Lecture 3-4
Satellite Systems

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REFERENCE

"MOBILE COMPUTING PRINCIPLES, DESIGNING AND DEVELOPING MOBILE APPLICATIONS WITH UML AND XML", REZA B'FAR

Contents

Introduction to satellite systems

History of mobile communication

Please refer to Tables 1.1 - 1.6,   pp. 2-10

- **Challenges were faced:**

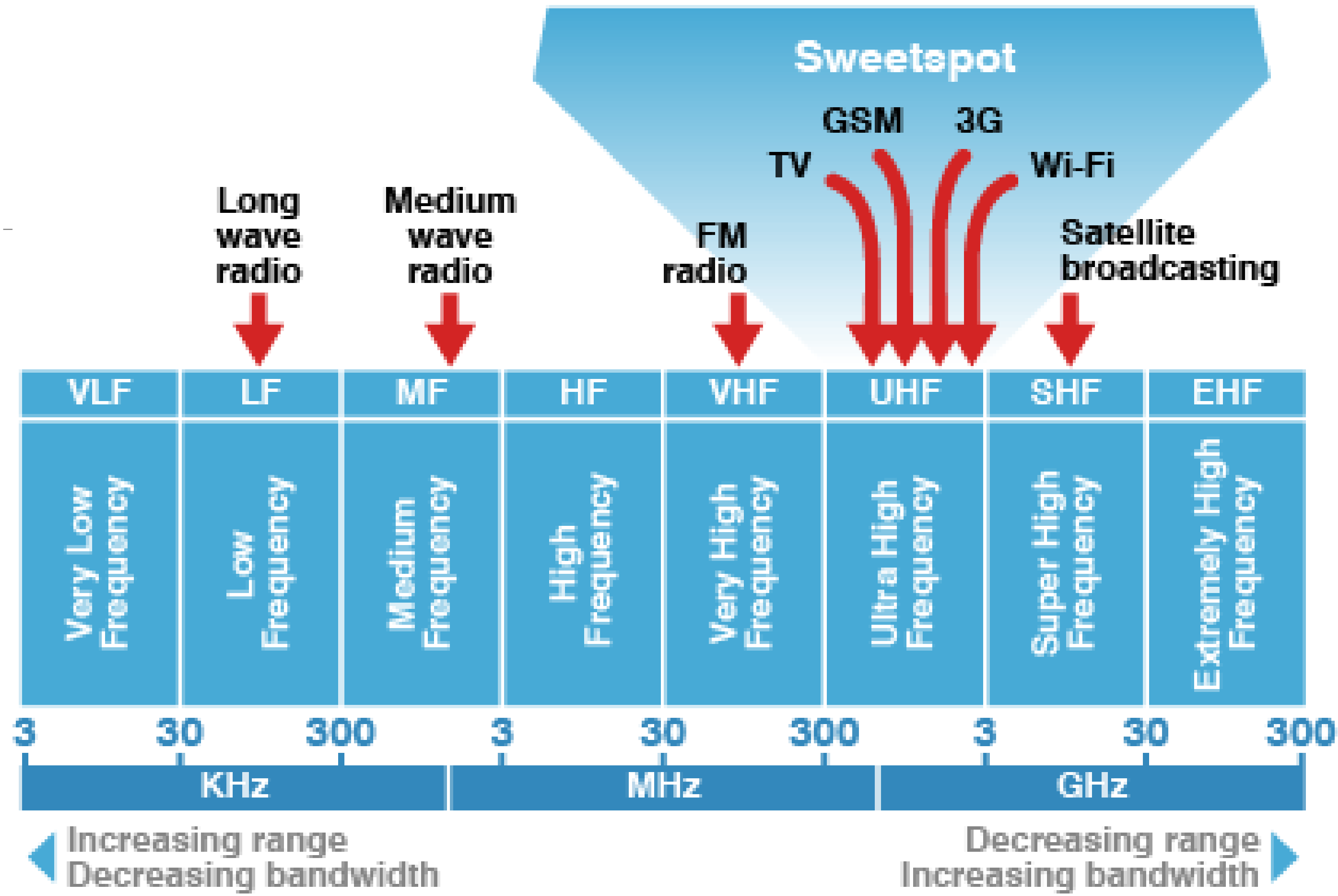
✓ Growing number of users

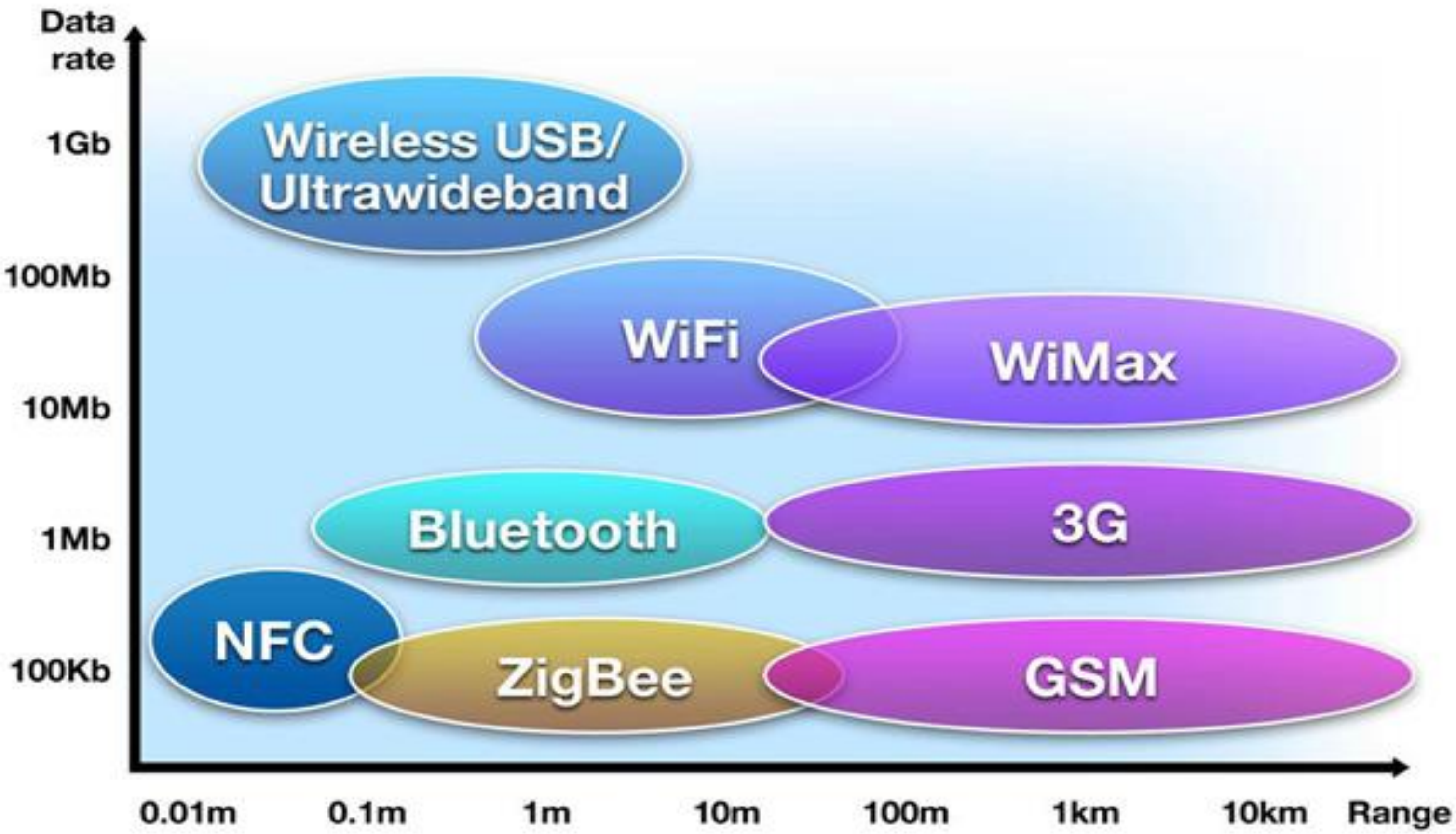
✓ Covered area (cell size)

