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Wireless Network

EBU5211: Ad Hoc Networks

Dr. Yan SUN (Cindy)

History of wireless communications

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- 1865 James Clerk Maxwell published his equations
- 1887 Heinrich Hertz demonstrated EM wave propagation
- 1893 Nicola Tesla demonstrated communication by radio
- 1895 Aleksandr Popov demonstrated a wireless system
- 1896 Guglielmo Marconi demonstrated wireless telegraphy
- 1901 First wireless signal sent across the Atlantic Ocean from Cornwall to St. John's, Newfoundland (Canada)
- Marconi was not the 'inventor', but appreciated the commercial opportunities offered by the new medium.

Why wireless?

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- No more cables
  - No cost for installing wires or rewiring
  - Wiring is infeasible or costly in some areas, e.g.. rural areas, old buildings…
- Mobility and convenience
  - Allows users to access services while moving: walking, in vehicles…
- Flexibility
  - Roaming allows connection any where and any time
- Scalability
  - Easier to expand network coverage compared to wired networks.

Emerging and existing wireless technology

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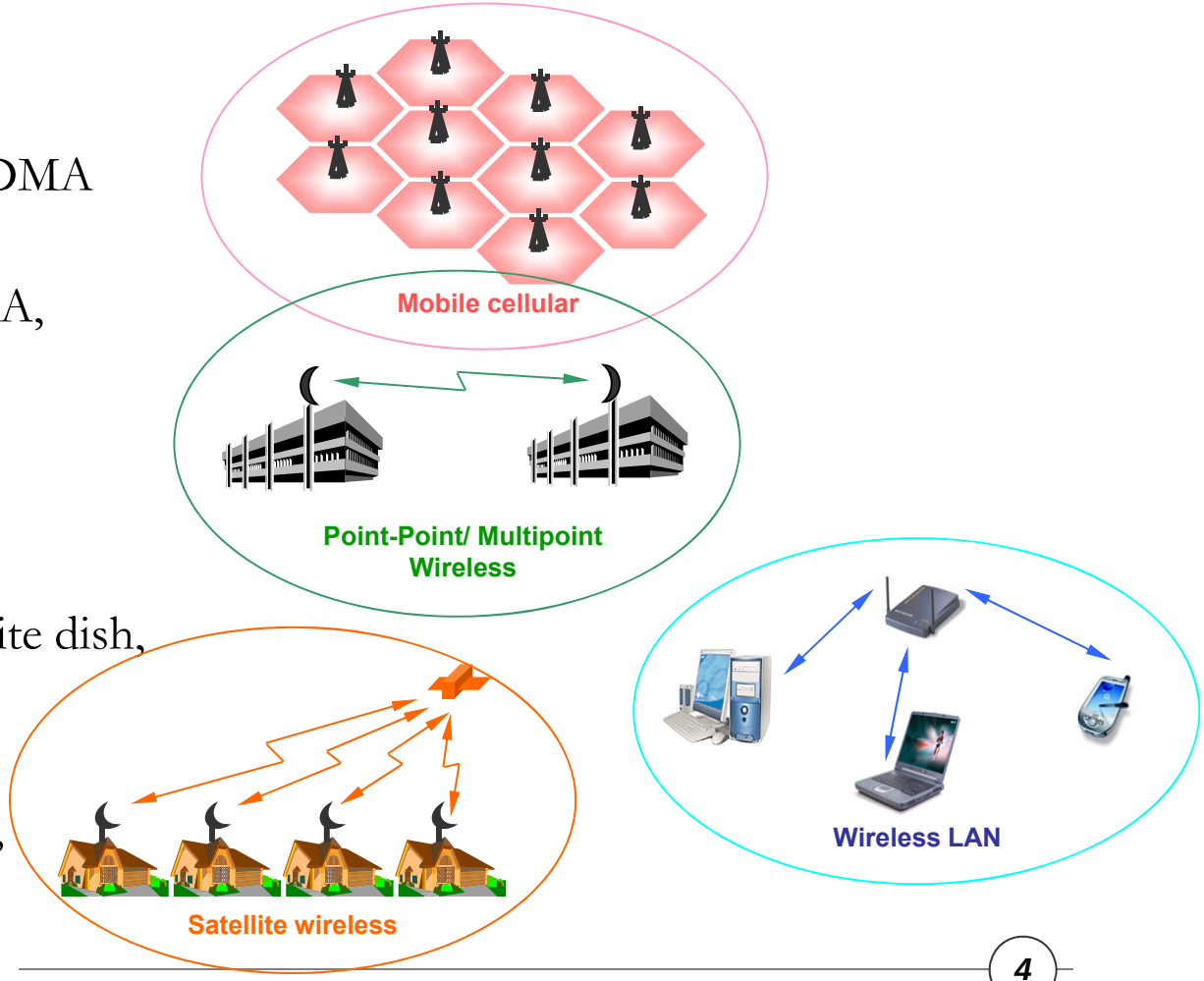
- Mobile Wireless:
  - 1G: Analog
  - 2G: GSM, TDMA, CDMA
  - 2.5G EDGE, GPRS
  - 3G W-CDMA, HSDPA, HSUPA
  - 4G – LTE
  - 5G
- Fixed Wireless:
  - MMDS, LMDS, Satellite dish, Microwave
- Wireless LAN:
  - IEEE 802.11, Ad-hoc, Bluetooth, ZigBee



