Wireless Cellular Networks: 3G

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These slides are available on-line at:

http://www.cse.wustl.edu/~jain/cse574-06/

Overview

- Wireless Generations: 1G, 2G, 2.5G, 3G
- CDMA
- GSM
- CDPD
- GPRS, EDGE
- EV-DV, EV-DO
- WCDMA, CDMA2000, TD-SCDMA
- HSDPA

3G Technologies

- Wideband CDMA (W-CDMA): Next Generation GSM. Uses 5 MHz channel width $\Rightarrow$ 2 Mbps

- CDMA2000: Next Generation CDMA (IS-95)
  1.25 MHz Channels $\Rightarrow$ 144 kbps

- 3x, 6x, 9x, and 12x in future

- 3x (3XRTT): 3.75 MHz channel $\Rightarrow$ 2 Mbps

- UWC-136: Next Generation TDMA (IS-136)
  200 kHz Channels $\Rightarrow$ 384 kbps or
  1.6 MHz Channels $\Rightarrow$ 2 Mbps
  Developed by Universal Wireless Communications Consortium (UWCC)

- Goal: Provide high-speed packet based Voice and Data

3G

❑ Also known as ITU IMT-2000 Project. Started in 1980.

❑ Goal: To have one world-wide standard and a common frequency band for mobile networking

❑ Result:

> Three frequency bands: Below 1 GHz, 1.7GHz, 2.5GHz

> Three different technologies: W-CDMA (Europe) CDMA2000 (North America) , and TD-SCDMA in China.

WCDMA

❑ Wideband CDMA

❑ Proposed by European Telecom Std Inst (ETSI) Alpha group

❑ WCDMA has 5MHz single carrier system w Freq Div Duplexing and direct sequence (FDD-DS) $\Rightarrow$ 2 Mbps data

❑ 3rd Generation Partnership Project (3GPP.org)

❑ 2.5G:

➢ HSCSD (High-Speed Circuit Switched Data)

➢ GPRS (General Packet Radio Service)
144 kbps data only

➢ EDGE (Enhanced Data for GSM Evolution)
384 kbps data

➢ HSDPA (High-speed downlink packet access)
Asymmetric. 2 Mbps+ downlink.

CDMA2000

❑ Proposed by Third Generation Partnership Project 2 (3GPP2.org).

❑ 3GPP2: Partnership of 5 Telecom standards bodies: ARIB and TTC in Japan, CWTS in China, TTA in Korea and TIA in North America

❑ Full backward compatibility with IS-95B (CdmaOne)

❑ CDMA2000 is also known as CDMA-MC (multi-carrier)

❑ It uses n carriers of 1.2288 MHz each. 1x, 3x, 6x, 9x, 12x

❑ 2.5G: Operators can overlay CDMA2000 1x now over CdmaOne. Also known as CDMA2000 1xEV. Implemented in 2 steps:

  ➢ 1xEV-DO (Evolution data only),

  ➢ 1xEV-DV (Evolution data and voice on one carrier).

TD-SCDMA

❑ Time Division Synchronous CDMA

❑ Proposed by China Wireless Telecommunication Standards group (CWTS)

❑ Uses Time Division Duplex (TDD)

❑ Synchronous $\Rightarrow$ All base station clocks are synchronized

❑ http://www.tdscdma-forum.org/
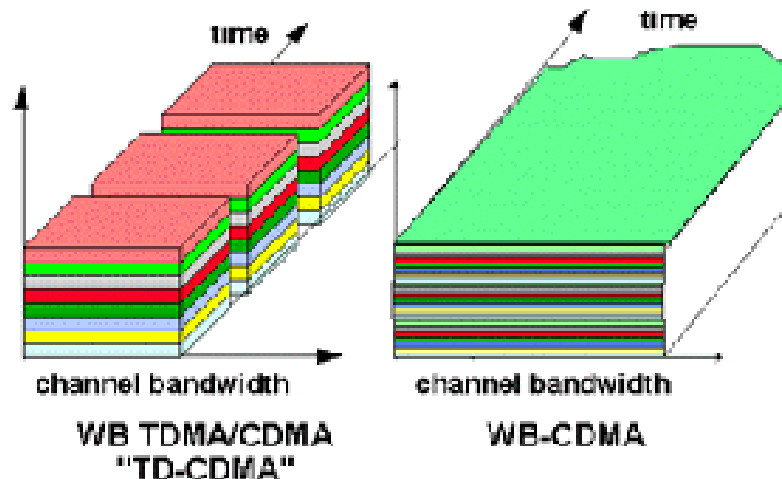
2.5 G

Data services over 2G networks

❑ GSM

  ➢ High-speed circuit-switched data (HSCSD)