✓ Mobility

✓ QoS

✓ Cost


Sweetspot
GSM
3G
TV
Wi-Fi
Long wave radio
Medium wave radio
FM radio
Satellite broadcasting
VLF
LF
MF
HF
VHF
UHF
SHF
EHF
Very Low Frequency
Low Frequency
Medium Frequency
High Frequency
Very High Frequency
Ultra High Frequency
Super High Frequency
Extremely High Frequency
3
30
300
3
30
300
3
30
300
KHz
MHz
GHz
Increasing range
Decreasing bandwidth
Decreasing range
Increasing bandwidth


Data rate
1Gb
100Mb
10Mb
1Mb
100Kb
Wireless USB/ Ultrawideband
WiFi
WiMax
Bluetooth
3G
NFC
ZigBee
GSM
0.01m
0.1m
1m
10m
100m
1km
10km
Range

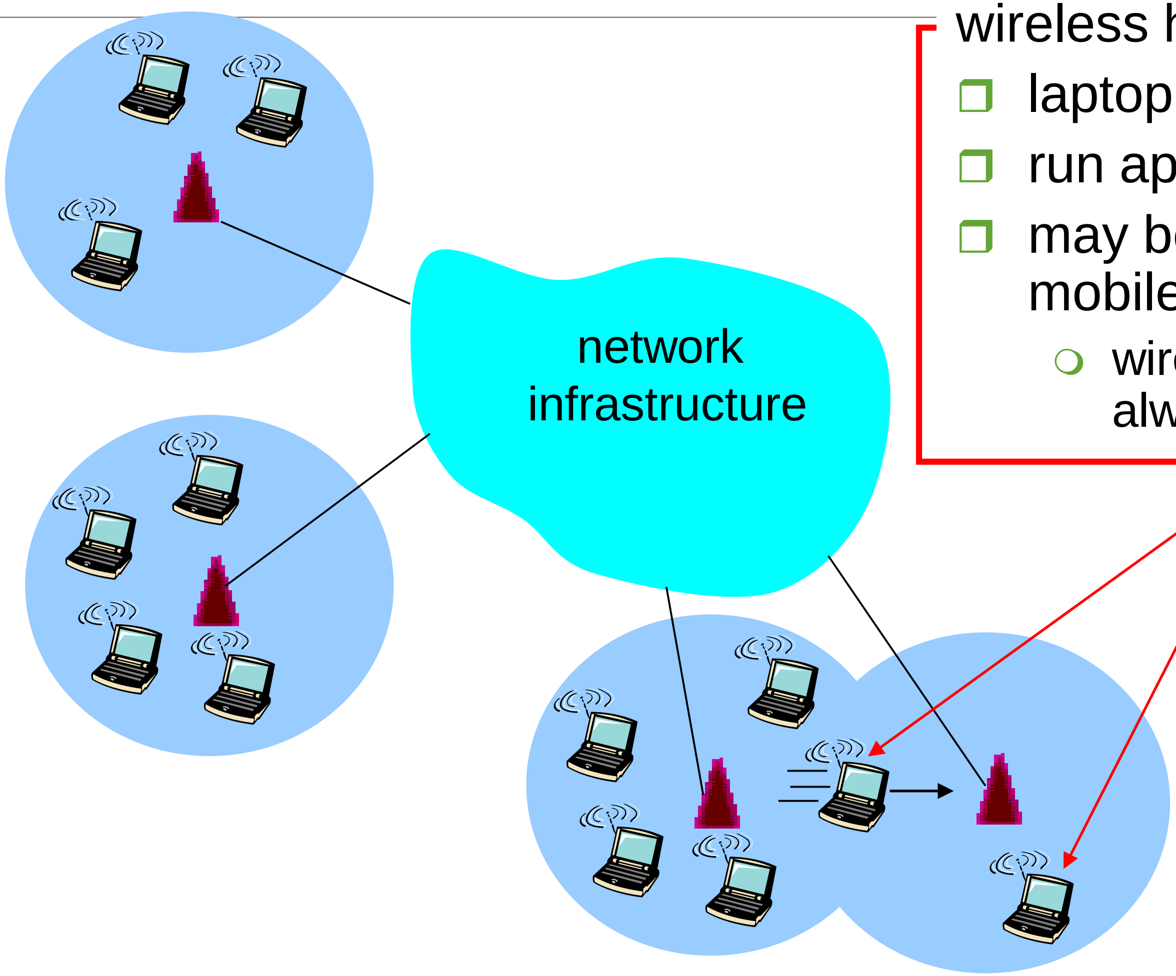
Technology	Services or Features	Coverage Area	Limitations	Examples
Cellular	Voice and data through handheld phones	Continuous coverage limited to metropolitan regions	Available bandwidth is very low for most data intensive applications	Cellular phones, personal digital assistant
Wireless local area network (LAN)	Traditional LAN extended with wireless interface	Used only in local environments	Limited range	NCR's Wavelan, Motorola's ALTAIR, Proxim's range LAN, Telesystem's ARLAN
GPS	Helps to determine the three-dimensional position, velocity, and time	Any place on the surface of earth	It is still not affordable by everyone	GNSS, NAVSTAR, GLONASS
Satellite-based PCS	Applications mainly for voice paging and messaging	Almost any place on earth	It is costly	Iridium, Teledesic

Ricochet	High-speed, secure mobile access to the desktop (data) from outside the office	Some major cities, airports, and some university areas	Has a transmission limitation. Environmental conditions affect quality of service	MicroCellular Data Network (MCDN)
Home networking	To connect different PCs in the house to share files and devices such as printers	Anywhere in the house	Limited to a home	Netgear Phoneline 10X, Intel AnyPoint Phoneline Home Network, 3Com Home Connect Home Network Phoneline
Ad hoc networks	Group of people come together for a short time to share data	Equal to that of local area network, but without fixed infrastructure	Limited range	Defense applications
WPAN (Bluetooth)	All digital devices can be connected without any cable	Private ad hoc groupings away from fixed network infrastructures	Range is limited due to the short-range radio link used	Home devices
Sensor networks	A large number of tiny sensors with wireless capabilities	Relatively small terrain	Very limited range	Defense and civilian applications

2-Characteristics of satellite systems

- Wireless systems had a high-power transmitter covering the entire service area.
- Different wireless devices need to be supported for different types of services; telephone, PDA, laptop (mobile subscriber)
- It has to maintain connectivity with the world while moving.

