3rd Generation Systems

• Review of Cellular Wireless Networks
• UMTS
Cellular Wireless Network Evolution

• **First Generation**: Analog
  – AMPS: Advance Mobile Phone Systems
  – Residential cordless phones

• **Second Generation**: Digital
  – IS-54: North American Standard - TDMA
  – IS-95: CDMA (Qualcomm)
  – GSM: Pan-European Digital Cellular
  – DECT: Digital European Cordless Telephone
Cellular Evolution (cont)

• Third Generation: T/CDMA
  – combines the functions of: cellular, cordless, wireless LANs, paging etc.
  – supports multimedia services (data, voice, video, image)
  – a progression of integrated, high performance systems:
    (a) GPRS
    (b) EDGE
    (c) UMTS
Cellular Concept

- Geographical separation
- Capacity (frequency) reuse
- Backbone connectivity
AMPS (Advanced Mobile Phone System): FDMA

In each cell, 57 channels each for A-side carrier and B-side carrier

Channels are divided into 4 categories:

1. Control (base to mobile) to manage the system.
2. Paging (base to mobile) to alert mobile users to incoming calls.
3. Access (bidirectional) for call set up and channel assignment.
4. Data (bidirectional) for voice, FAX, or data

Frequencies are not reused in adjacent cells
Handoff

- Handoff: Transfer of a mobile from one cell to another
- Each base station constantly monitors the received power from each mobile.
- When power drops below given threshold, base station asks neighbor station (with stronger received power) to pick up the mobile, on a new channel.
- The handoff process takes about 300 msec.
Digital Cellular: IS-54 TDMA System

• Second generation: digital
• Same frequency as AMPS
• Each 30 kHz RF channel is used at a rate of 48.6 kbps
  – 3 TDM slots/RF band
  – 8 kbps voice coding
  – 16.2 kbps TDM digital channel

• 4 cell frequency reuse
• Capacity increase per cell per carrier
  – $3 \times 416 / 4 = 312$ (instead of 57 in AMPS)
  – Additional factor of two with speech activity detection.
IS-54 slot and frame structure

Frame
1944 bits in 40 ms (48600 b/s)

SLOT 1 | SLOT 2 | SLOT 3 | SLOT 4 | SLOT 5 | SLOT 6

MOBILE TO BASE
DATA 130 | DATA 130 | DVCC 12 | SACCH 12 | DATA 122 | DATA 122
SYNC 28 | SACCH 12 | DATA 130 | DVCC 12 | DATA 130 | RSVD 12

BASE TO MOBILE
SYNC 28 | SACCH 12 | DATA 130 | DVCC 12 | DATA 122 | RSVD 12

G: GUARD TIME  R: RAMP TIME
DVCC: DIGITAL VERIFICATION COLOR CODE
RSVD: RESERVE FOR FUTURE USE
GSM (Group Special Mobile)

Pan European Cellular Standard
Second Generation: Digital
Frequency Division duplex (890-915 MHz Upstream; 935-960 MHz Downstream)
125 frequency carriers
Carrier spacing: 200 Khz
8 channels per carrier (Narrowband Time Division)

Speech coder: linear predictive coding (Source rate = 13 Kbps)

Modulation: phase shift keying (Gaussian minimum shift keying)

Multilevel, time division frame structure

Slow frequency hopping to overcome multipath fading
GSM functions - TDMA access technique

BURST TRANSMITTED BY

MOBILE 1

MOBILE 2

MOBILE 8

TDMA FRAME (4.6 ms)

TIME-SLOT: 577 μs

SIGNAL BURST: 546 μs
GSM network architecture and functions

Signalling channels

**BCCH**: Broadcast Control Channel
- point-to-multipoint unidirectional control channel
  broadcasting system information to MS

**CCCH**: Common Control Channel
- **up-link**: RACH (Random Access Channel)
- **down-link**: PCH (Paging Channel)
  AGCH (Access Grant Channel)

**DCCH**: Dedicated Control Channel
- point-to-point bidirectional control channel
- SACCH (Slow Associated Control Channel)
- FACCH (Fast Associated Control Channel)
- SDCCH (Stand Alone Dedicated Control Channel)
UMTS (Universal Mobile Transport Service)

Requirements

• 384 Kbps for full area coverage
• 2 Mbps for local area coverage
• variable bit rate
• packet traffic support
• flexibility (eg, multiple, multimedia streams on a single connection)
Third generation services

- **2M**
  - Video conference
- **384K**
  - Video conference
- **64K**
- **32K**
- **16K**
  - Remote medical service
- **9.6K**
- **2.4K**
- **1.2K**