Future Wireless Networks

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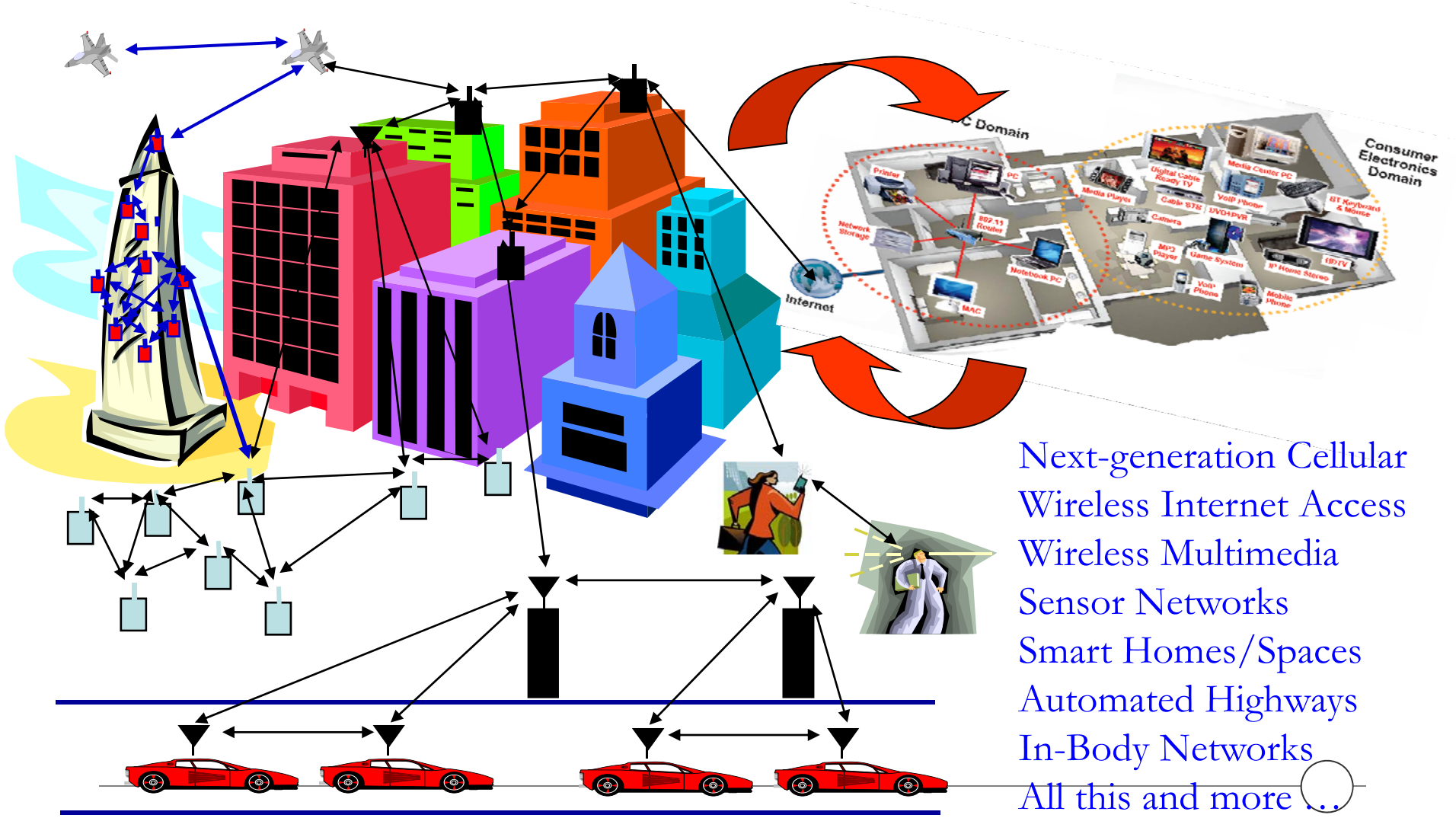
Ubiquitous Communication Among People and Devices



