NSS Enriching Knowledge for Information and Communication Technology Curriculum Series: (5) Latest Technologies on 'Internet Services & Applications' and 'Wireless Computer Network'

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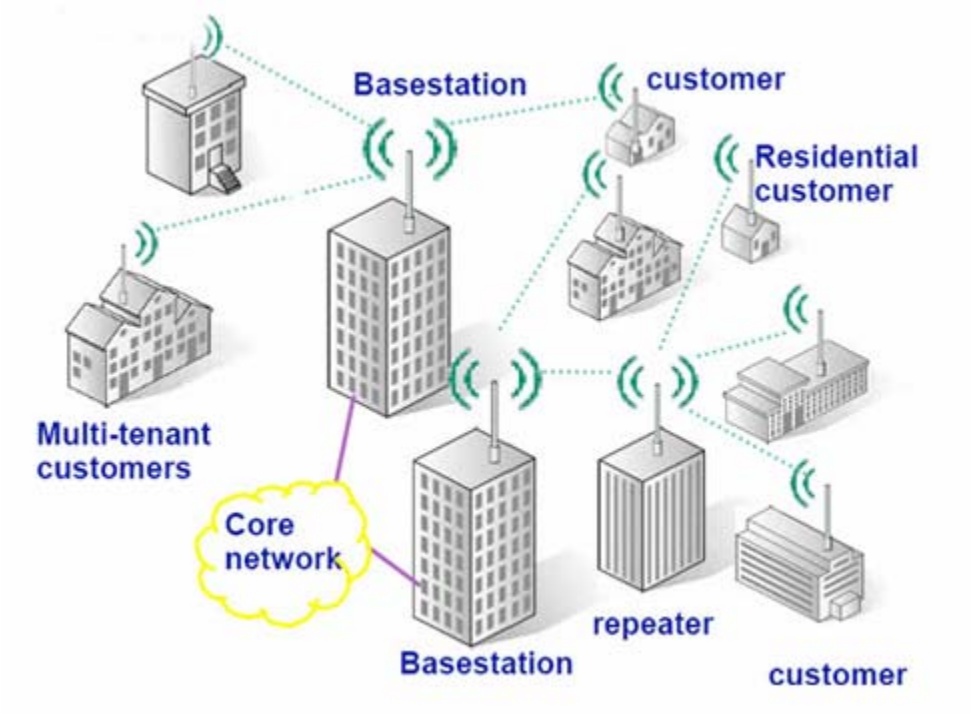
28 Feb 2008



Introduction and Several Recent Advances of Wireless Communications

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- Minghua Chen (CUHK)
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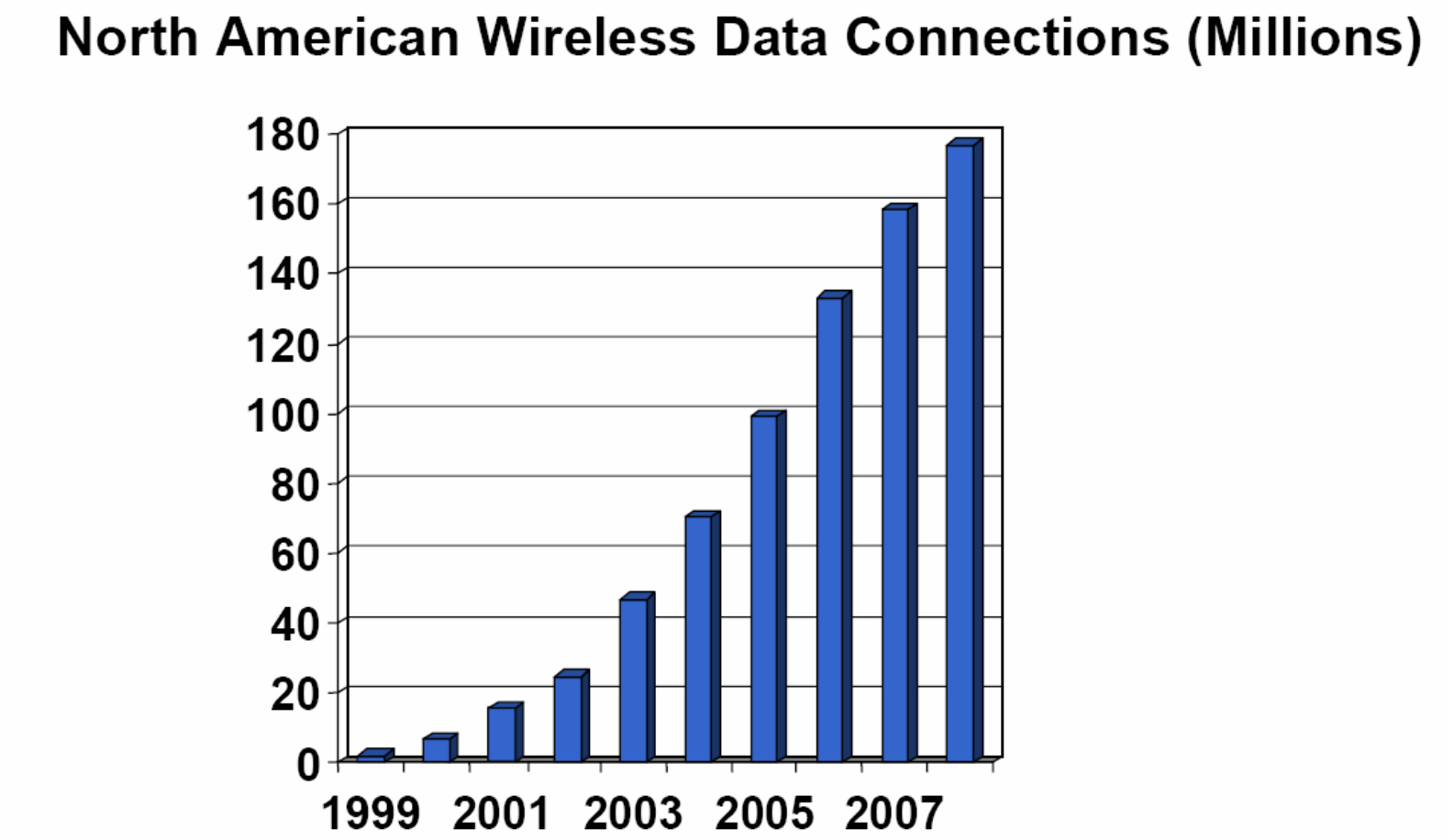
Why Wireless?

- Users want to get connected anywhere

- Reality (2006):
  - USA: 12%
  - Korea: 50%
  - Hong Kong: 25%

- Service providers want easy/cheap provision
  - No wire or infrastructure node
  - Cheap: establishment cost (1/4 of cable),
  - Easy installation, low operation cost, robust…

Usage Trend



Source: Gartner, “U.S. Wireless Data Market Update, 2004”

Technology Trend

- Throughput
  - Cellular: 14.4 kbps (modem) ➔ 144 kbps (1xRTT) ➔ 384kbps (EDGE) ➔ 2Mbps (EV-DO) ➔? (WiMax) ➔…
  - Wi-Fi: 2 Mbps (AT&T Wave) ➔ 11 Mbps(802.11b) ➔ 54 Mbps (802.11 a/g) ➔ 74/248 Mbps? (802.11n) ➔ …
- Catching up the throughput of wired access links…
- Technologies:
  - TDMA ➔ FDMA ➔ CDMA ➔ OFDMA ➔ MIMO+OFDMA ➔ …