- **Point to point**
  - Internet
  - Telephone conference
  - Telephone
  - Pager
  - Electronic newspaper
  - FAX
  - Electronic publishing
  - ISDN
  - Distribution services (voice)
  - Distribution services (data)

- **Bidirectional**
  - Video conference
  - Voice mail

- **Unidirectional**
  - Video catalogue shopping
  - Video on demand

- **Multicast multipoint**
  - Mobile TV
  - Mobile radio

- **Data distribution services**
  - ISDN
  - FAX
  - Electronic publishing
  - Electronic newspaper
  - Voice mail
  - Video conference

- **Voice distribution services**
  - Mobile radio
  - Mobile TV
  - Voice mail
  - Video conference
  - Electronic newspaper
Third generation bandwidth assignment (I)

ITU

DECT

EUROPE

JAPAN
UTRAN (UMTS Terrestrial Radio Access Net) Architecture

UTRAN

Core Network

RNC

I_u

I_u

I_u

RNS

B-node

I_{ub}

Site Contr

BTS

BTS

BTS

Site Contr

BTS

BTS

BTS

B-node

I_{ub}

B-node

I_{ub}

B-node

I_{ub}

B-node
Access techniques for mobile communications

- **P** - Power
- **T** - Time
- **F** - Frequency

- **FDMA (TACS)**
- **TDMA (GSM, DECT)**
- **ATDMA (UMTS)**
- **CDMA (UMTS)**

P - Power
T - Time
F - Frequency
W-CDMA (Wide Band CDMA)

Key features

- Improved **capacity** and coverage (over second generation CDMA); backward compatible
- High degree of **service flexibility**: multiple, parallel services per connection; efficient pkt access
- **Operator flexibility**: asynchronous interstation operation; hierarchical cell structures (HCS); adaptive antenna arrays (enabled by uplink pilot symbols); TDD (Time Division Duplex) mode for asymmetric traffic and uncoordinated environments.
Radio Interface - protocol architecture

C-plane

U-plane

Logical channels

Transport channels

L3

L2/LAC

L2/MAC

L1

Physical Layer

MAC

RLC

RRC

LAC

Transport channels

Logical channels

C-plane

U-plane

Radio Interface - protocol architecture
Layer 1 - up link physical channels (W-CDMA)

Dedicated Physical Data Channel

Data

0.667 ms

Pilot Feedback indicator Transmit power control Transport format ind.

Dedicated Physical Control Channel

Slot#1 Slot#2 Slot#i Slot#15

Frame#1 Frame#2 Frame#i Frame#72

10 ms
Layer 1 - down link physical channels
(W-CDMA example)
## Transport channels (example)

<table>
<thead>
<tr>
<th>Channel Type</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dedicated Channel (DCH)</td>
<td>Fast change of bit rate (10ms)</td>
</tr>
<tr>
<td></td>
<td>Fast power control</td>
</tr>
<tr>
<td></td>
<td>Inherent MS addressing</td>
</tr>
<tr>
<td>Random Access Channel (RACH) - up link</td>
<td>Collision</td>
</tr>
<tr>
<td></td>
<td>Open loop power control</td>
</tr>
<tr>
<td></td>
<td>Explicit MS addressing</td>
</tr>
<tr>
<td>Broadcast Control Channel (BCH) - down link</td>
<td>Slow power control</td>
</tr>
<tr>
<td></td>
<td>Explicit MS addressing</td>
</tr>
<tr>
<td>Forward Access Channel (FACH) - down link</td>
<td>Use of sleep modes</td>
</tr>
<tr>
<td>Paging Channel (PCH) - down link:</td>
<td></td>
</tr>
</tbody>
</table>
Multiplexing transport channels onto physical channels
MS physical layer up-down link example of multiplexing

Up link:
- Coding and multiplexing
- mapping
- phy ch

TFI transmitted on the control channel

Down link:
- decoding and demultiplexing
- phy ch
- Cell 1
- Cell 2
- Cell 3
MAC Services and Functions

- set-up, release of logical channels
- data transfer service on logical channels
- allocation/re-allocation of radio resources
- measurement report

Functions

- Selection of the transport format
- Handling of priority within one user/between users
- Scheduling of control messages (broadcast, paging, notification)
- Multiplexing/de-multiplexing of higher layers PDUs on/from common or dedicated transport channels
- Contention control on the random access channel
Retransmission Protocol - services and functions

- Layer 2 connection set-up and release
- transparent data transfer
- unacknowledged data transfer
- acknowledged data transfer

Functions

- connection control
- segmentation and re-assembly
- error detection/recovery and in-sequence delivery
- transfer of user data
- flow control
- duplicate detection
- QoS adaptation