  ➢ General Packet Radio Service (GPRS)

  ➢ Enhanced Data Rate for GSM Evolution (EDGE)

❑ CdmaOne:

  ➢ 1xEV-DO

  ➢ 1xEV-DV

HSCSD

❑ High-Speed Circuit Switched Data (HSCSD)

❑ First attempt to get high-speed data over GSM

❑ Allows data users to get 1 to 8 slots
Data rates up to 115 kbps

❑ Circuit switched $\Rightarrow$ Constant data rate
Not suitable for bursty data
Not widely implemented
GPRS is more widely implemented

GPRS

❑ General Packet Radio Service (GPRS)

❑ Standard GSM has 8 slots per 200 kHz channel
$\Rightarrow$ 9.6 kbps data

❑ GPRS allows any number of slots to a user
- ➢ 4 different codings used depending upon channel condition
- ➢ 9.05 kbps to 21.4 kbps per slot
- ➢ 76-171 kbps using all 8 slots.

❑ GPRS user can hop channels (as in CDPD). 2.5G Technology

Gi = GSM User

Gpi = GPRS User

	t_0	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_0	t_1	t_2
Uplink 1	G1		G2		GP2			GP1	G1		G2
Uplink 2				GP1			GP2				
Downlink 1	G1	GP1	G2		GP2			GP1	G1		G2
Downlink 2	GP1				GP1					GP2	

GPRS (Cont)

❑ Supports intermittent and bursty data transfers
  Point-to-multipoint also supported

❑ Need to add two new elements to GSM networks:

  ➢ Service GPRS support node (SGSN)
    – Security, Mobility, Access control

  ➢ Gateway GPRS support node (GGSN)
    – Connects to external packet switched networks

❑ Standardized by ETSI

EDGE

❑ Enhanced Data Rates for GSM Evolution (EDGE)

❑ Standard GSM uses Gaussian Minimum Shift Keying (GMSK) modulation

❑ EDGE changes to 8-PSK modulation $\Rightarrow$ 3 bits/Hz

❑ GPRS+EDGE $\Rightarrow$ 384 kbps

❑ Need better radio signal quality

❑ 76 mobile network operators in 50 countries have committed to deploy EDGE (March 2004)
http://www.gsacom.com/news/gsa_158.php4

Data Rates

Technology	Bandwidth	Data Rate/User (Theory)	Data Rate/User (Realistic)
GSM	200 kHz	9.6 kbps	9.6 kbps
GPRS	200 kHz	172 kbps	40 kbps
EDGE	200 kHz	474 kbps	100 kbps
CDMA2000 3x	3.75 MHz	2 Mbps	384 kbps
WCDMA	5 MHz	2 Mbps	1 Mbps

HSDPA

❑ High-Speed Downlink Packet Access for WCDMA

❑ Improved spectral efficiency for downlink $\Rightarrow$ Asymmetric

❑ Up to 10 Mbps in theory, 2Mbps+ in practice

❑ Announced by Siemens, then by Ericsson, Alcatel, Fujitsu

❑ Adaptive modulation and coding (AMC)

❑ Multi-code (multiple CDMA channels) transmission

❑ Fast physical layer (L1) hybrid ARQ (H-ARQ)

❑ Packet scheduler moved from the radio network controller (RNC) to the Node-B (base station)
$\Rightarrow$ advanced packet scheduling techniques
$\Rightarrow$ user data rate can be adjusted to match the instantaneous radio channel conditions.

