Telephony and Mobile Cellular Systems

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Reading directives

Forouzan 4th: 9.1, 9.3, 12.3, 16.1
Forouzan 5th: 12.3, 14.1, 16.2
Kihl: 11

However, the content is defined by the lecture slides.
Public Service Telephone Network (PSTN)

Core network (SONET/SDH)

Local station

Access network

Copper cable

Digital

Analog
Data transfer in telephone networks

- The telephone core networks are digital.
  - PCM in local stations
  - Data transfer with 8-bits samples.
- The telephone networks use circuit switching.
  - A connection is set up for each call.
- The core networks use Synchronous Time Division Multiplexing.
From the telephone to local station (end office), the analog data is transferred on the 0-4 kHz frequency band.

In the local station, PCM is used to create 8-bit samples that are coded and transmitted in the network using circuit switching and STDM.

Also, there are gateways to the Internet and mobile networks.
Circuit switching

One link, $n$ channels

Path

A

M
Control messages

Switching stations (offices) communicate with standardized protocols using a separate network.

SP: Signal point  
STP: Signal transfer point  
SCP: Service control point

Data transfer network
Comparison with the Internet

- In the Internet, control messages are sent the same path as data packets.
  - Special protocols, for example ICMP, ARP, DNS
  - Included in headers of data packets.
- In the telephone networks, the data transfer is separated from the control messages.
  - Delays for setting up and tearing down connections.
  - Very efficient data transfer with circuit switching.
Signaling System No. Seven (SS7)

The protocol stack for telephone networks is called Signaling System No. Seven (SS7).

**MTP:** Message transfer part  
**SCCP:** Signaling connection control point  
**TCAP:** Transaction capabilities application part  
**TUP:** Telephone user port  
**ISUP:** ISDN user port
Reliability aspects

- A telephone switching station can be down only 6 minutes during 10 years.
- This means that:
  - All software updates must be performed during runtime.
  - All hardware parts are doubled for redundancy.
  - Much automatic error detection and failure recovery mechanisms.
Internet access with xDSL

xDSL (ADSL, VDSL, etc) is used for providing Internet access via the telephone access line.
Mobile cellular (telephone) networks

Access network

Base station

Mobile station

Core network
The Frequency is the main performance problem...

Very Low Frequency (VLF) 0.3-30 KHz
Low Frequency (LF) 30-300 KHz (e.g. submarines)
Medium Frequency (MF) 0.3-3 MHz (e.g. radio stations)
High Frequency (HF) 3-30 MHZ (e.g. radio stations)
Very High Frequency (VHF) 30-300 MHz (e.g. TV stations)
Ultra High Frequency (UHF) 0.3-3 GHz (e.g. mobile telephony)
Super High Frequency (SHF) 3-30 GHz (e.g. WLAN and microwave links)
Extremely High Frequency (EHF) 30-300 GHz
Optical transmission >300 GHz (e.g., IR, visible light, UV)
Together with mobility…

A cellular system should manage to maintain a connection even when the mobile station moves in high speeds, maybe across networks.
Cells and frequency reuse

- The network is geographically divided into cells.
- In each cell there is a base station.
- Each cell is given some frequencies. The frequencies are reused in other cells according to a specific pattern.
Cellular access network

Several cells are controlled by one base station controller.
Channelization (Multiple access)

- Several mobile terminals need to access the shared capacity of one cell.
  - Multiple access method needed
- Three basic so called channelization techniques:
  - Frequency-Division Multiple Access (FDMA)
  - Time-Division Multiple Access (TDMA)
  - Code-Division Multiple Access (CDMA)
Frequency-Division Multiple Access

In FDMA, the terminals have separate frequency bands.
Time-Division Multiple Access

In TDMA, the terminals use separate time slots on a shared frequency band.
Code-Division Multiple Access

