestation Systems
  - *Christopher Rose and Otilia Popescu*

- "Where" is in signal space !
  - Depends on Interference and Radio Channels of Other Users
  - Receivers find sweet spots in signal space
    - Transmitters move to the sweet spots

Ad Hoc Wireless Networks

- Using Mobility for Delay-Tolerant Data Transmission in Ad-Hoc Networks
  - *Christopher Rose and Furuzan Atay*
- Routing in Ad Hoc Networks
  - *Roy Yates and Ivana Maric*
- Effects of Channel Models on Performance of MobileAd Hoc Networks
  - *Roy Yates and Wing Ho (Andy) Yuen*
- Power Control in Ad Hoc Networks Using Hello and Data Packets
  - *Roy Yates and Wing Ho (Andy) Yuen*

- Theme: Disseminate data efficiently among peers
- Users in sweet spots assist others

Overlapping Research Areas