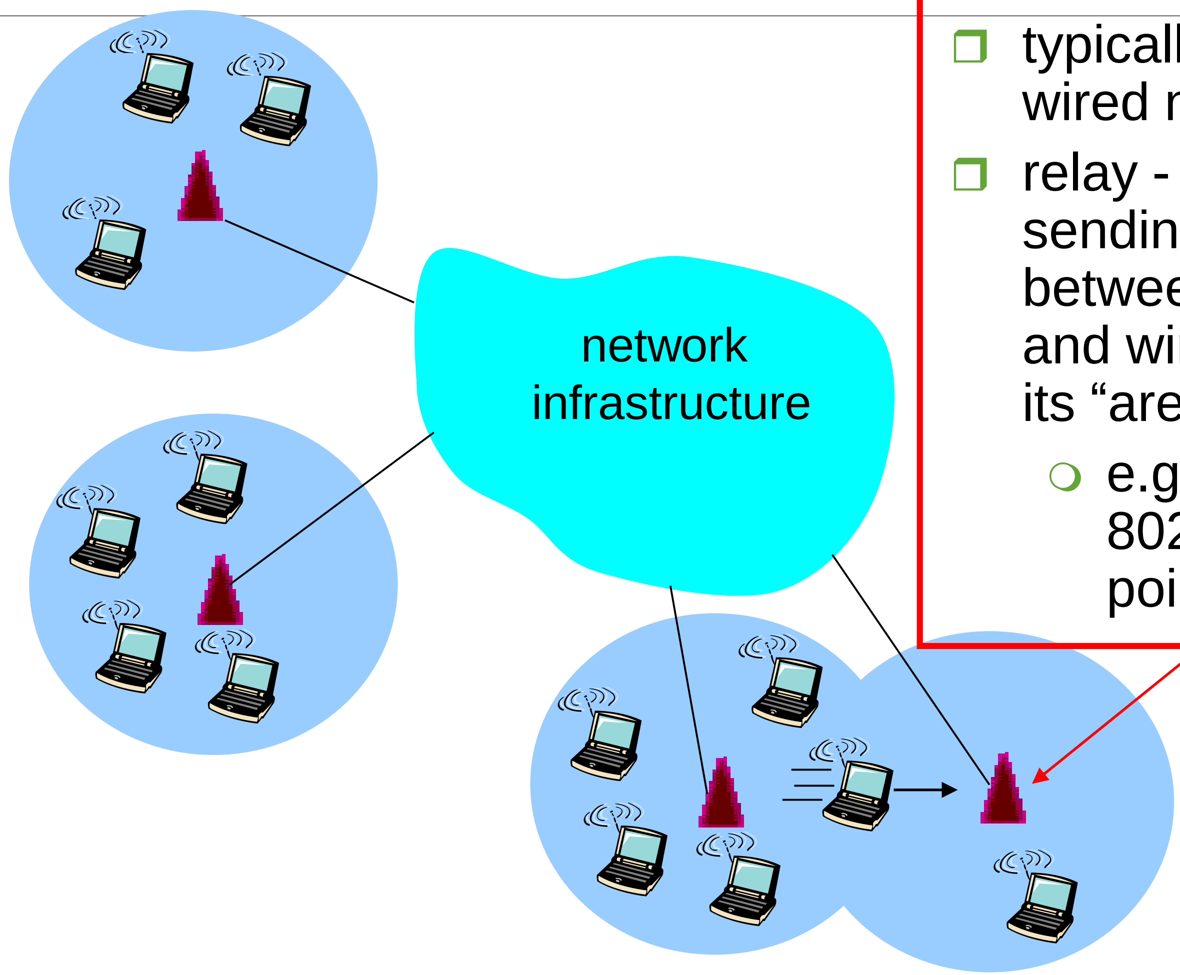
Elements of a wireless network



wireless hosts

- laptop, PDA, IP phone
- run applications
- may be stationary (non-mobile) or mobile
  - wireless does *not* always mean mobility

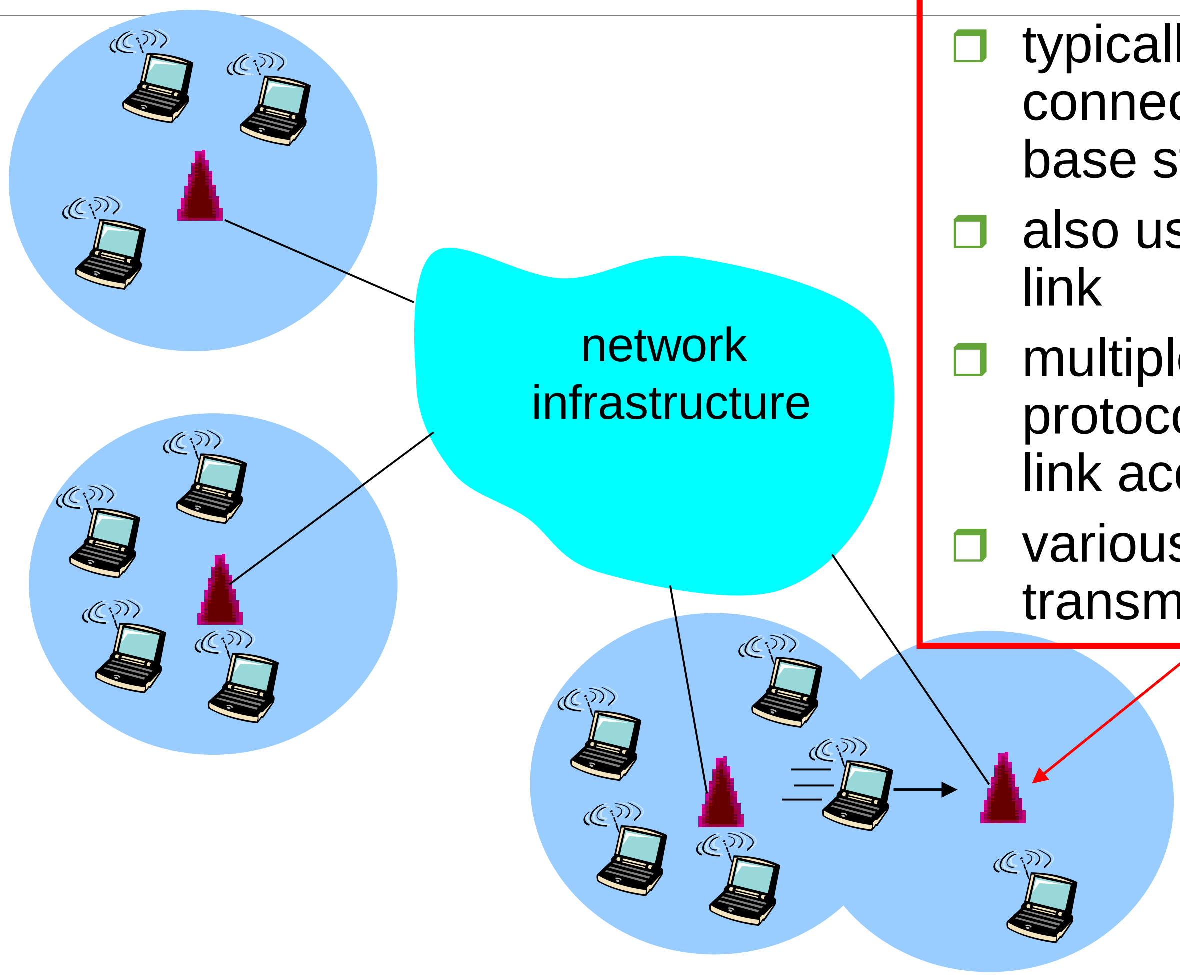
Elements of a wireless network



base station

- typically connected to wired network
- relay - responsible for sending packets between wired network and wireless host(s) in its “area”
  - e.g., cell towers, 802.11 access points

Elements of a wireless network



wireless link

- typically used to connect mobile(s) to base station
- also used as backbone link
- multiple access protocol coordinates link access
- various data rates, transmission distance

continued

- ***Cell*** basically represents the area that can be covered by a transmitting station, usually called a base station **(BS).**

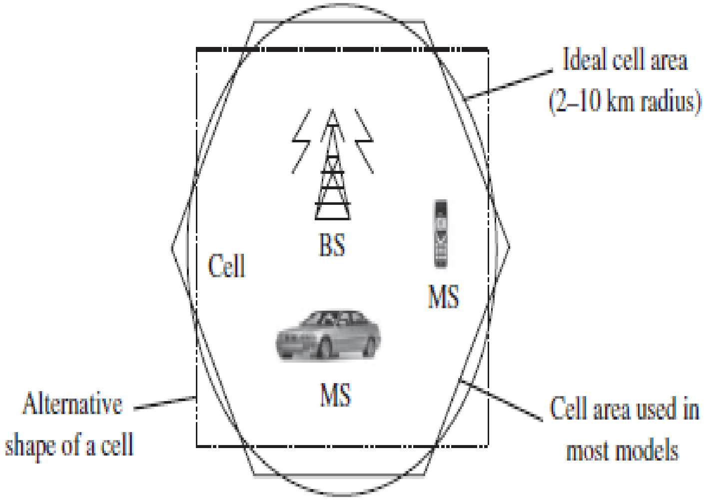
radius of the cell is equal to the reachable range of the transmitted signal.