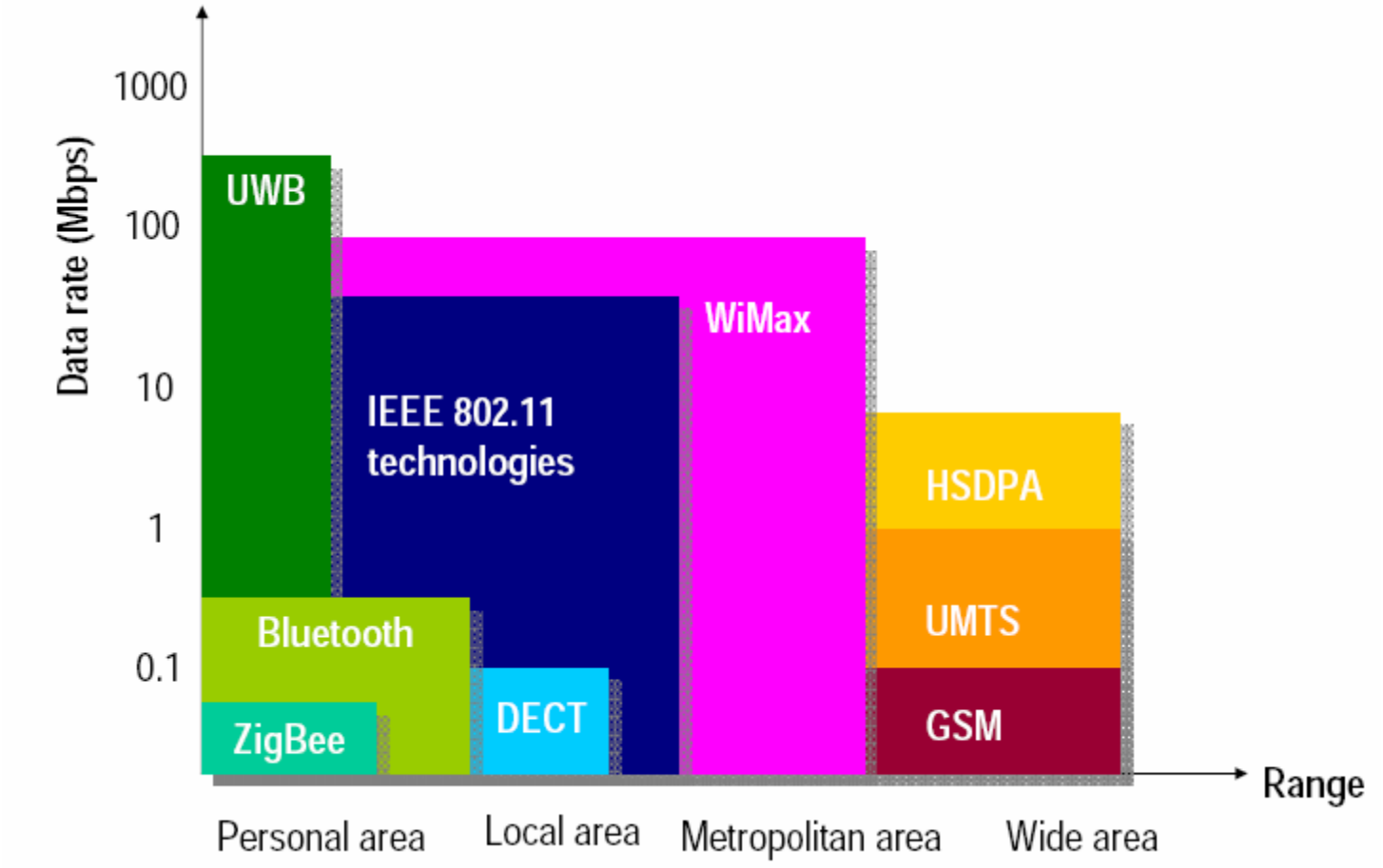
Mobile Internet Access methods

Standard	Family	Primary Use	Radio Tech	Downlink (Mbps)	Uplink (Mbps)
802.16e	WiMAX	Mobile Internet	MIMO-SOFDMA	70	70
HIPERMAN	HIPERMAN	Mobile Internet	OFDM	56.9	56.9
WiBro	WiBro	Mobile Internet	OFDMA	50	50
iBurst	iBurst 802.20	Mobile Internet	HC-SDMA	64	64
UMTS W-CDMA HSDPA+HSUPA	UMTS/3GSM	Mobile phone	CDMA/FDD	.384 14.4	.384 5.76
UMTS-TDD	UMTS/3GSM	Mobile Internet	CDMA/TDD	16	16
LTE UMTS	UMTS/4GSM	General 4G	OFDMA/MIMO/SC-FDMA (HSOPA)	>100	>50
1xRTT	CDMA2000	Mobile phone	CDMA	0.144	0.144
EV-DO 1x Rev. 0 EV-DO 1x Rev.A EV-DO Rev.B	CDMA2000	Mobile Internet	CDMA/FDD	2.45 3.1 4.9xN	0.15 1.8 1.8xN

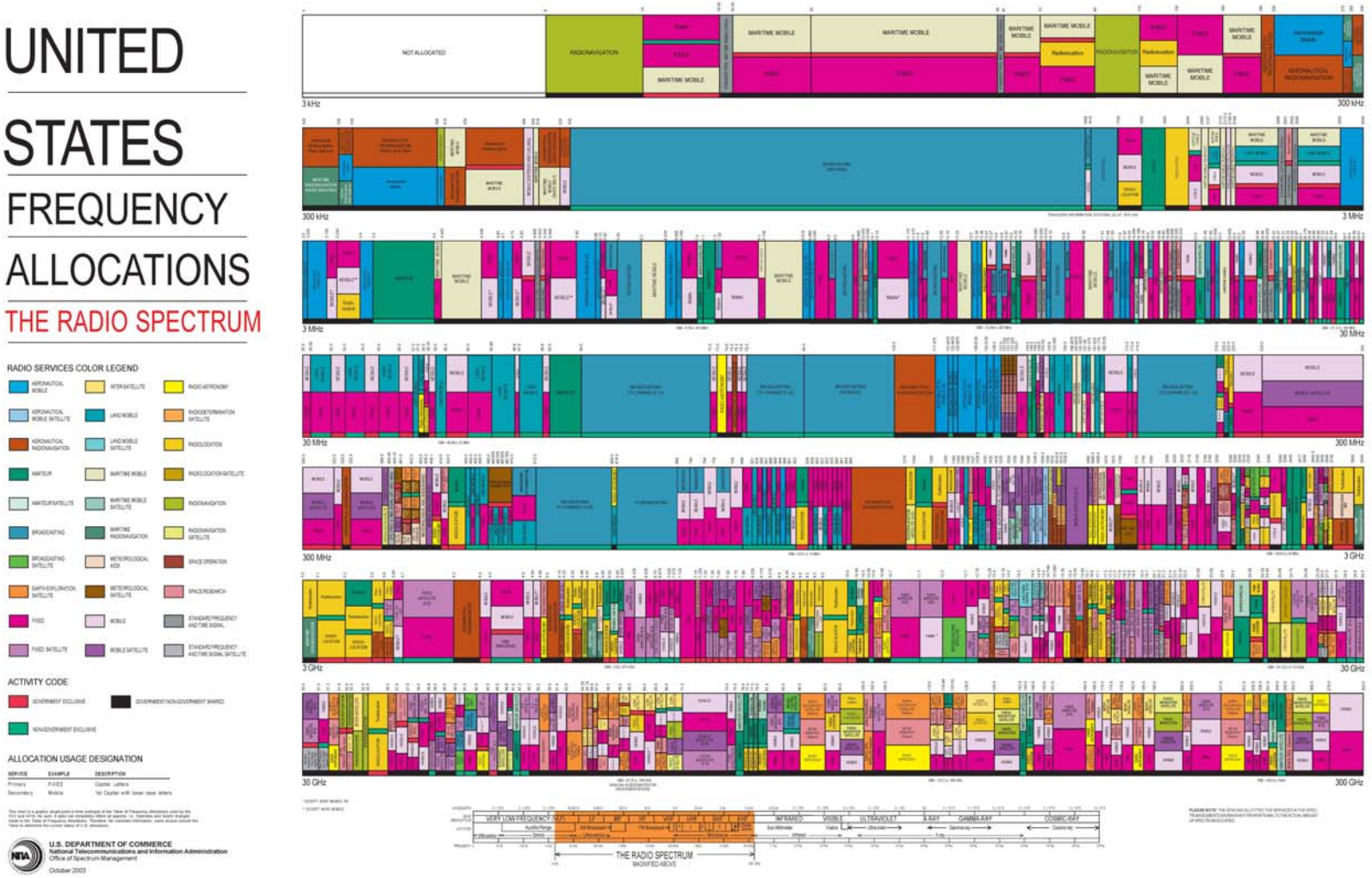
802.11 Family

	802.11a	802.11b	802.11g	802.11n
Speed	54Mbps	11Mbps	54Mbps	74/248Mbps
Frequency	5 GHz	2.4GHz	2.4GHz	2.4 and/or 5Ghz
Tech.	OFDM	TDMA	OFDM	MIMO+OFDM
Indoor Range	25-75 feet	100-200 feet	100-200 feet	200-300 feet
Compatibility	Incompatible with b, g, n	Compatible with g and n	Compatible with b and n	Compatible with a, b, and g