Next-generation Cellular
Wireless Internet Access
Wireless Multimedia
Sensor Networks
Smart Homes/Spaces
Automated Highways
In-Body Networks
All this and more …

Basic Design Considerations

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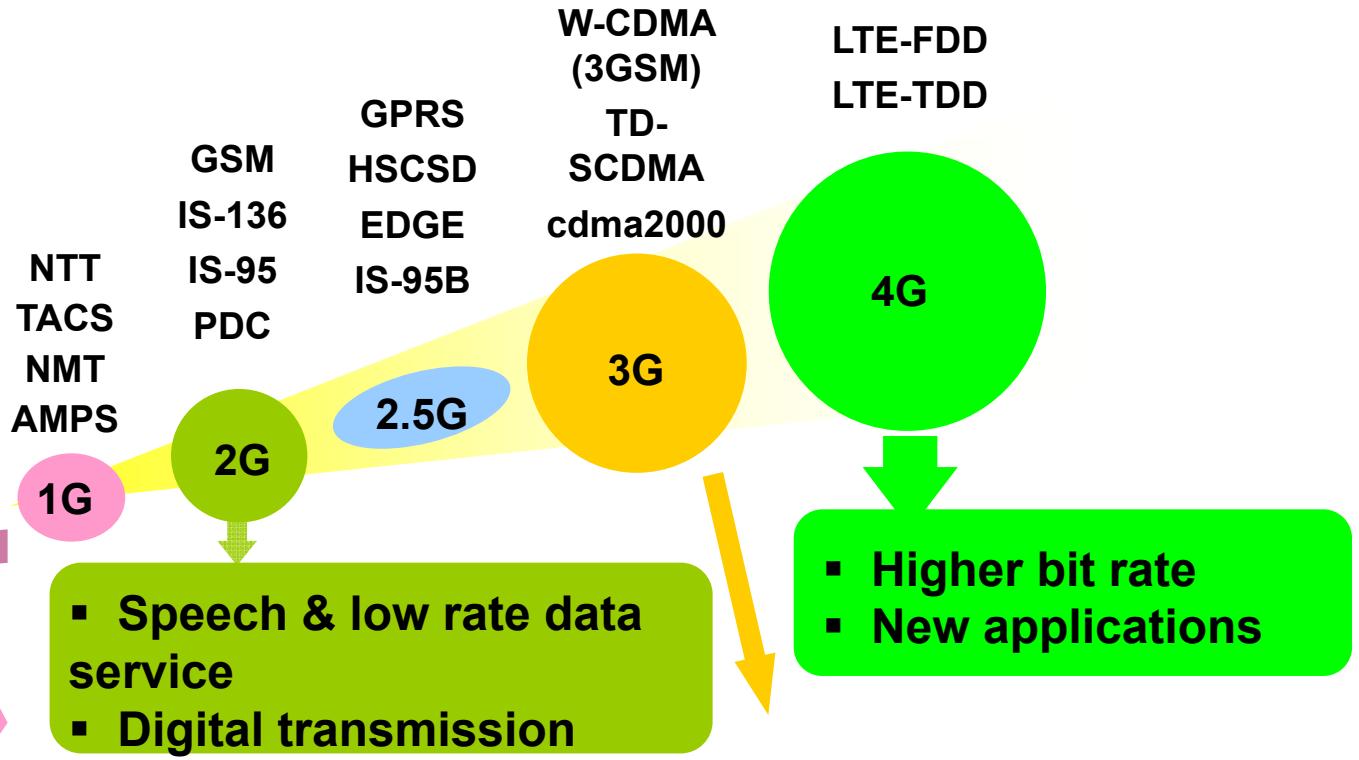
- Spectral Sharing
  - TD,CD or hybrid (TD/FD)
  - Frequency reuse
- Reuse Distance
  - Distance between cells using the same frequency, timeslot, or code
  - Smaller reuse distance packs more users into a given area, but also increases co-channel interference
- Cell radius
  - Decreasing the cell size increases system capacity, but complicates routing and handoff
- Resource allocation: power, BW, etc.