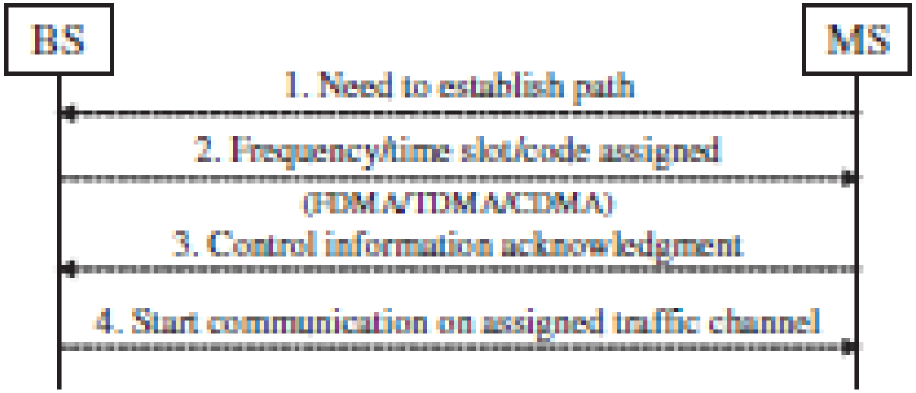
Each cell serves

multiple Mobile Subscribers

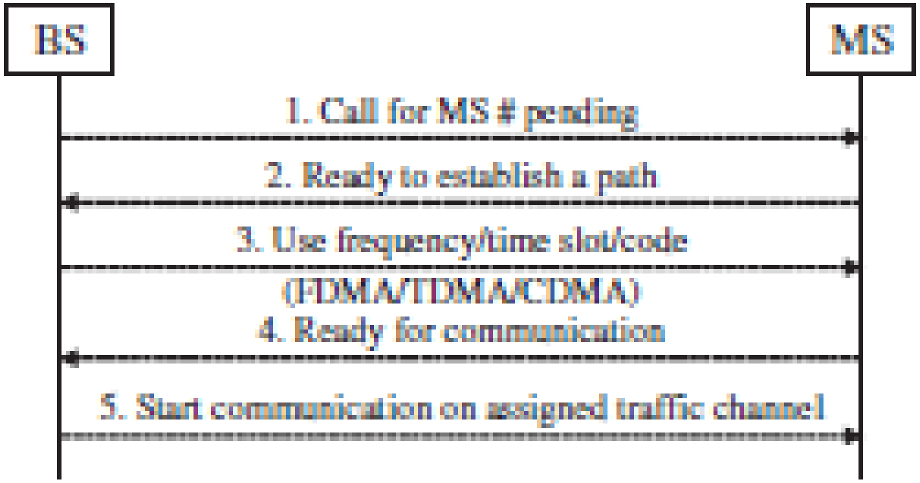
(MS) by connecting them

to single BS





(a) Steps for a call setup from MS to BS



(b) Steps for a call setup from BS to MS

Figure 1.21
Handshake steps for a call setup between MS and BS using control channels.

continued

Base station controllers (BSCs) which connect BS's via wire

Mobile switching center (MSC) are connected to a MSCs are connected to the ***telephone network***

continued

- ***mobile switching center (MSC) :***

Is responsible for routing calls, SMS, and data

- Contains three components:
  - Home Location Register (HLR)
    - Initial home location of MS where billing and access information are maintained
  - Visitor Location Register (VLR)
    - Information about visiting MSs
  - Authentication Center (AuC)
    - Authentication information of MS SIM card
- Each MS subscribes to only one MSC

continued

the MS needs to be in the area of one of the cells (and hence a BS) so that mobility of the MS can be supported.

BSs are connected through hard-wires and are controlled by a BS controller (BSC).

which in turn is connected to a mobile switching center (MSC).

Several MSCs are interconnected to a PSTN (public switched telephone network) and the

ATM (asynchronous transfer mode) backbone.