Data Rate VS. Range

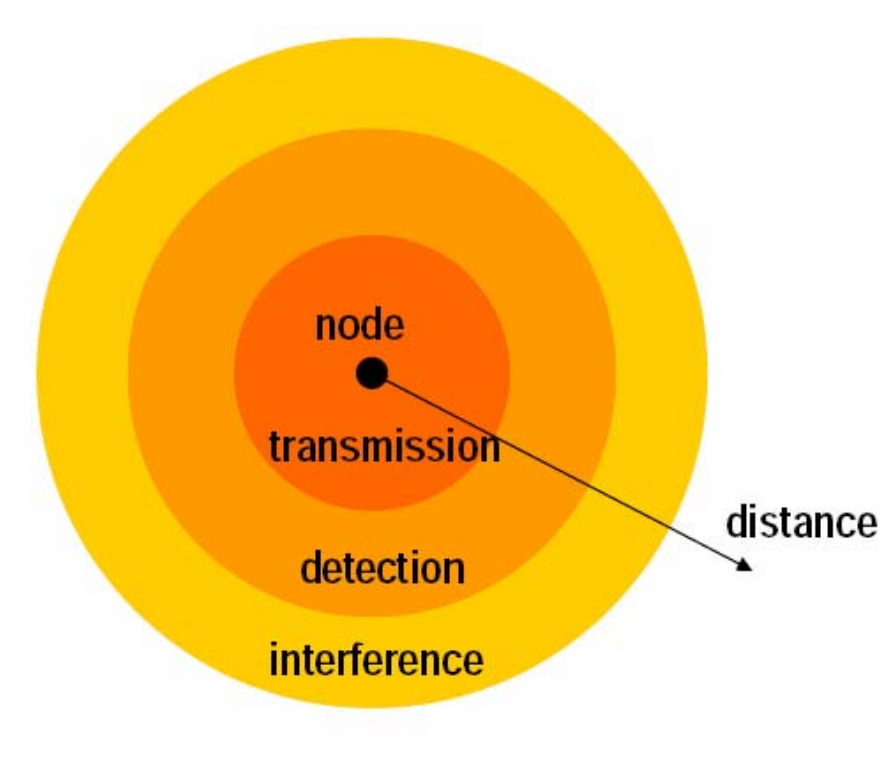


Spectrum – The Resources



Attenuation (For Fixed Power)

- Transmission range
  - High SNR
  - Low error rate
- Detection range
  - Mid SNR
  - Detecting wireless signal
- Interference range
  - Low SNR
  - Signal adds to the interfered noise

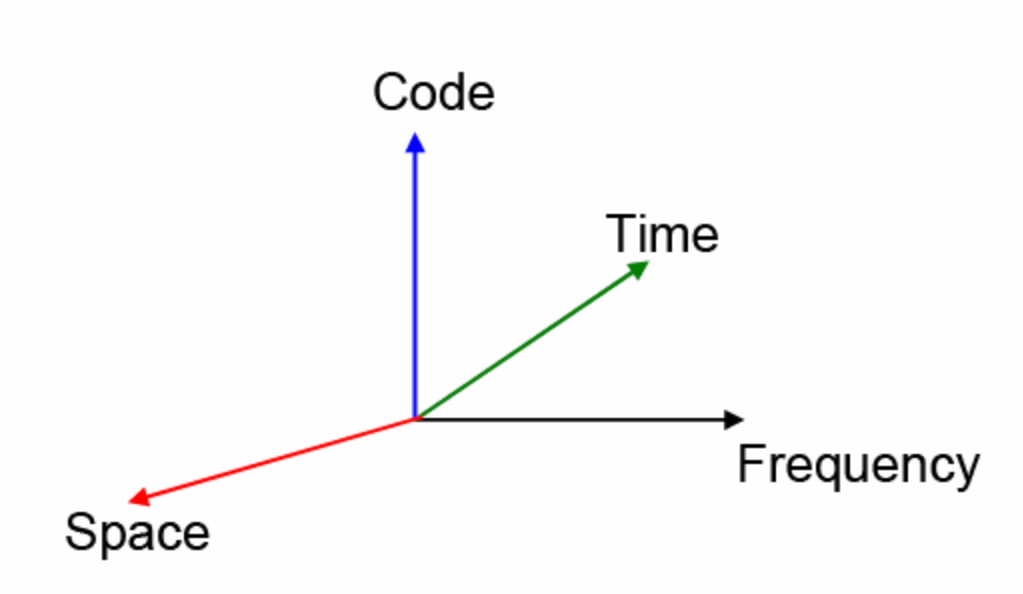


Special Topic I:

Multiplexing Techniques

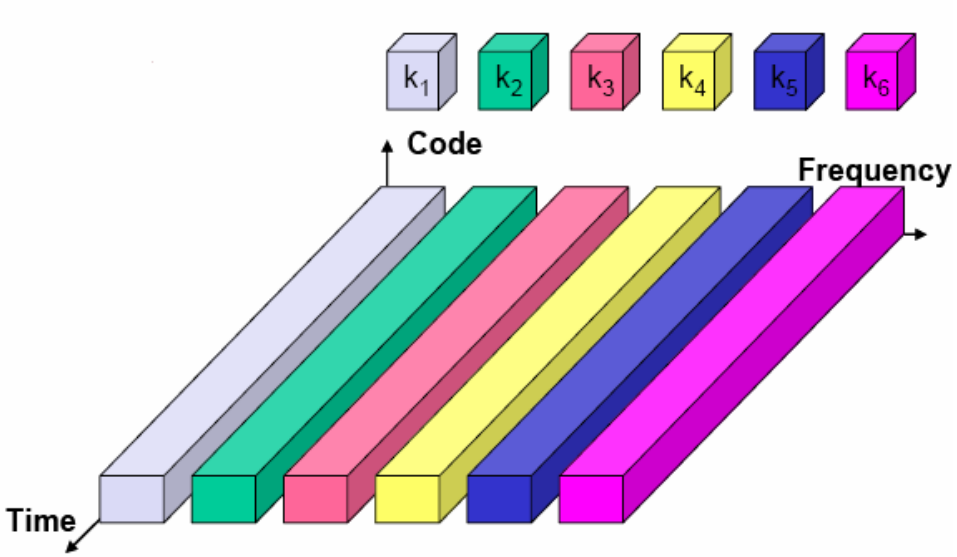
Multiplexing – Allowing Multiple Access

- Four dimensions
  - Time
  - Frequency
  - Space
  - Code



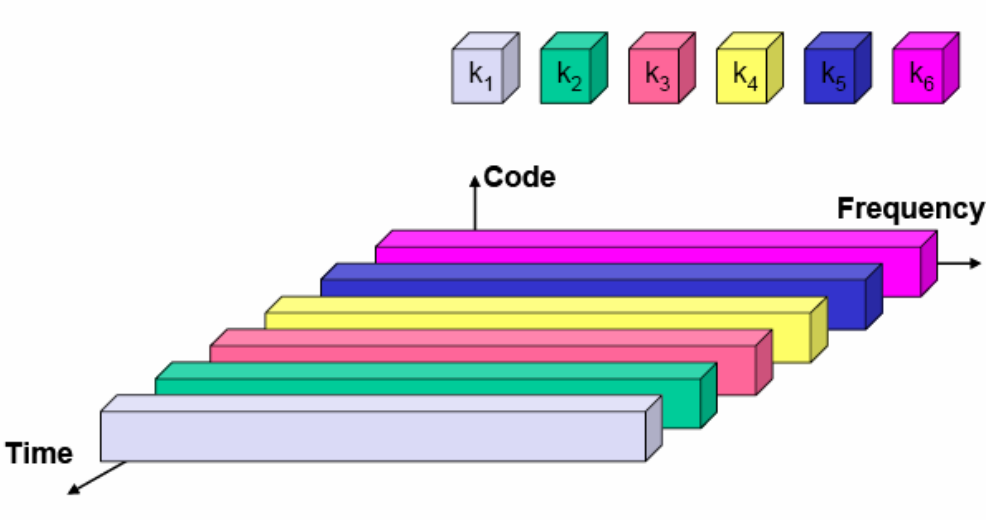
Frequency Division Multiple Access (FDMA)