Evolution of mobile networks



1G systems

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- Analogue
  - Speech
  - Some data at 1.2kbit/s
- Designed for car use
- First handportable – Motorola "Brick" (DynaTAC 8000X)
  - 1983
  - 800g
  - 30 mins talk time
  - USD 3995
- Insecure
  - Eavesdropping
  - Cloning
- Almost no roaming

Some 1G systems

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System	Band (MHz)	Example Locations
AMPS	800	US, Canada, Mexico, Australia, New Zealand, Hong Kong, Brazil, Argentina
TACS	900	UK, Ireland, Spain, Italy, Austria, China
NMT	450/900	Denmark, Finland, Norway, Sweden, Belgium, Austria, France, Hungary, Netherlands, Spain
NTT	800	Japan (First cellular system 1979)

- No real roaming apart from NMT

2G Systems

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- Speech and low bit rate data service
- Digital transmission
- Designed to be more secure
- Almost exclusively handportable

2G Systems

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System	Band (MHz)	Example Locations
D-AMPS (IS-54, IS-136)	800	North and South America
CDMA (IS-95)	800/1900	North and South America, S Korea, China
GSM	900/1800 1900	World-wide (except Korea and Japan) 1900 MHz US and Canada
JDC/PDC	800/1500	Japan

GSM

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- Officially launched in 1992
- Multiple access: TDMA 8 channels (frames of 8 time slots) on each carrier
- FDD (Frequency Division Duplex) – different frequencies for uplink and downlink
- 200kHz carrier bandwidth
- 9.6kb/s net data (13kb/s encoded voice)
- (Almost) worldwide availability with multi-band handset
- Useful link www.gsmworld.com

GSM worldwide success

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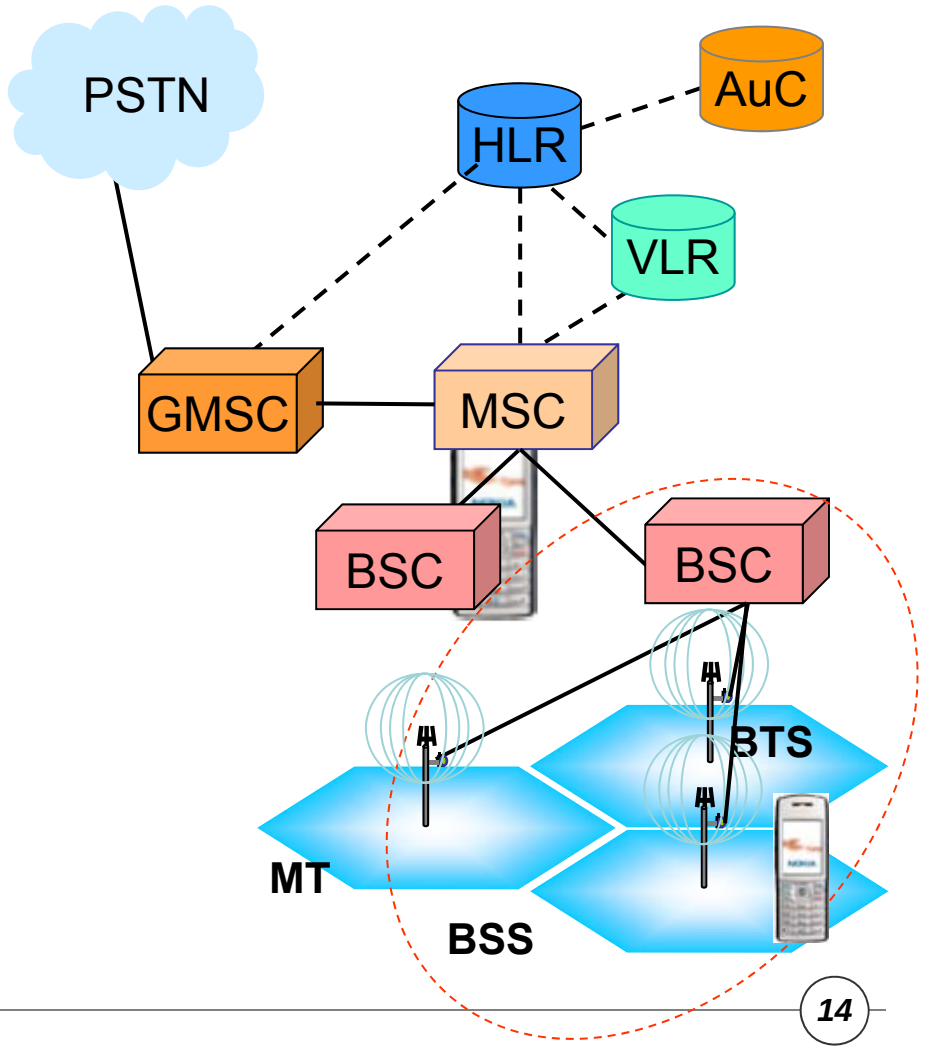
- Over 860 networks in 220 countries/areas
- Still growing: No of GSM + 3 GSM subscribers
  - 11/9/2011 00.55 (CN time) 5,231,269,752
  - In the next 5 mins an increase of: 7,106 !!!!!
  - World Population at same time: 6.914 billion
  - Penetration 59%