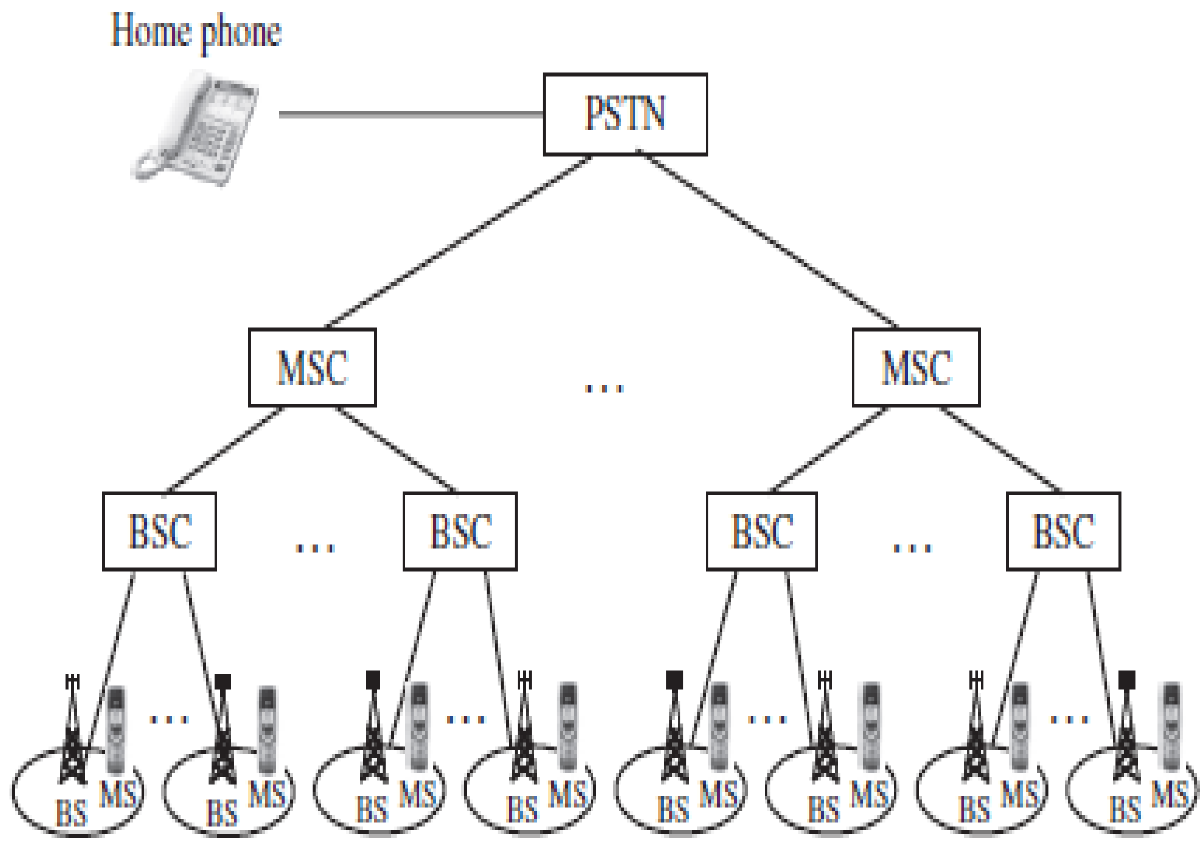


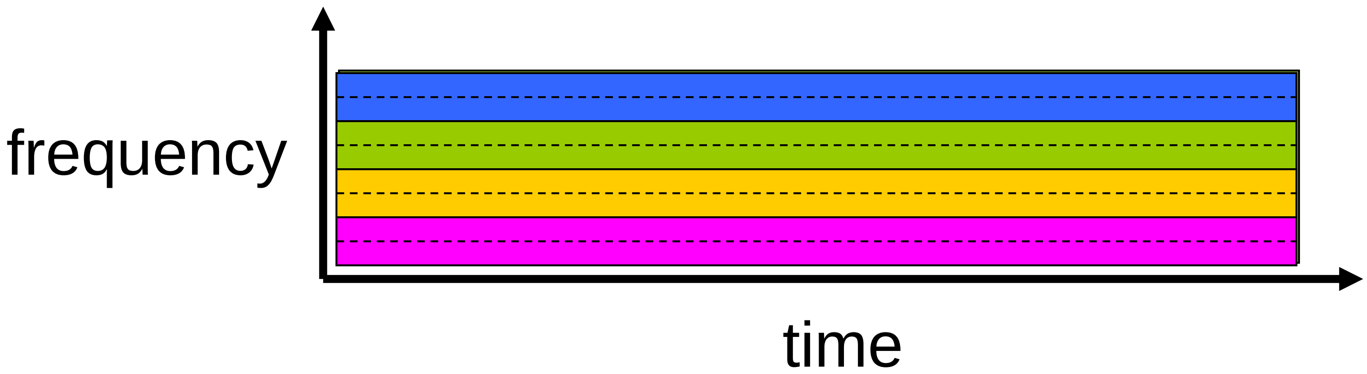
Figure 1.19
Cellular system infrastructure.

Circuit switching: FDM versus TDM

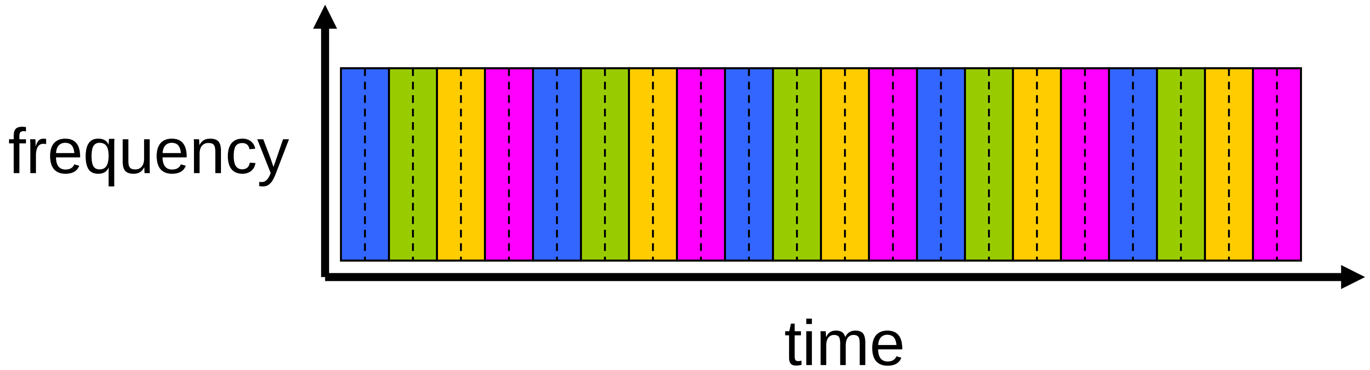
Example:

4 users

FDM



TDM



Cell Capacity

- **The offered traffic load or traffic intensity (a)** of a cell is characterized by:
  - Average number of MSs requesting the service (average call arrival rate λ)
  - Average length of time the MSs requiring the service (average holding time T)
- $a = \lambda T$
- A servicing channel that is kept busy for an hour is quantitatively defined as one **Erlang**
- If 30 requests are generated by users per hour, and T = 360 *sec*, then:
- $\lambda = \frac{30}{3600}$ and $a = \frac{30}{3600} \times 360 = 3\ Erlang$

Cell Capacity

- **Erlang B (B_c)** is the blocking probability, probability of loss, or probability of rejection for an arriving call
  - A call is blocked if all n channels are occupied when the call arrives

$$B_c = \mathrm{Erl}(n, a) := \frac{\frac{a^n}{n!}}{\sum_{i=0}^{n} \frac{a^i}{i!}}$$

  - $QoS = 1 - B_c$
- **Erlang C** is the probability of an arriving call being delayed

Cell Capacity

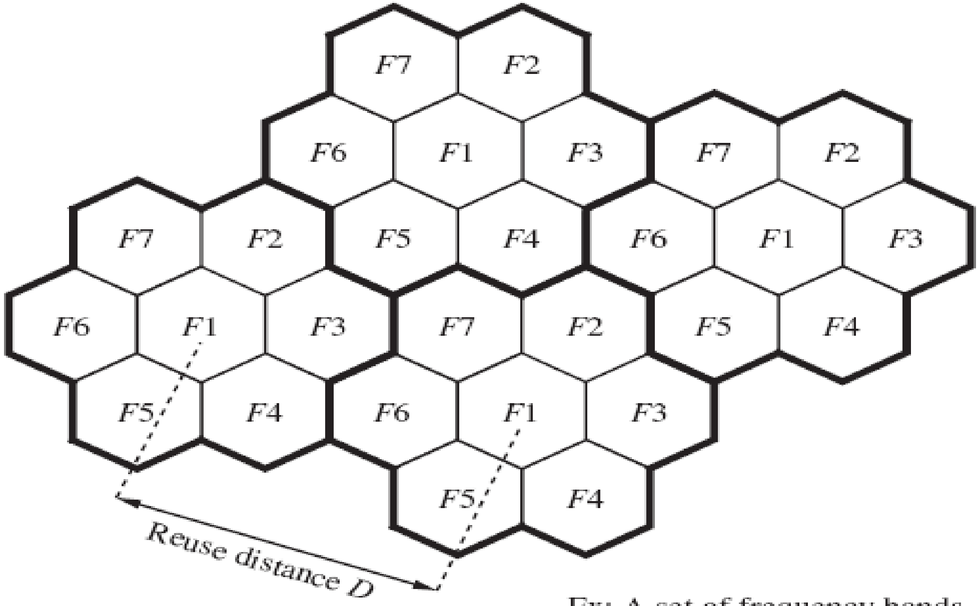
- **Capacity (n)** is the number of channels required for the cell based on its traffic load and a given blocking probability
- $n(a) = \min\{i = 1,2, | Erl(i,a) < B_{C_{max}}\}$
- Assume that the offered traffic is $a = 2.0\ Erlang$, and the blocking probability is 1%
- $n(2.0) = \min\{i = 1,2, \ldots. | Erl(i, 2.0) < 0.01\}$

$$B_c = \mathrm{Erl}(4,2) = \frac{\frac{2^4}{4!}}{1 + 2 + \frac{2^2}{2!} + \frac{2^3}{3!} + \frac{2^4}{4!}} = \frac{\frac{16}{24}}{1 + 2 + \frac{4}{2} + \frac{8}{6} + \frac{16}{24}} = \frac{2}{21} \approx 9.5\%$$

$$B_c = \mathrm{Erl}(6,2) = \frac{\frac{2^6}{6!}}{1 + 2 + \frac{2^2}{2!} + \frac{2^3}{3!} + \frac{2^4}{4!} + \frac{2^5}{5!} + \frac{2^6}{6!}} \approx 1.2\%$$

Frequency Reuse

- A frequency band or channel in a cell can be ***reused*** in another cell if those cells are apart and there would be no **interference**