- Divide frequency band into small sub-band
- Each sub-band is a channel
- Example: 1G



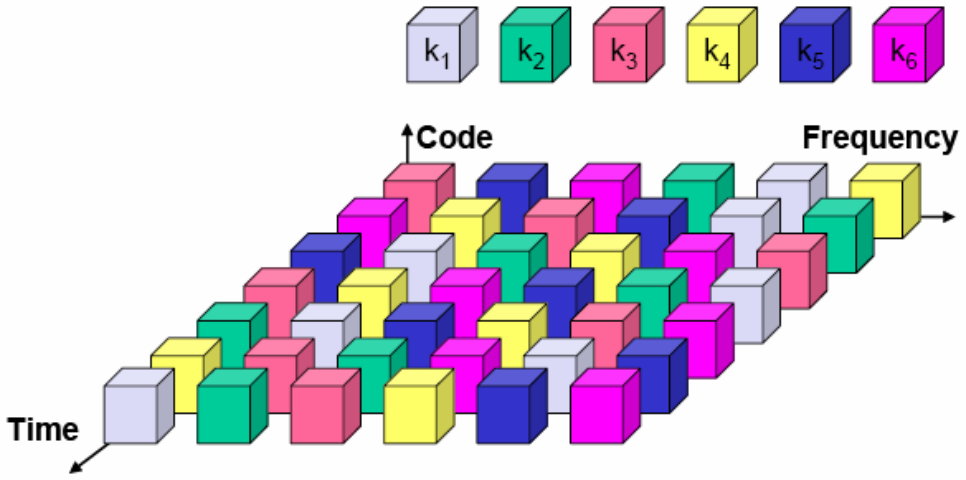
Time Division Multiple Access (TDMA)

- Divide time into small slots
- Each slot is a channel
- Need synchronization
- Example: 2G



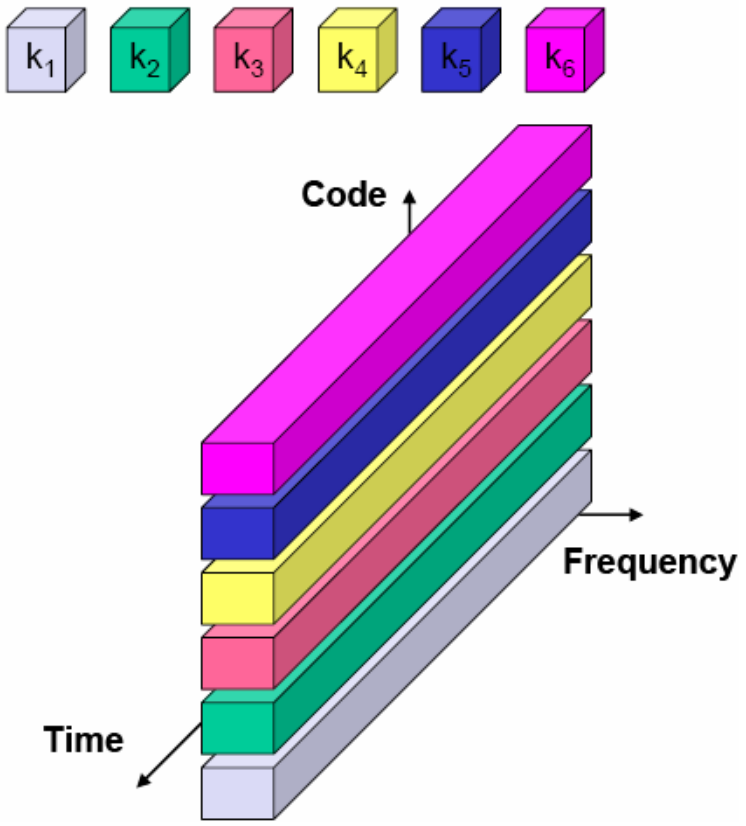
Frequency/Time Division Multiple Access (F/TDMA)

- Frequency-time is divided into small F/T block
- Channel is a series of block
- Need synchronization
- Example: GSM



Code Division Multiple Access (CDMA)

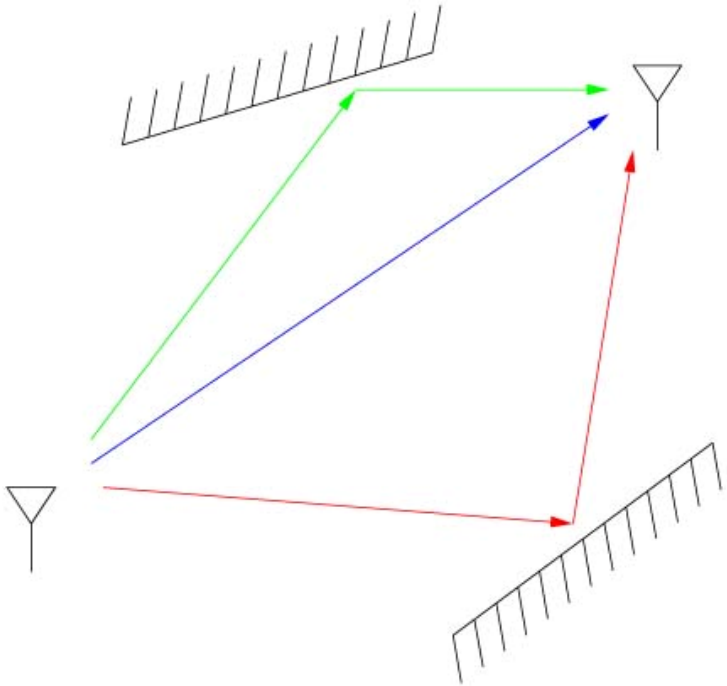
- No division into sub-band/slot/block, use the entire frequency band any time
- Divide the signal space into many orthogonal sub-spaces, using orthogonal codes, assign each device one code
- Project the received signal to your space and decode
- No synchronization
- Example: IS-95, CDMA 2000, WCDMA…

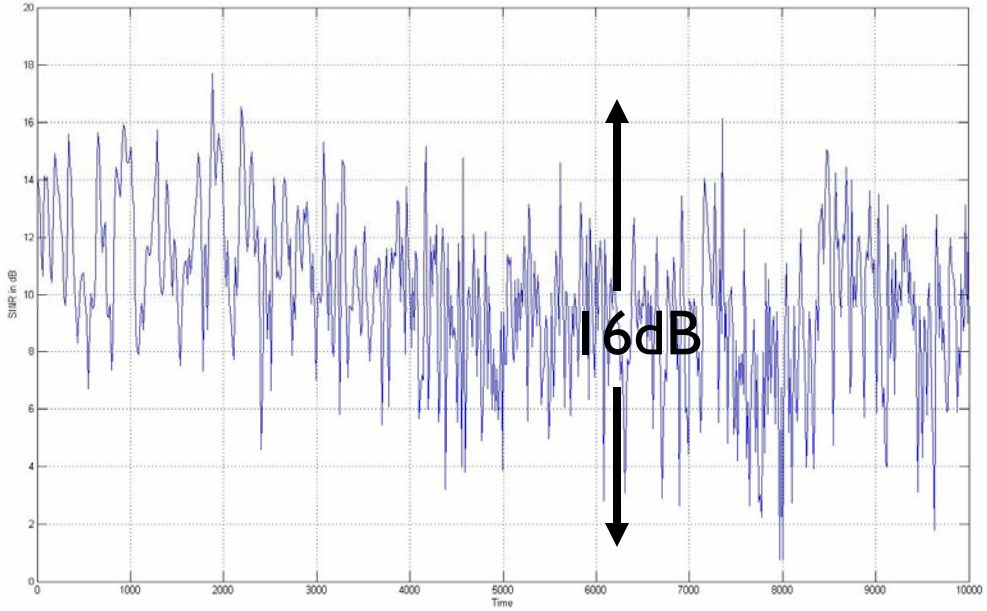


Special Topic II:

Opportunistic Communications

Multipath Fading

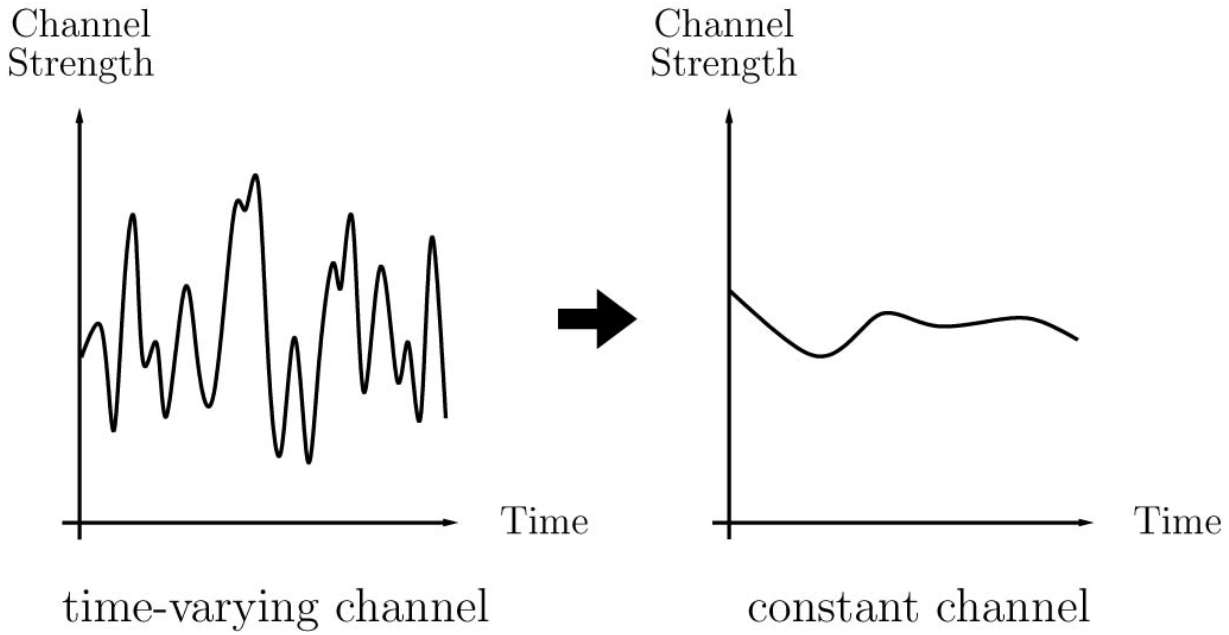




Classical view: fading channels are unreliable

Modern view: multipath fading can be exploited to increase spectral efficiency.

Traditional Approach to Wireless System Design

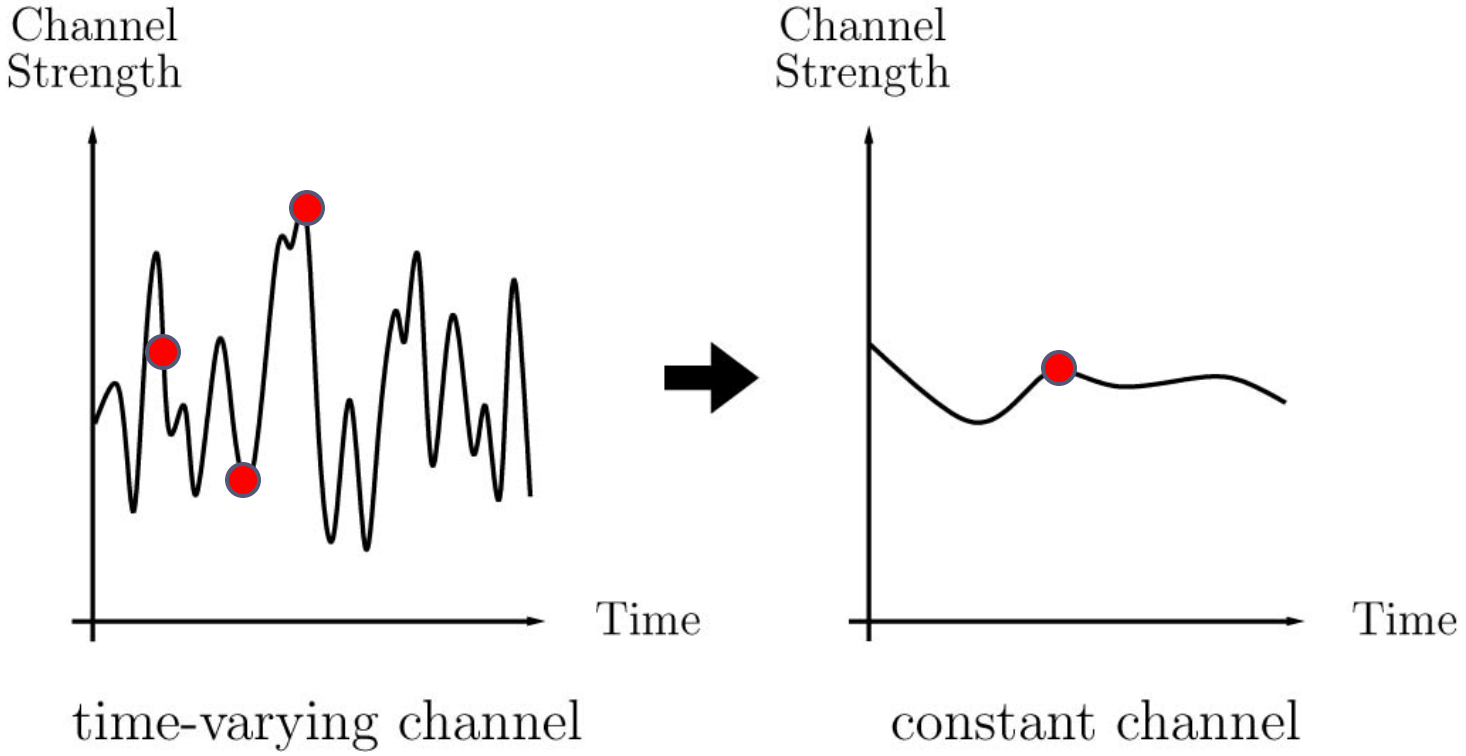


Compensates for deep fades via diversity techniques over time, frequency and space.

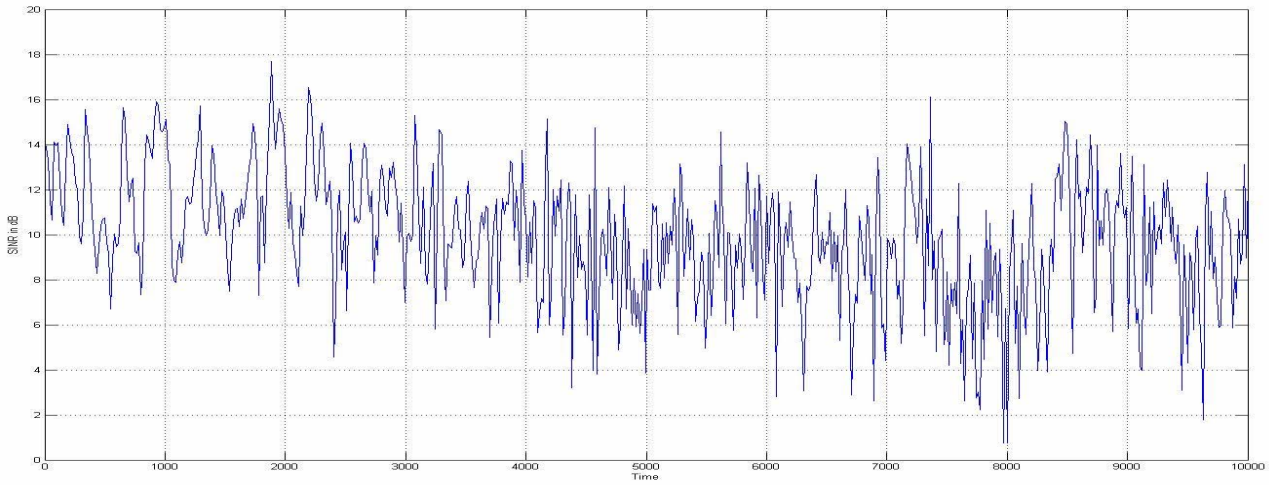
(Glass is half empty.)