In CDMA, the terminals send data on the same channel at the same time but with different chip sequences.
Example: chip sequences

\[
\begin{align*}
\textbf{C}_1 & = [+1 \ +1 \ +1 \ +1] \\
\textbf{C}_2 & = [+1 \ -1 \ +1 \ -1] \\
\textbf{C}_3 & = [+1 \ +1 \ -1 \ -1] \\
\textbf{C}_4 & = [+1 \ -1 \ -1 \ +1]
\end{align*}
\]
Example: data representation

- Data bit 0 → −1
- Data bit 1 → +1
- Silence → 0
Example: Resulting data on channel

- Bit 0
  - Station 1
    - $C_1$ = [+1 +1 +1 +1]
    - $d_1 \cdot c_1$ = [-1 -1 -1 -1]
  - Station 2
    - $C_2$ = [+1 +1 +1 -1]
    - $d_2 \cdot c_2$ = [-1 -1 -1 +1]

- Station 3
  - $C_3$ = [+1 +1 -1 -1]
  - $d_3 \cdot c_3$ = [0 0 0 0]

- Station 4
  - $C_4$ = [+1 -1 -1 +1]
  - $d_4 \cdot c_4$ = [+1 -1 -1 +1]

- Silent
  - Bit 0: -1
  - Bit 1: +1

Data: [-1 -1 -3 +1]

Common channel
Example: GSM access

GSM uses a combination of FDMA and TDMA. Originally developed only for voice data.
Cellular core network nodes
(general model)

PSTN

Internet

Other mobile operators

HLR = Home Location Register
VLR = Visitor Location Register
Problems with mobility

The necessary signal strength depends on the mobile station’s distance to the base station (*power control*).

The mobile stations can move to another cell (*handover/handoff*).

The mobile station can move to another network, maybe in another country (*roaming*).
Example: Finding a mobile station in GSM (or 3G)

- The network is divided into Location areas, each controlled by one BSC.
- Also, there are *administrative regions*, each controlled by one MSC.
- The VLR contains information about *all* mobile stations in the region (location areas).
- The MSC *pages* the BSCs about the exact location of a mobile station,
Mobile Internet

Application centric

Internet community

TCP/IP

“de facto” standards

ATM, SDH, SS#7

Telecom operators

Standard organizations

Technology centric
Objective: More bandwidth and Internet access

- Today, mobile cellular networks are not only used for telephony.
- Internet applications require much more bandwidth!
- Circuit switching is not optimal for Internet applications.
- Standardization of mobile cellular networks is focused on higher data rates and Internet access.
Universal Mobile Telecommunication System (UMTS)

- Already in 1992, a world-wide frequency band around 2 GHz was reserved for the 3rd generation systems.
- Internet access was included in the standard from the beginning.
- Several 3G projects in the world, problems with standardization.
- UMTS is one of the solutions for 3rd generation cellular telephony networks.
- 3rd Generation Partnership Project (3GPP) was started to unite solutions based on the GSM core network.

UE = User Equipment (Mobile station)
Node B = Base station
RNC = Radio Network Controller (Base station controller)
Medium Access in UMTS

- The frequency band is divided into channels as in GSM.
- Uplink and downlink channels are separate, either in time (TDD) or frequency (FDD).
- Each channel is shared between several users.
- The medium access method is Code Division Multiple Access (CDMA).
- Power control is essential!
The capacity for each user is dynamically allocated (each 10 ms). This allows for a more efficient use of the frequency band.
With HSDPA, a special shared downlink channel for data is used.

- Special modulation scheme
- Fast link adaptation
- Fast scheduling to users with favorable radio conditions
Long Term Evolution (LTE)

- 4th generation mobile networks
- Difference compared to GSM/UMTS:
  - Packet-switching!
  - Main service is Internet access, not telephony!
  - Higher data rates (of course)
- Solutions needed to provide Voice over LTE
- Higher data rates require much smaller cells than before, so called pico and femtocells.