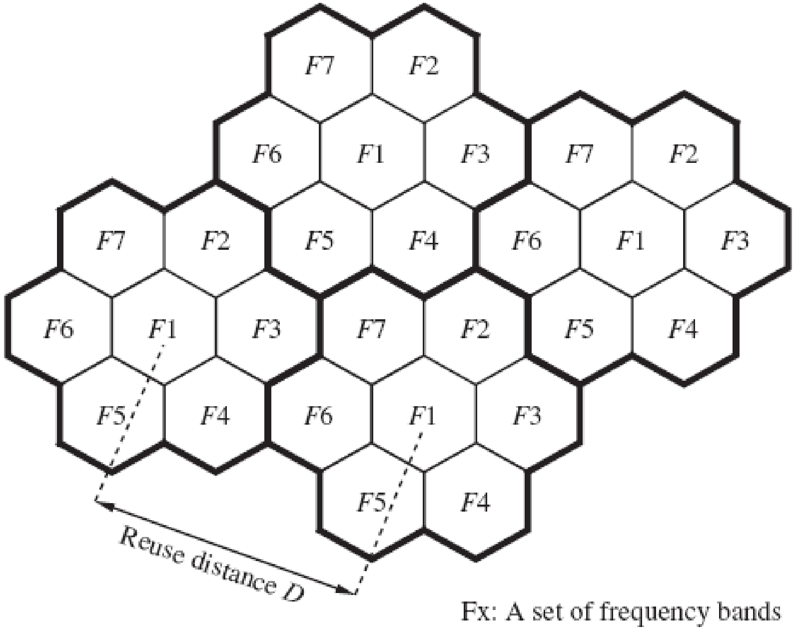
Fx: A set of frequency bands

Frequency Reuse

- In the real world, **path loss** and **link budgets** are computed from the terrain features and antenna data
- This determines to coverage of each base station and interference to other cells
- **Path loss** is a model that describes signal attenuation between Tx and Rx antennas as a function of the **propagation** distance
- $L(dB) = 10n \log_{10}(d) + C$
  - n → path loss exponent (2 to 4 in free space and 4 to 6 in indoor environments)
  - d → distance between Tx and Rx
  - C → constant for system loss

Reuse Distance

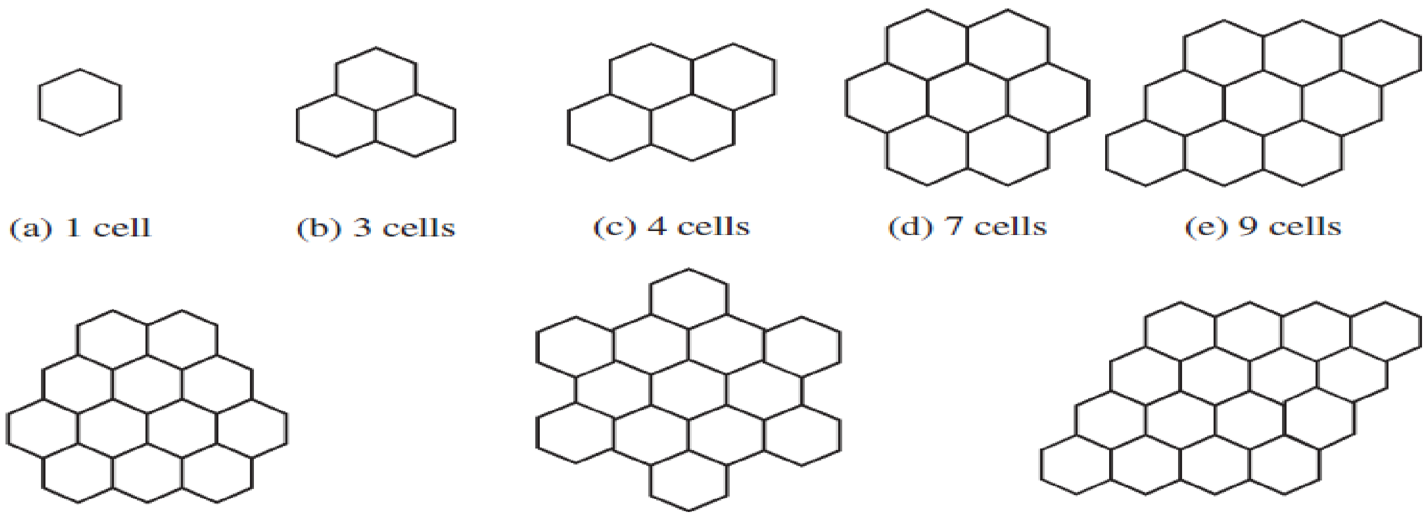
- **Reuse Distance** is the closest distance between the centers of two cells using the same frequency
- Determined by cluster size (a group of cells using different frequency bands)
- If we have:
  - N (number of cells in a cluster)
  - R (cell radius)
- Then we have **Reuse Distance**:
  - $D = \sqrt{3NR}$



Typical Cluster Sizes

Cluster size $C = i^2 + ij + j^2 = 1, 3, 4, 7, 9, \ldots$

$C = 1$	$i = 1, j = 0$	}Cluster size for CDMA net
$C = 3$	$i = 1, j = 1$	
$C = 4$	$i = 2, j = 0$	
$C = 7$	$i = 2, j = 1$	}Usual cluster sizes for analogue
$C = 9$	$i = 3, j = 0$	}cellular telephone nets
$C = 12$	$i = 2, j = 2$	

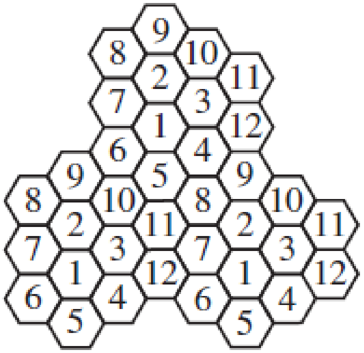


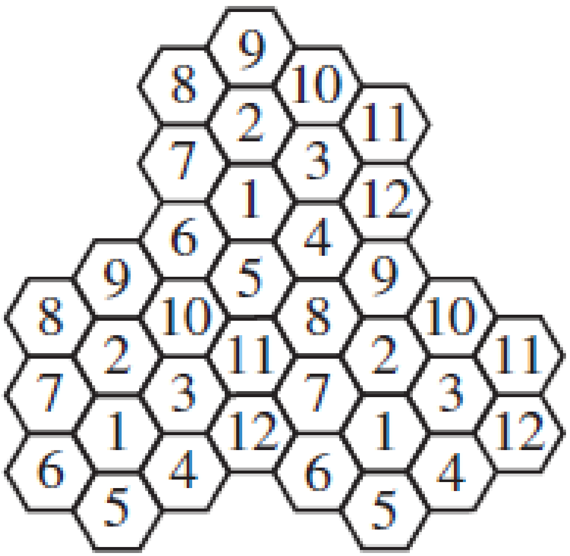
(a) 1 cell (b) 3 cells (c) 4 cells (d) 7 cells (e) 9 cells

(f) 12 cells (g) 13 cells (h) 16 cells

Frequency Reuse Example

- In the figure below, find the reuse distance if the radius of each cell is 2 km
- If each channel is multiplexed among 8 users, how many calls can be simultaneously processed by each cell if only 10 channels per cell are reserved for control, assuming a total bandwidth of 30MHz is available and each **simplex channel** consists of 25 kHz?





(a) $D = \sqrt{3N}R \Rightarrow D = 2 * (3 * 12)^{0.5}$

The reuse distance = 12 kms

(b) One duplex channel = 2 (BW of one simplex channel) $= 2 * 25 = 50$ kHz

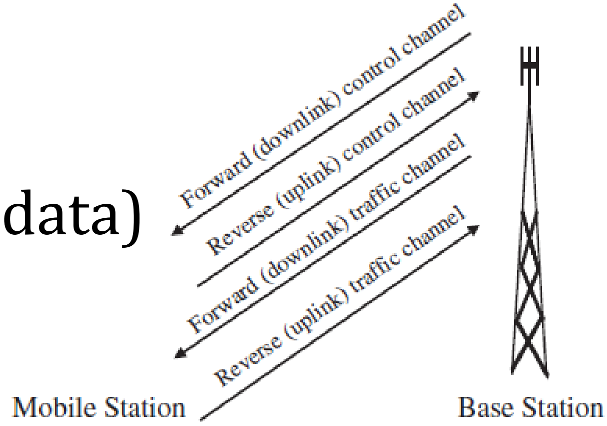
Number of channels $= (\frac{30 * 10^3}{50}) - 10 * 12 = 600 - 120 = 480$ channels