Example: GSM/CDMA

- frequency diversity via Rake combining
- time diversity via interleaving and coding

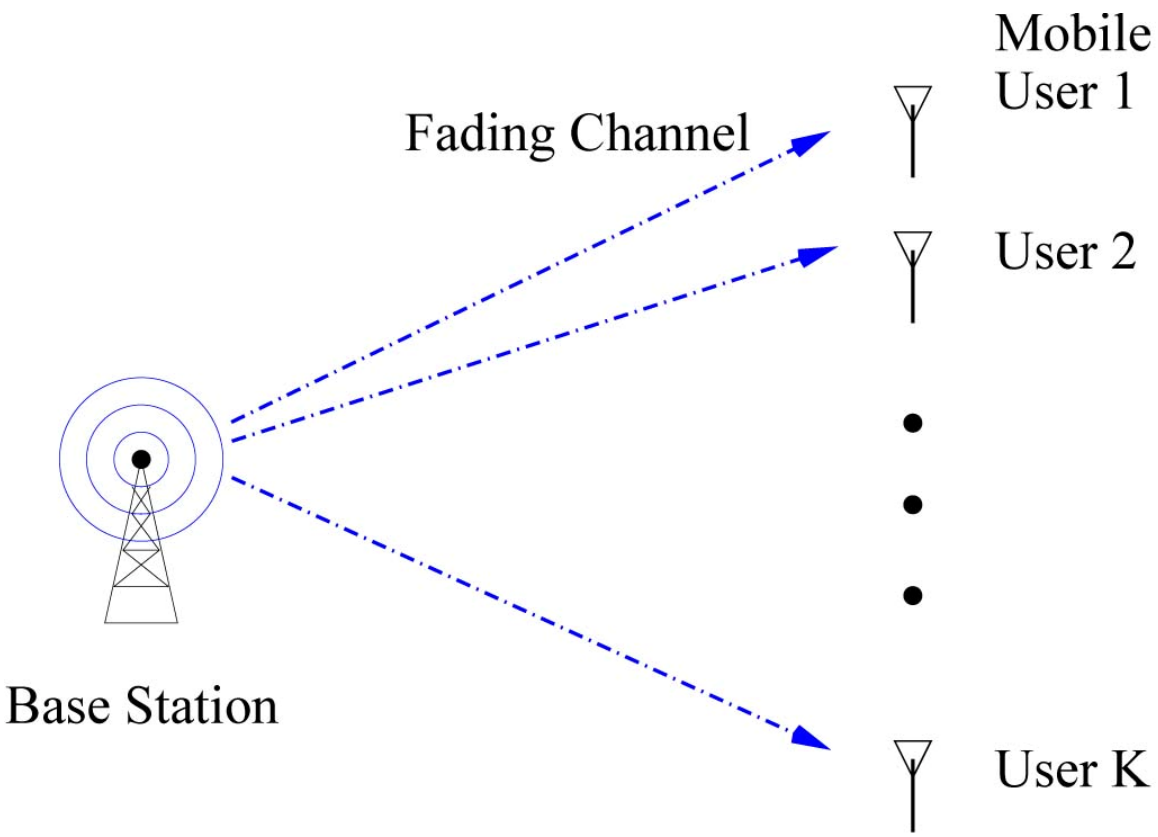


Multipath Fading: Another Look

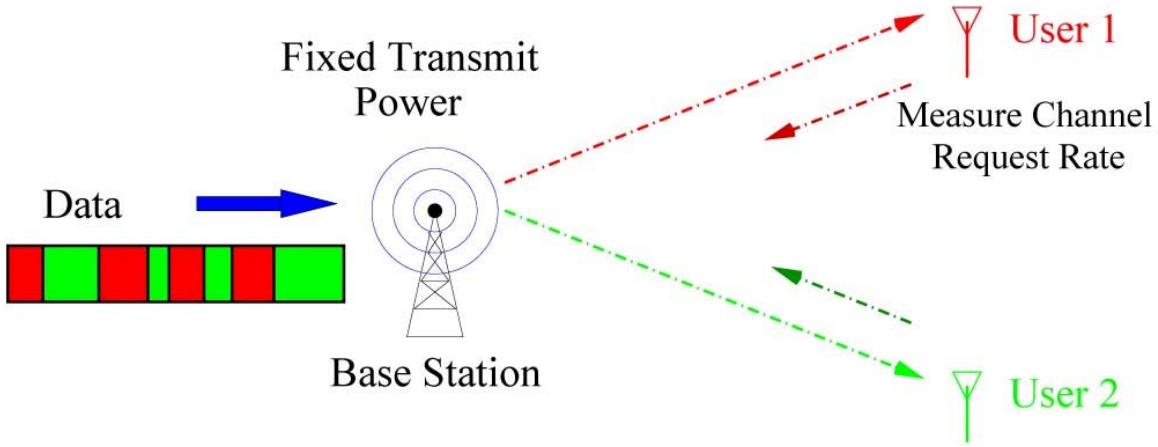


- Multipath fading provides high peaks to exploit.
- Channel capacity is achieved by such an opportunistic strategy.