System	Uplink (MHz)	Downlink (MHz)
GSM850	824 -849	880 -915
GSM900	890 -915	935 –960
GSM1800 (DCS1800)	1710 –1785	1805 –1880
GSM1900 (PCS1900):	1930 –1990	1850 –1910

GSM network architecture – core components

- BTS: Base Transceiver Station
- BSC: Base Station Controller
- BSS: Base Station Subsystem
- MSC: Mobile Switching Centre
- HLR: Home Location Register
- VLR: Visitors Location Register
- AuC: Authentication Centre
- GMSC: Gateway MSC
- PSTN: Public Switched Telephone Network



GSM network architecture – other elements

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- EIR: Equipment Identity Register
  - Record of status of phone
  - White / grey /black (stolen)
- SMS-C: Short Message Service Centre
- OMC: Operation and Maintenance Centre

Locating a Mobile terminal

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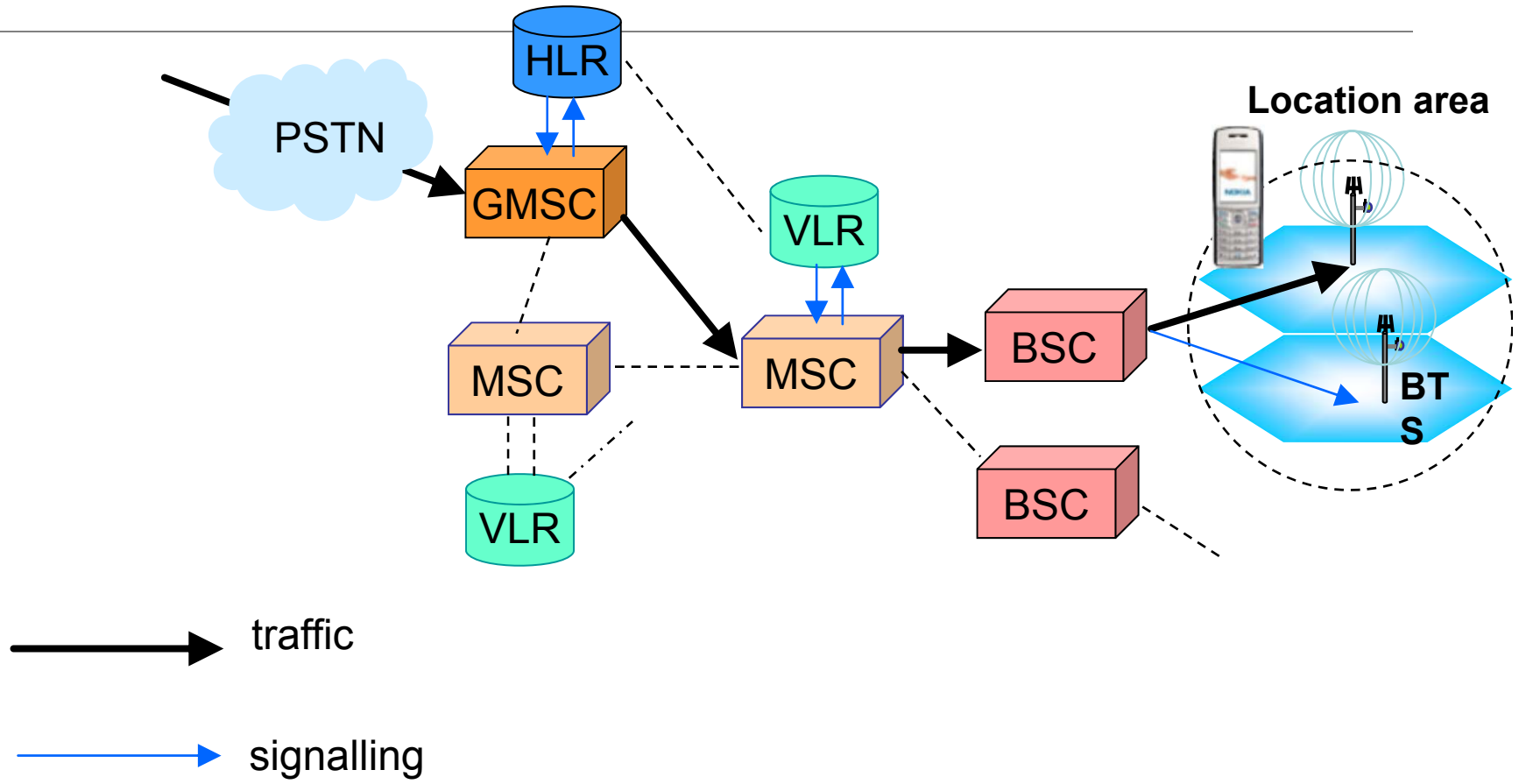
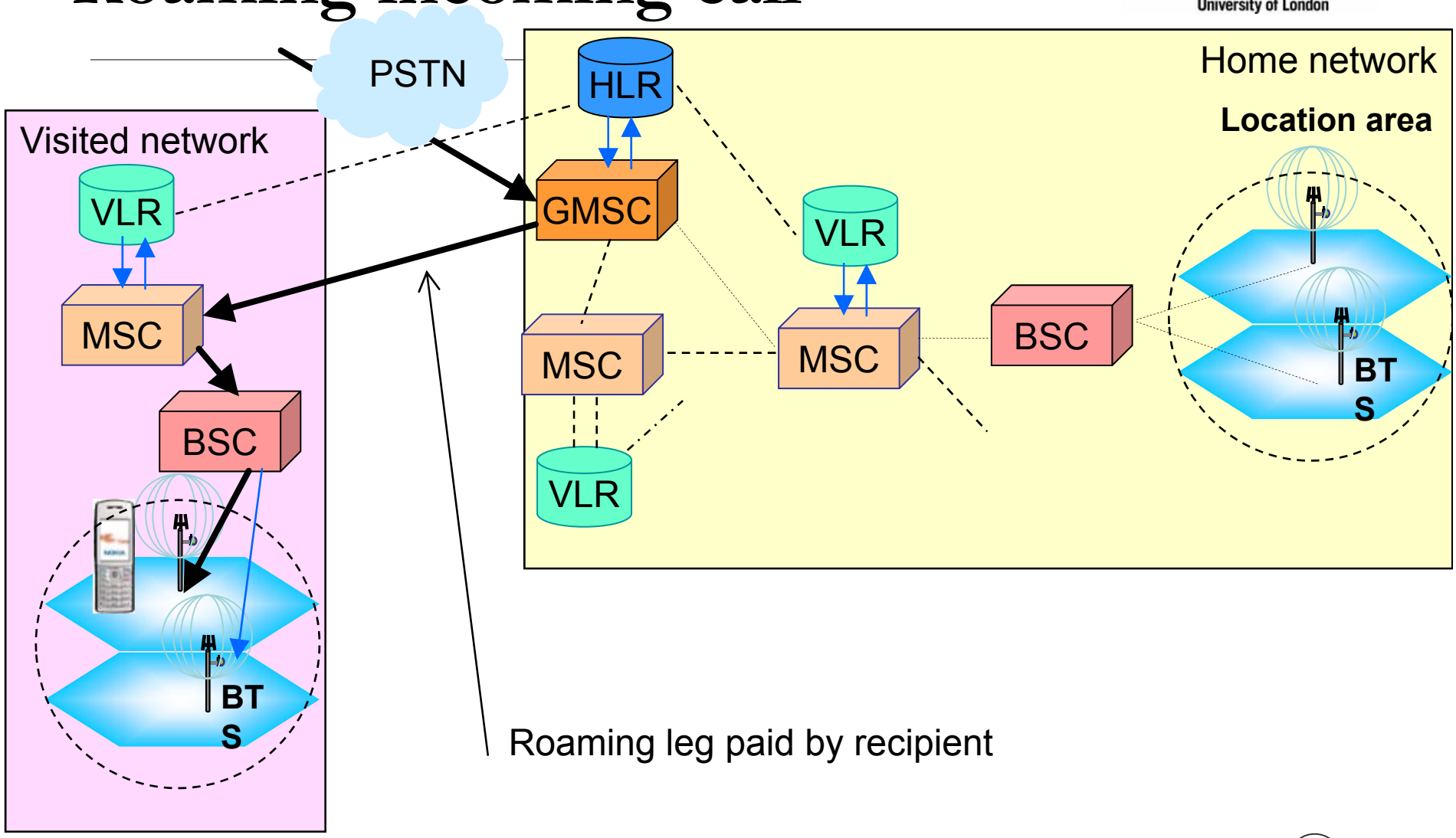
When a MT moves from one location area to another:

- MT initiates the location updating procedure.
- HLR is notified by the new MSC/VLR.
- HLR removes old MSC/VLR information
- HLR confirms and updates the new MSC/VLR.
- location area update is confirmed with the MT.

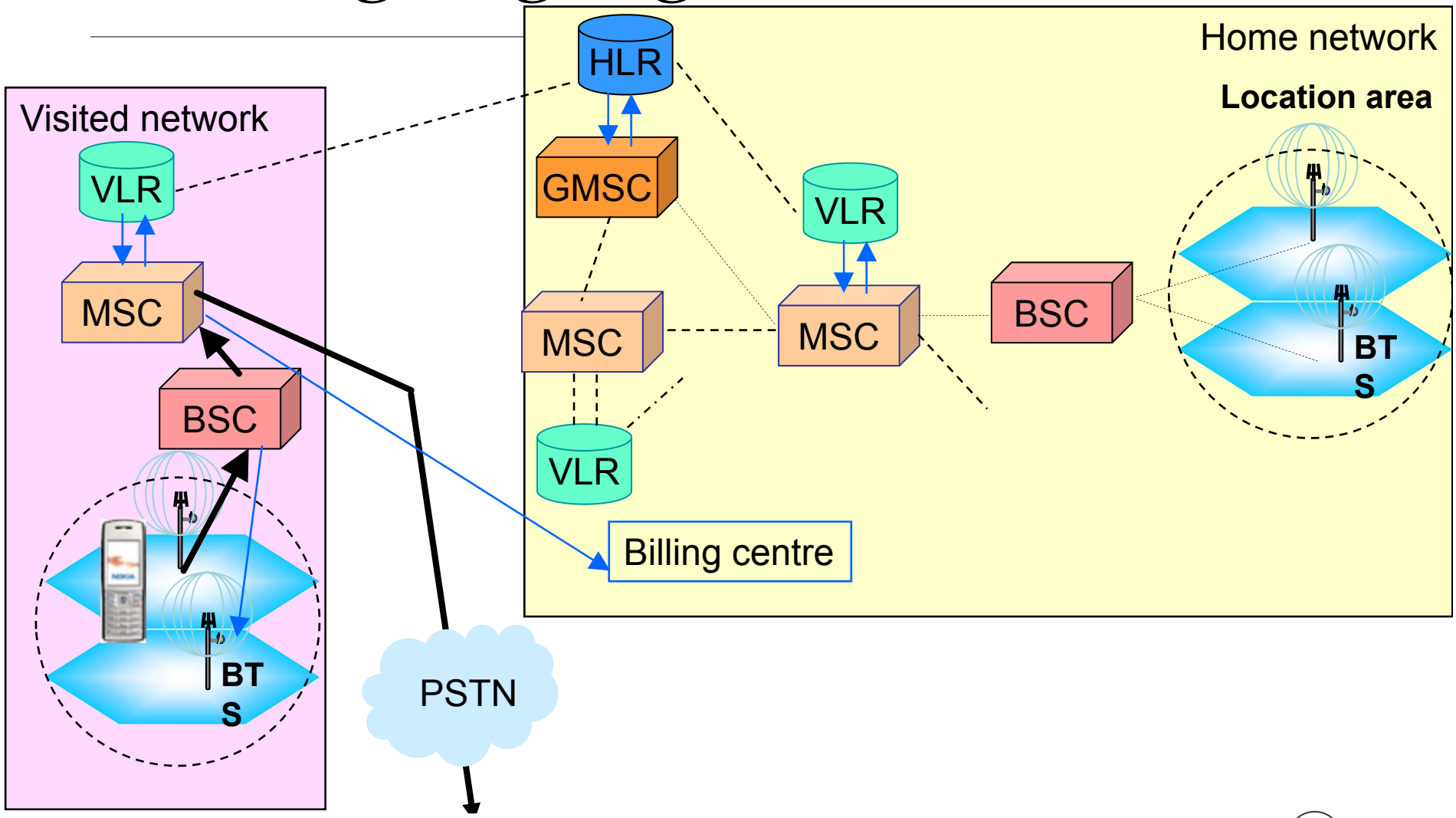
Mobile Terminating call