Number of channels per cell $= \frac{480}{12} = 40$ /cell

Total number of calls per cell $= 8 * 40 = 320$ calls/cell

A Note on Signaling

- Control Plane
  - Used to control bearer traffic (authentication, subscriber info, call parameter negotiations)
- Data (User) Plane
  - Used for subscriber traffic (voice & data)



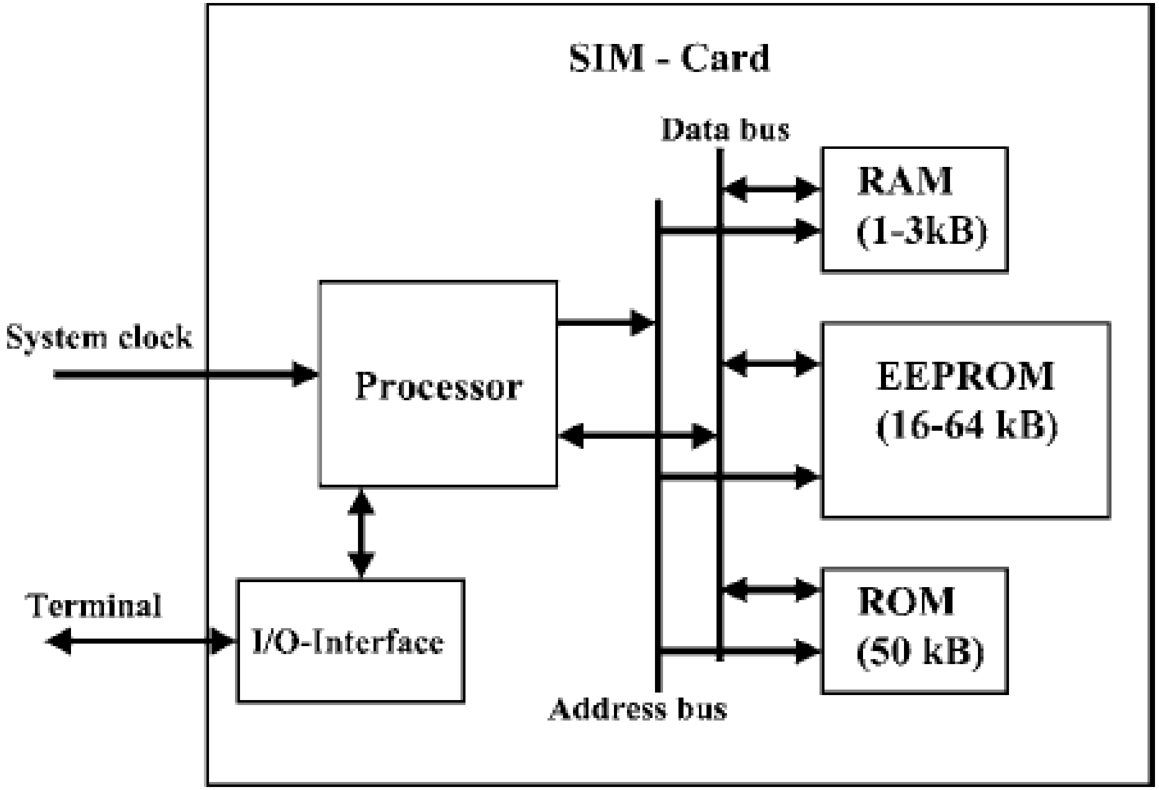


Figure 1.48 Block diagram of SIM card components

Table 1.7 SIM card properties

CPU	8- or 16-bit CPU
ROM	40–100 kbyte
RAM	1–3 kbyte
EEPROM	16–64 kbyte
Clock rate	10 MHz, generated from clock supplied by mobile phone
Operating voltage	3 V or 5 V