Multiuser Opportunistic Communication

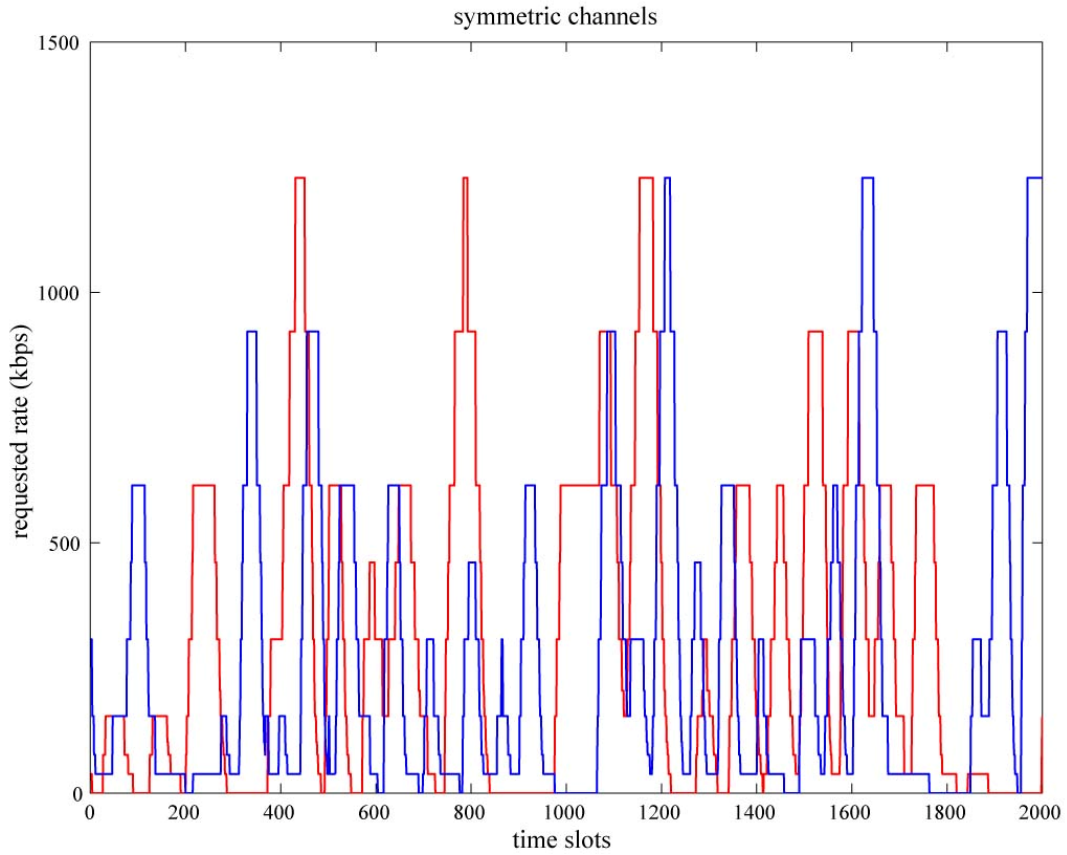


Application to CDMA 2000 1x EV-DO



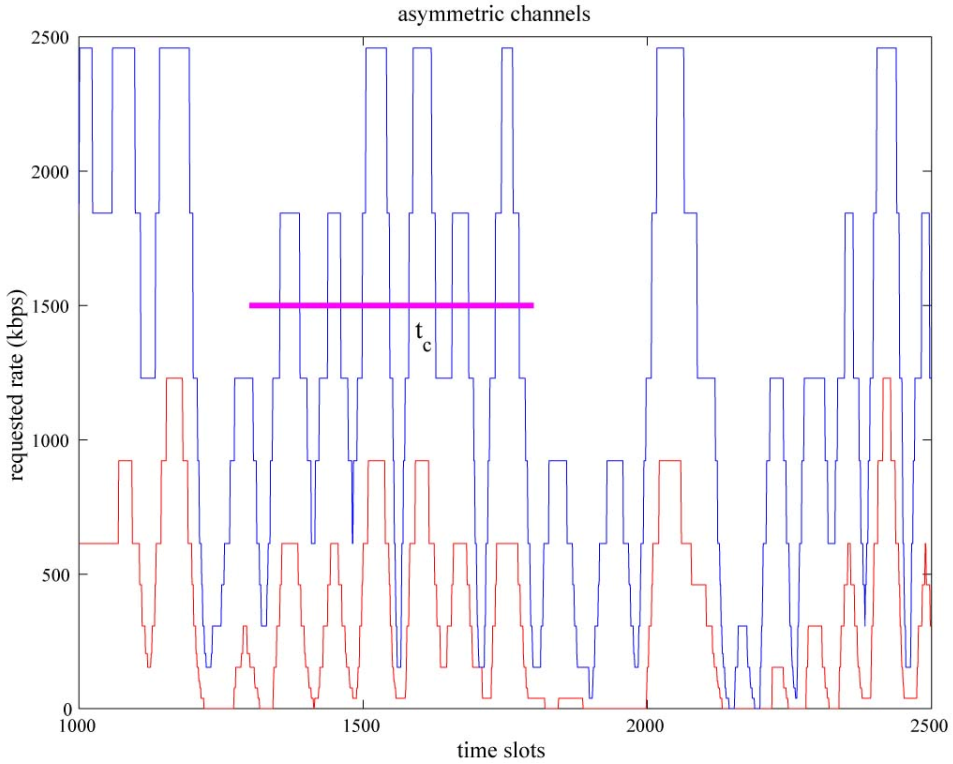
- Multiuser diversity provides a system-wide benefit.
- Challenge is to share the benefit among the users in a fair way.

Symmetric Users



Serving the best user at each time is also fair in terms of long term throughputs.

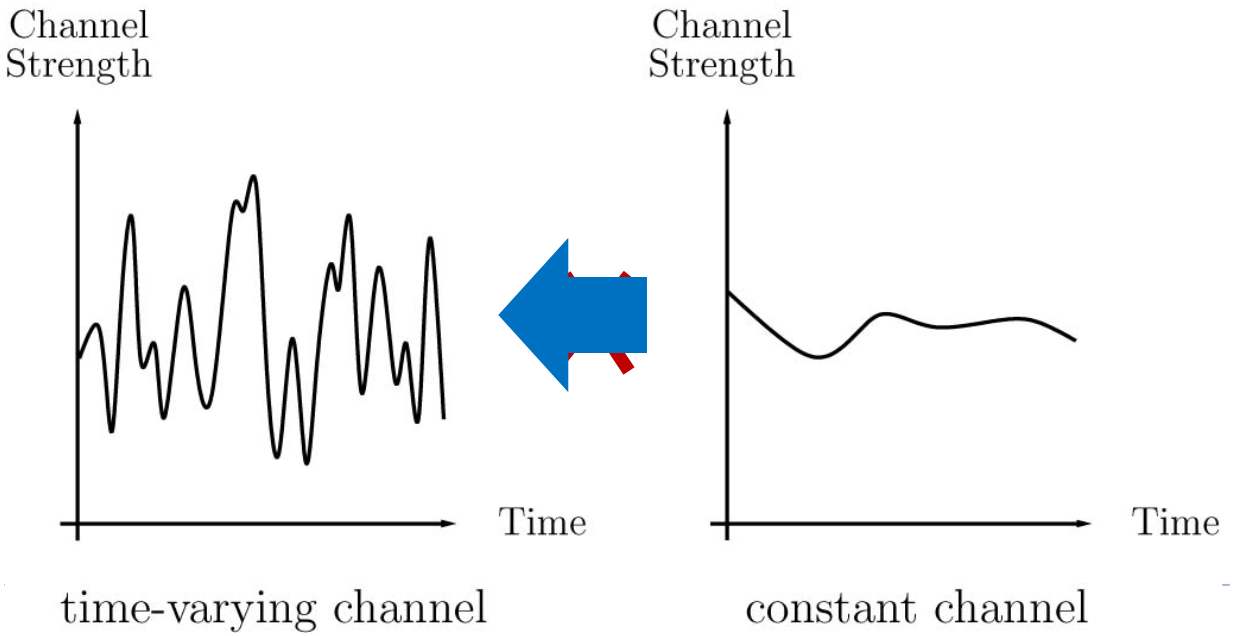
Asymmetric Users: Hitting the Peaks



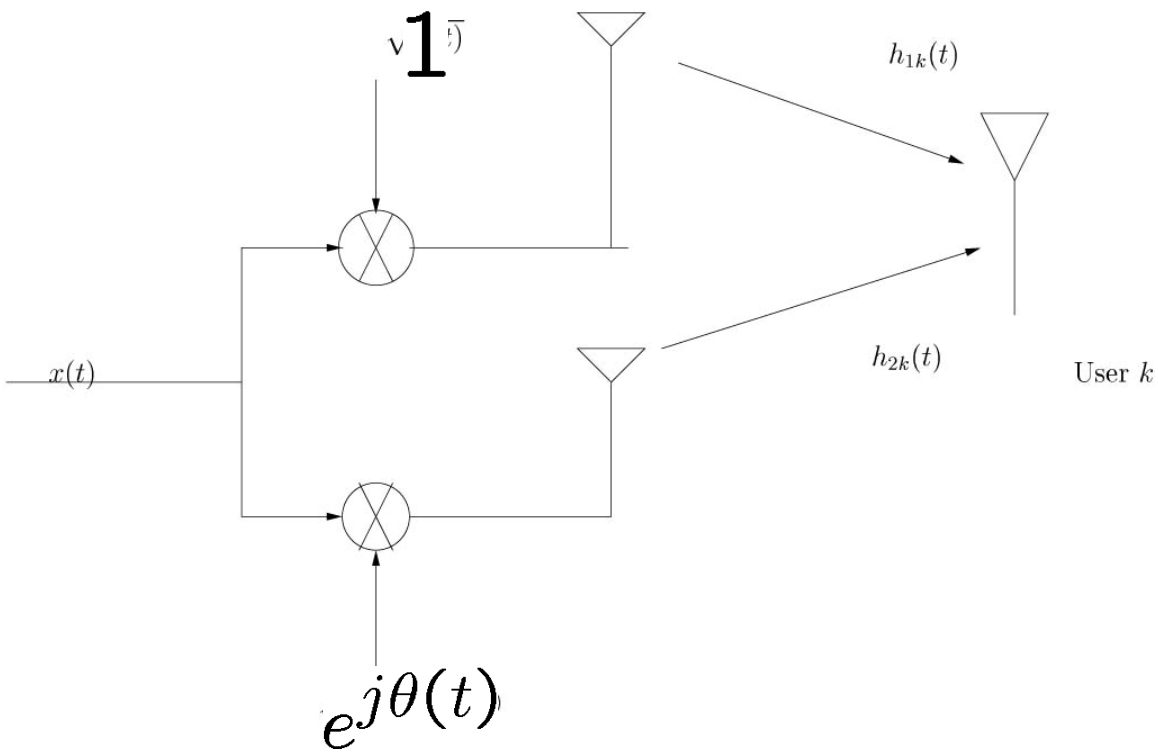
Want to serve each user when it is at its peak.
A peak should be defined with respect to the latency time-scale t_c of the application.