Services

- RCLP PDU
  - 160 bit
  - 10ms
  - 32kbit/s
  - 10ms
  - 16kbit/s

- RCLP PDU
  - 160 bit

- RCLP PDU
  - 160 bit
Radio Resource control - functions

- Broadcast of information provided by the Core Network related to the access segment
- Set-up, maintenance and release of an RRC connection
- Set-up, maintenance and release of radio bearers on the user plane
- Assignment, reconfiguration and release of radio resources for the connection
- Arbitration of radio resource allocation between cells
- RRC connection mobility functions
- Quality of Service control and radio resource allocation among the cells
- Admission and congestion control
- Control of the MS measurement reporting
Orthogonal Variable Spreading Factor

\[ c_{4,1} = (1,1,1,1) \]
\[ c_{2,1} = (1,1) \]
\[ c_{4,2} = (1,1,-1,-1) \]
\[ c_{2,2} = (1,-1) \]
\[ c_{4,3} = (1,-1,1,-1) \]
\[ c_{4,4} = (1,-1,-1,1) \]
Uplink Variable Rate

1-rate
1/2-rate
1/4-rate
0-rate
Variable rate

R = 1
R = 1/2
R = 0
R = 0
R = 1/2

10 ms

: DPCCH (Pilot+TPC+RI)
: DPDCH (Data)
Downlink Variable Rate (DTX based)

- 1-rate
- 1/2-rate
- 1/4-rate
- 0-rate

0.625 ms

- DPCCH-part (Pilot+TPC+RI)
- DPDCH-part (Data)
**TD-CDMA** *(Time Division Duplex)*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple access scheme</td>
<td>TDMA/CDMA</td>
</tr>
<tr>
<td>Channel spacing</td>
<td>5 MHz</td>
</tr>
<tr>
<td>Carrier chip rate</td>
<td>3.84 Mchips/s</td>
</tr>
<tr>
<td>Spreading factor</td>
<td>1-16</td>
</tr>
<tr>
<td>Frame length</td>
<td>10 ms</td>
</tr>
<tr>
<td>Multirate concept</td>
<td>multislot /multicode</td>
</tr>
<tr>
<td>Modulation</td>
<td>QPSK</td>
</tr>
<tr>
<td>Burst Types</td>
<td>burst 1 long delay spread</td>
</tr>
<tr>
<td></td>
<td>burst 2 short delay spread</td>
</tr>
<tr>
<td>Detection</td>
<td>Coherent, based on midamble</td>
</tr>
</tbody>
</table>
TDD - frame structure

multiframe = 24 frames (240 ms)

frame = 15 TS (10 ms)

DL>UL  UL>DL
switching points

BCCH  RACH  UL TCH  DL TCH
Packet Data Service

In W-CDMA, data packets can be transmitted in 3 ways:

- (a) **RACH** (Random Access Channel): used for small amount of data; no reservations, thus low latency; but, collisions and no power control (on RACH)

- (b) **Request a dedicated channel** (like VC setup): MS sends a Res Req msg (on RACH) with traffic specs; network returns a Req All + Cap All (with transport formats) on FACH, if resources are available; Cap_All may be issued separately (later) if the network load is high; MS transmits after receiving the Cap All.
Packet Data Service (cont)

• (c) use **existing dedicated channel** (before it expires): if a DCH was recently used, go ahead and tx the unscheduled pkt on that channel. If timer expired, the MS can still omit the Res Req and issue just the Cap All
Fig. 16. Packet transmission on the RACH.

Fig. 17. Packet transmission on a dedicated channel.
Fig. 18. Resource request and allocation on the RACH and FACH, respectively, followed by transmission of data on the dedicated channel.

Fig. 19. Packet transmission on the dedicated channel.
Real time services

- MS issues Res_Req on RACH (or on DCH if it has one going)
- Network issues Res All (with TF parameters)
- MS starts transmission immediately (no wait for Cap_All)
- Network may later reduce/restore the TF depending on load fluctuations
Congestion Control

- Congestion may occur even after careful admission control
- Without congl. control, mobiles tend to increase their tx power, to combat interference, thus aggravating the problem
- Solutions:
  (a) lower bit rate of users insensitive to delay;
  (b) perform interfrequency handovers
  (c) remove connection(s)
- Congestion control remedies activated by load thresholds
Handover functions - basic feature for the RAN architecture

Handover modes:
- Hard
- Seamless
- Soft
Macrodiversity - active set

- Cell A
- Cell B
- Cell C

- Signal margin
- Time margin
- ADD threshold
- DROP threshold

- Soft handover region

- Ec/No vs. Time

Macrodiversity - active set
The macrodiversity control

control point

two control points

control points mobility

mobility