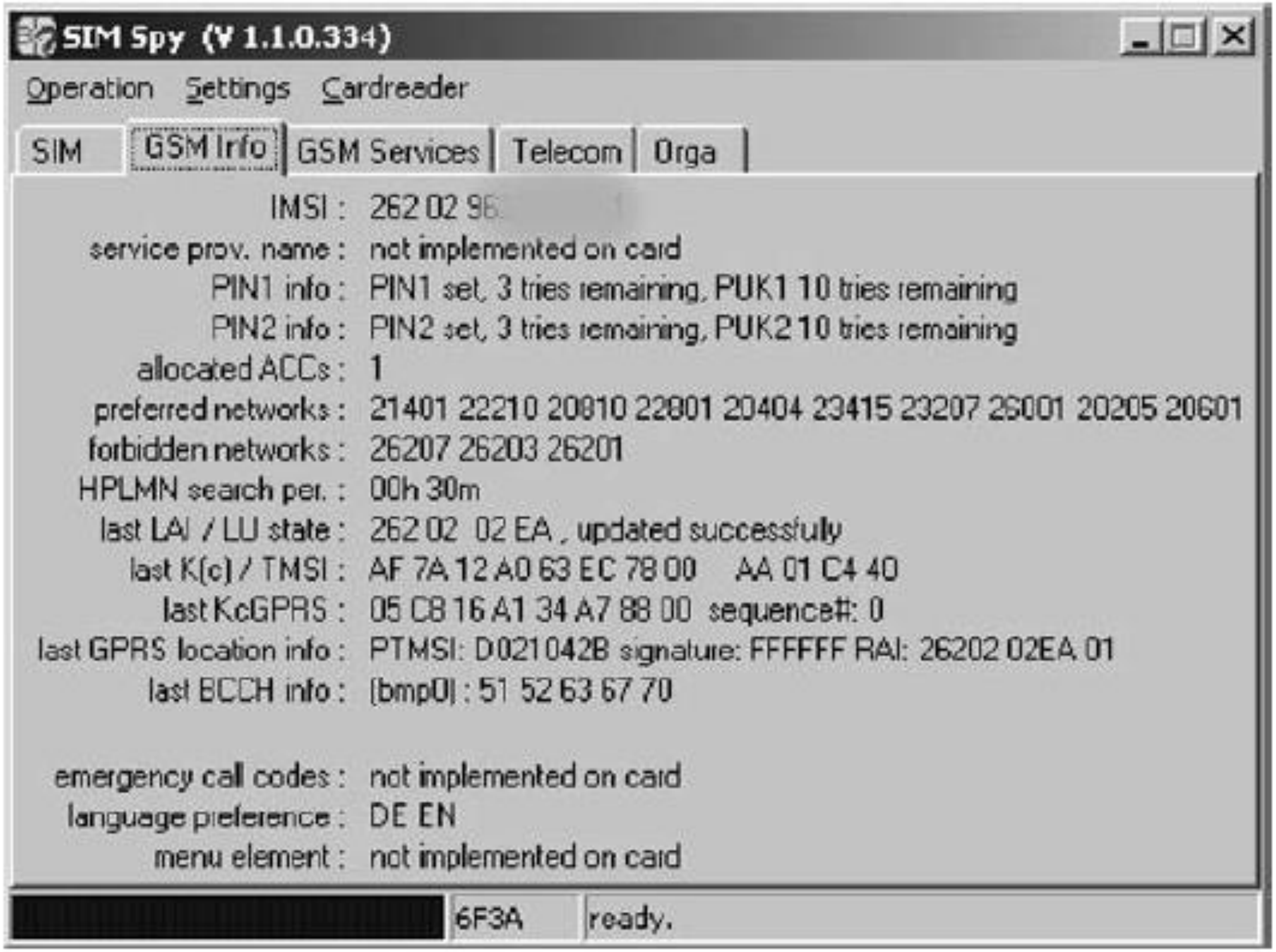


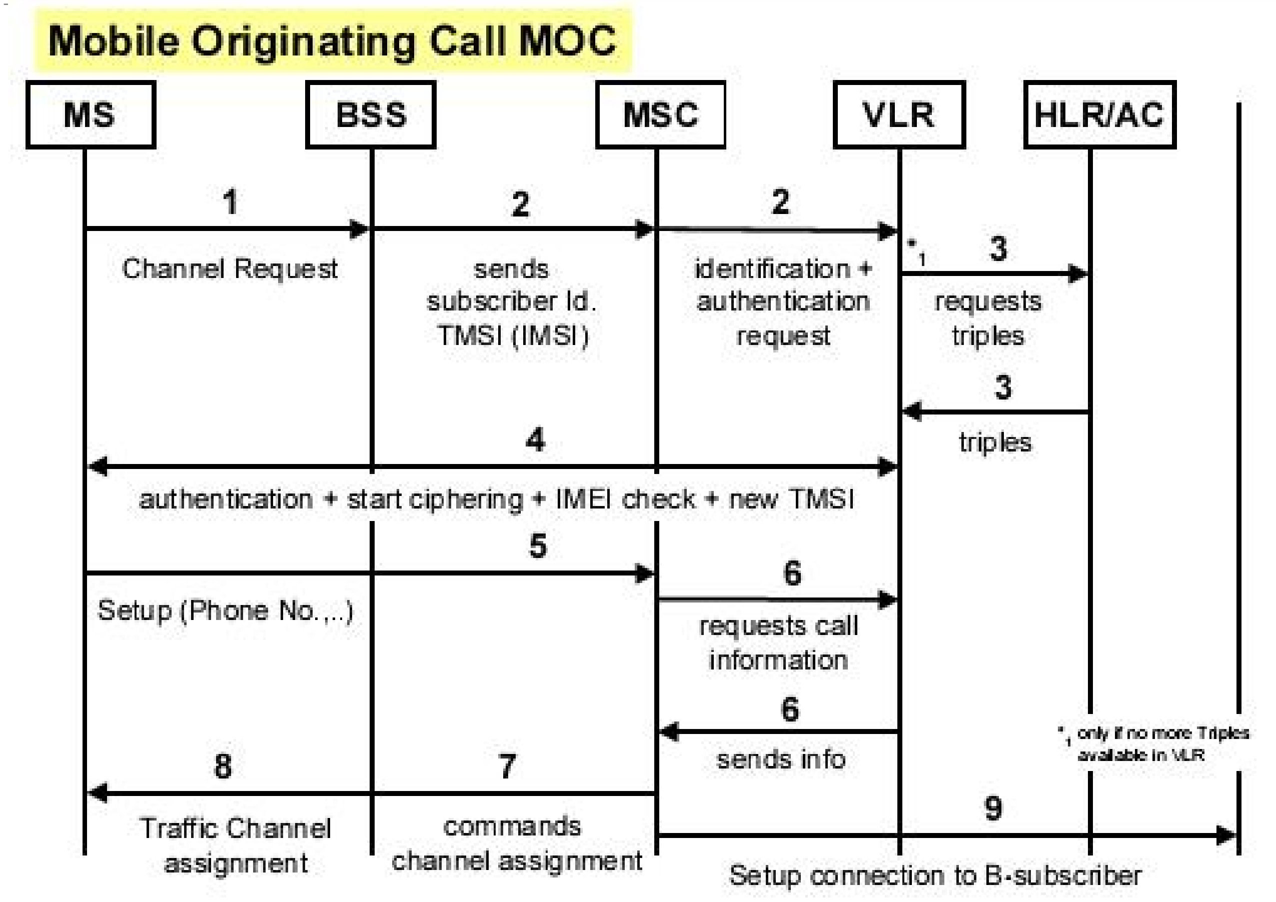
Figure 1.47 Example of a tool to visualize the data contained on a SIM card

A Typical Call Setup

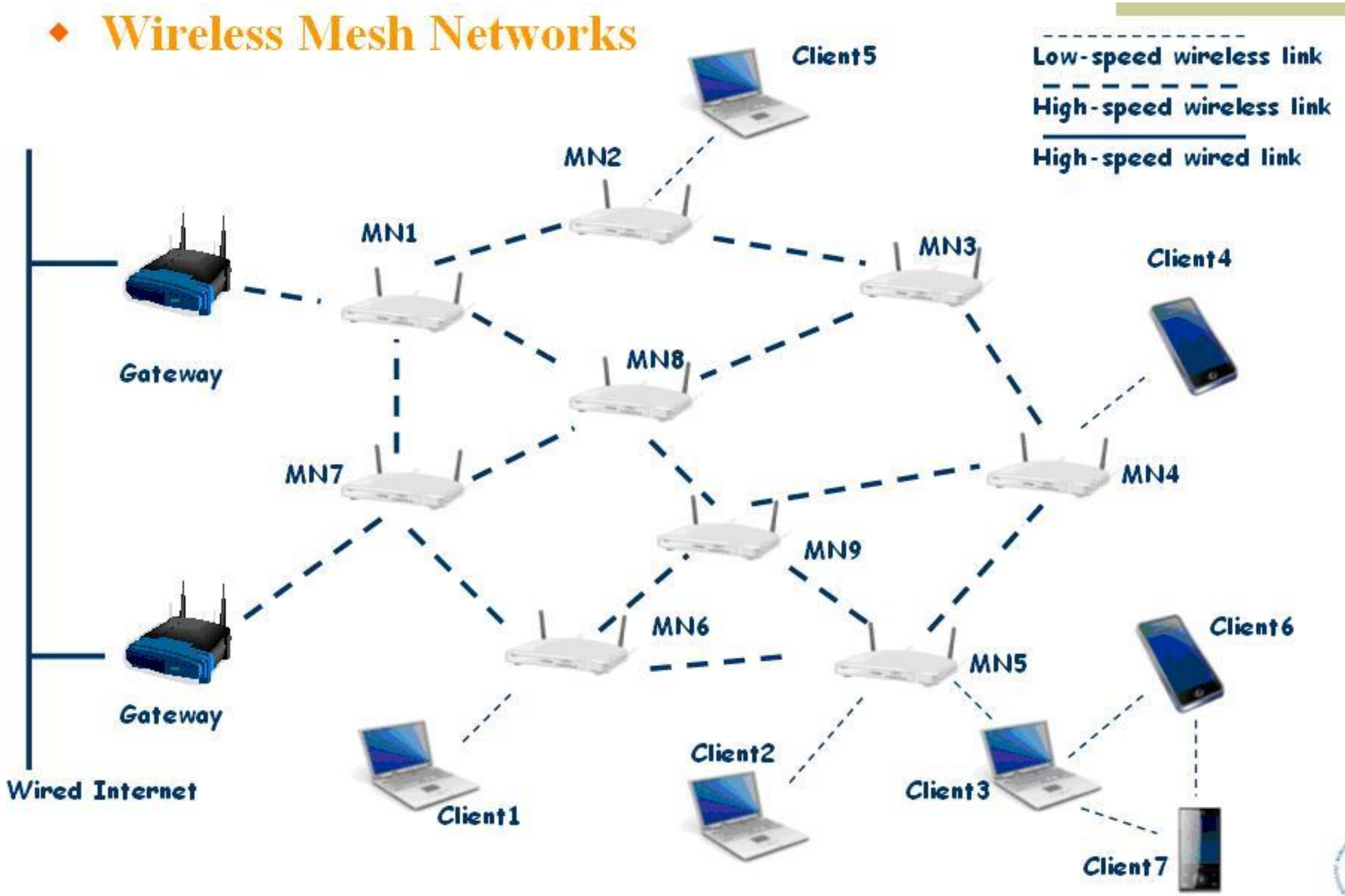
1. Validate information of subscriber originating the call (**authentication**)
2. Find the cell where the receiver is currently located (**location management**)
3. Allocate downlink and uplink channels (**resource management**)
4. Maintain the call if receiver moves while call is active (**handoff/admission control**)

- Channels used are either *control* or *data*, and either *uplink* (MS → BS) or *downlink* (BS → MS)

A Typical Call Setup



5. Wireless mesh networks



Thanks- Questions !