Changes of View

- Traditional view: fading is bad, constant is good
  - GSM/CDMA (IS-95)
- Modern view: fading can be exploited
- Not enough fading? ➔ introduce them in purpose

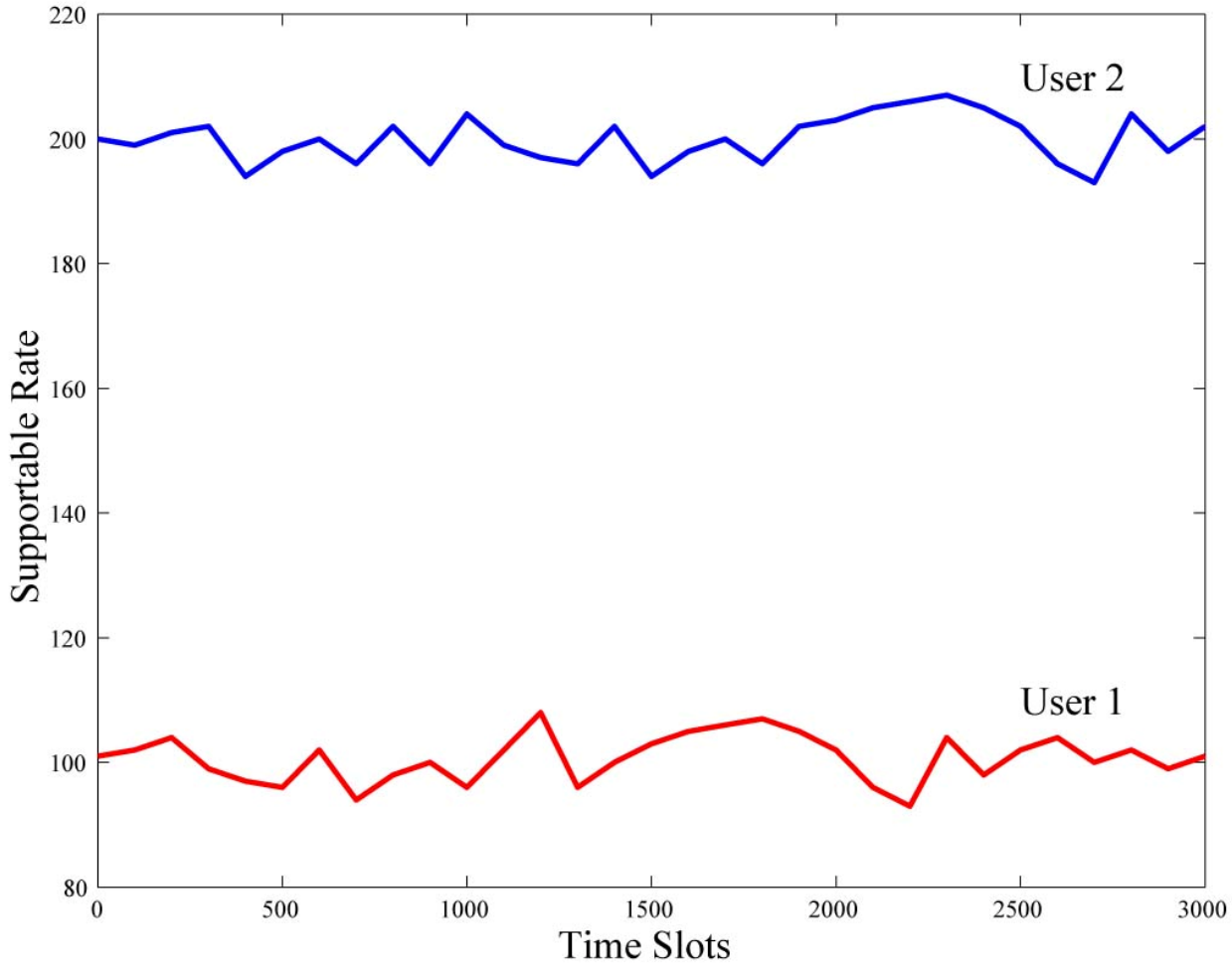


Dumb Antennas

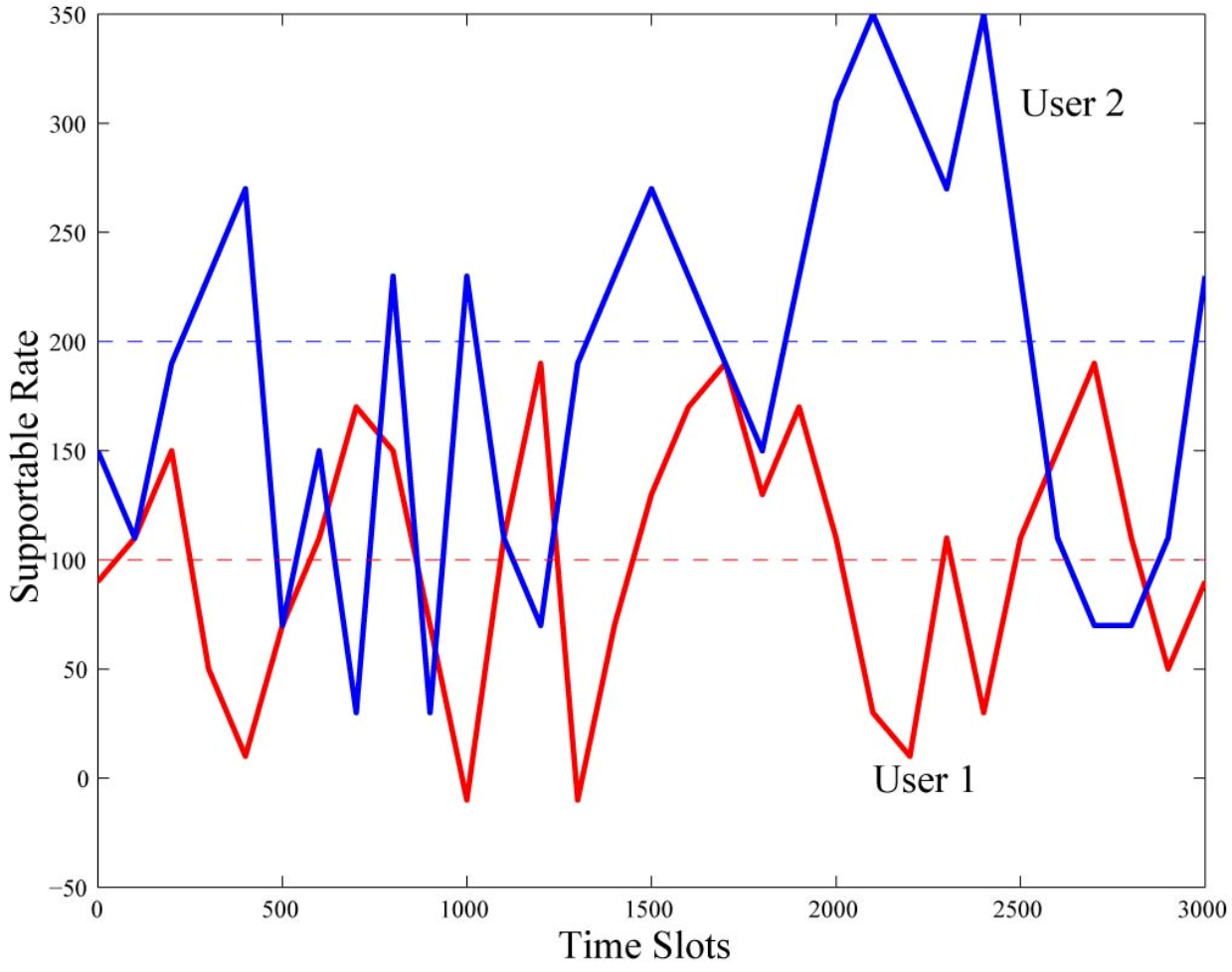


The information bearing signal at each of the transmit antenna is multiplied by a time-varying phase.

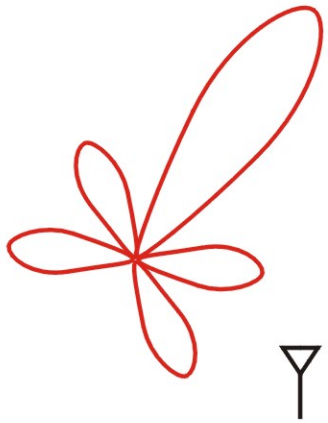
Slow Fading Environment: Before



After


User 2
User 1
Supportable Rate
Time Slots
350
300
250
200
150
100
50
0
−50
0
500
1000
1500
2000
2500
3000

Dumb Antennas in Action: One User



Most of the time, the beam is nowhere near the user.

Many users: Opportunistic Beamforming

•In a large system, there is likely to be a user near the beam at any one time.

•By transmitting to that user, close to true beamforming performance is achieved, without knowing the locations of the users.

Conclusions

- Wireless industry is ever growing
- Better technology with higher throughput
- Many tough and open engineering questions
- We need more good people (including your students!)