1xEV-DV

❑ 1x Evolution to Data and Voice (1xEV-DV)

❑ Single 1.25 MHz bandwidth shared between voice and data users

❑ 3.1 Mbps peak data rate on Forward Packet Data Channel

❑ Voice users are usually scheduled first

❑ Dynamic allocation of the unused BS power to data users every slot cycle (1.25 ms)
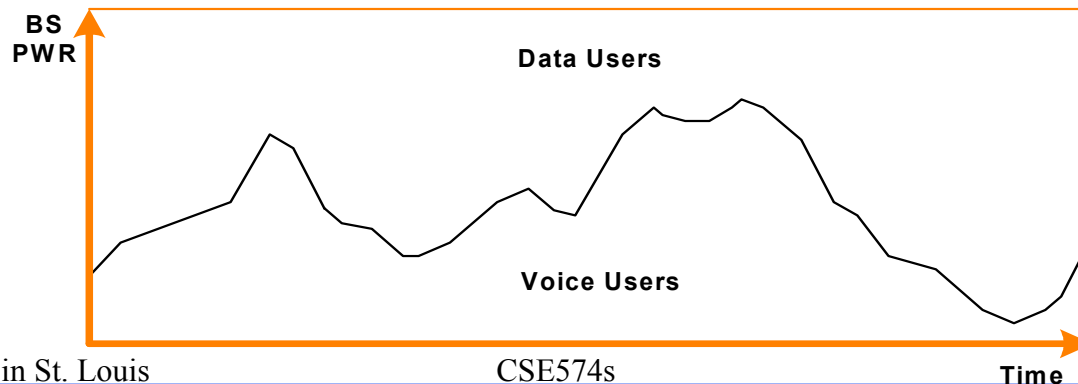
1xEV-DV vs. 1xEV-DO

❑ EV-DV uses 1 RF channel for data and voice while EV-DO requires separate carrier frequencies

❑ Fully compatible with CdmaOne and CDMA2000 allowing all types of handoff between those systems $\Rightarrow$ economical, incremental deployment; uninterrupted voice and data coverage

❑ EV-DV provides smooth coexistence between voice and data services

❑ IS-2000 Rel 0 BS can be upgraded to support EV-DV Rel C by addition of channel card and SW upgrade

❑ To upgrade the same BS to support EV-DO in addition to 1x, a separate RF path (from antennas through PA's to channel card) is needed
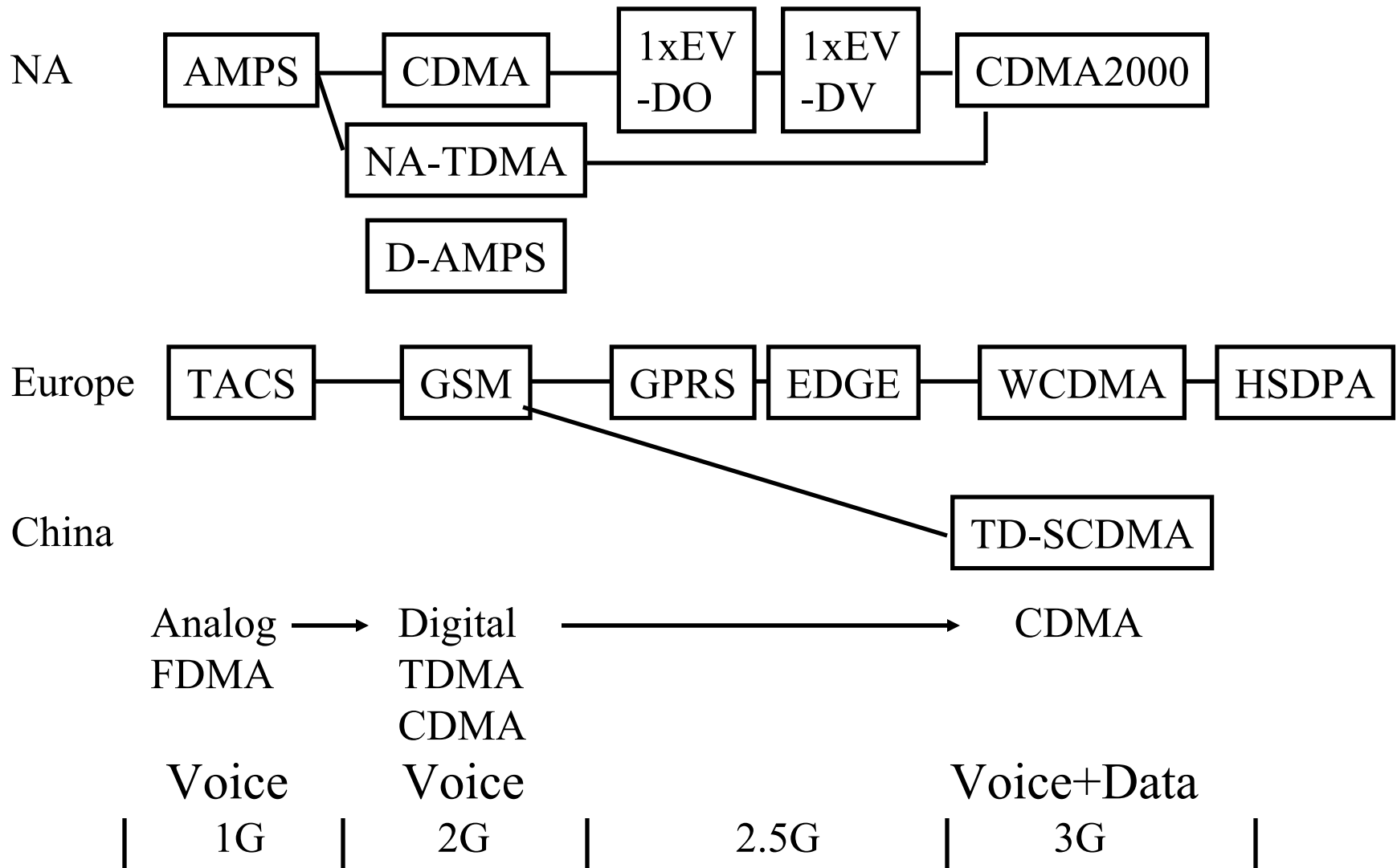
Data Rates

	Down Link	Up Link
1x	9.6 kbps – 614.4 kbps	9.6 kbps – 460.8 kbps
1xEV-DV Rel. C	9.6 kbps – 3.09 Mbps	9.6 kbps – 460.8 kbps
1xEV-DV Rel. D	9.6 kbps – 3.09 Mbps	9.6 kbps – 1.5 Mbps
1xEV-DO	38.4 kbps – 2.45 Mbps	9.6 kbps – 450.8 kbps
1xEV-DO Rel. A	38.4 kbps – 2.45 Mbps	9.6 kbps – 1.5 Mbps

3G Deployments
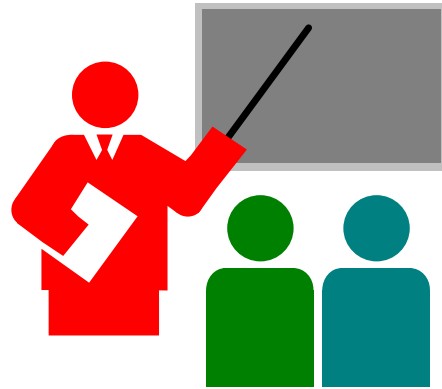
❑ 3G deployments are finally happening.

❑ 18 Deployments by mid-2005

❑ UMTS forum lists a few dozen installations
  Ref: http://www.umts-forum.org/servlet/dycon/ztumts/umts/Live/en/umts/Resources_Deployment_index

❑ Mostly in Japan and Korea

❑ NTT DoCoMo uses W-CDMA for its 3G service

❑ Deployments starting in Brazil, Canada, Japan, Korea, USA, and UK (2004)

Evolution of Cellular Technologies

NA

AMPS — CDMA — 1xEV-DO — 1xEV-DV — CDMA2000

NA-TDMA

D-AMPS

Europe: TACS — GSM — GPRS — EDGE — WCDMA — HSDPA

China: TD-SCDMA

Analog → Digital → CDMA
FDMA   TDMA
        CDMA
Voice   Voice   Voice+Data
| 1G | 2G | 2.5G | 3G |

Summary

- Geometry of cells and frequency reuse
- Fading, diffraction, scattering, multi-path
- Three generations: 1G (Analog), 2G (digital), 3G (Data)
- AMPS
- IS-95
- IMT2000 (W-CDMA, CDMA2000, TD-SCDMA)

Reading Assignment

❑ Read sections 3.1 to 3.6 from Murthy and Manoj