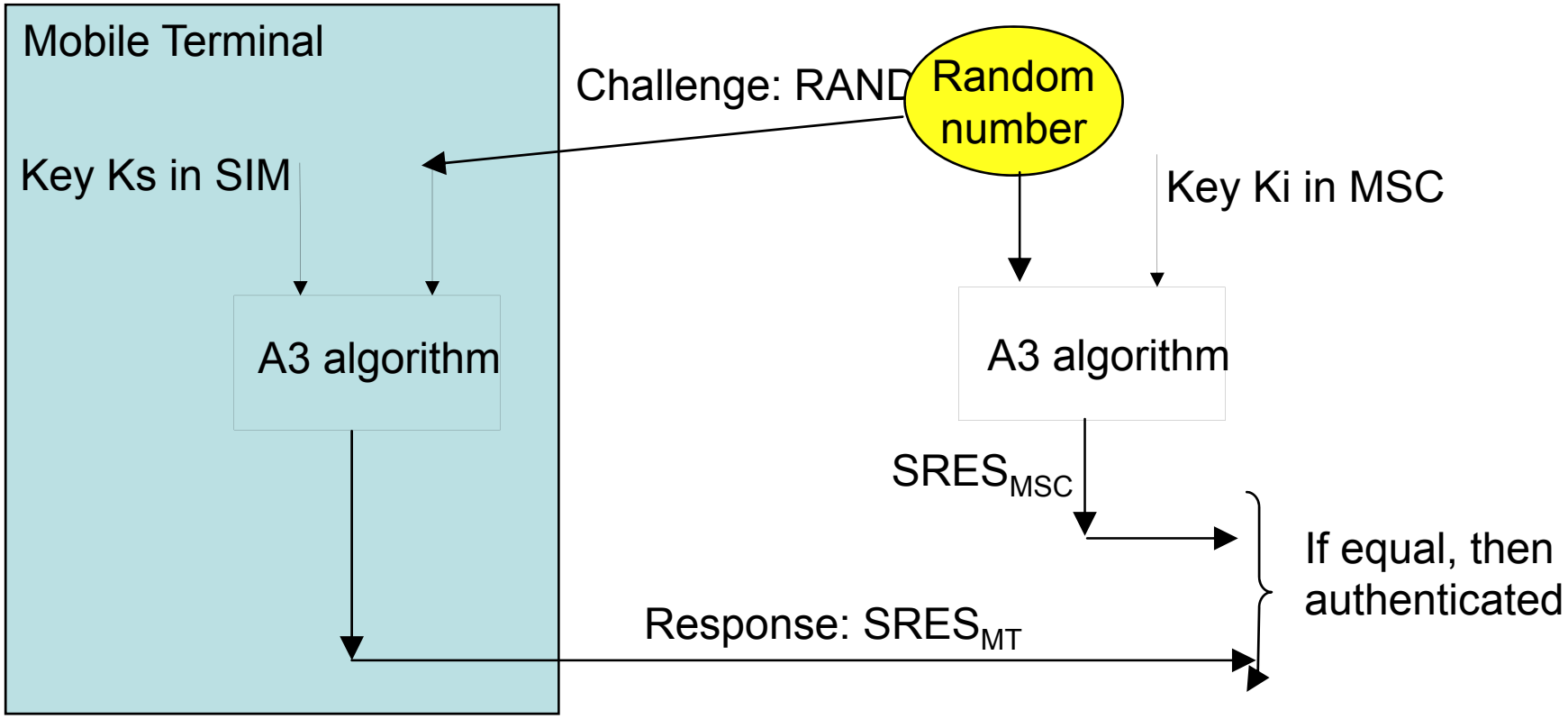
Roaming incoming call



Roaming outgoing call



GSM Mobility Management: Authentication



If results match, Ks=Ki and the user is genuine
Only information transmitted over the air is RAND and SRES$_{MT}$

Radio access

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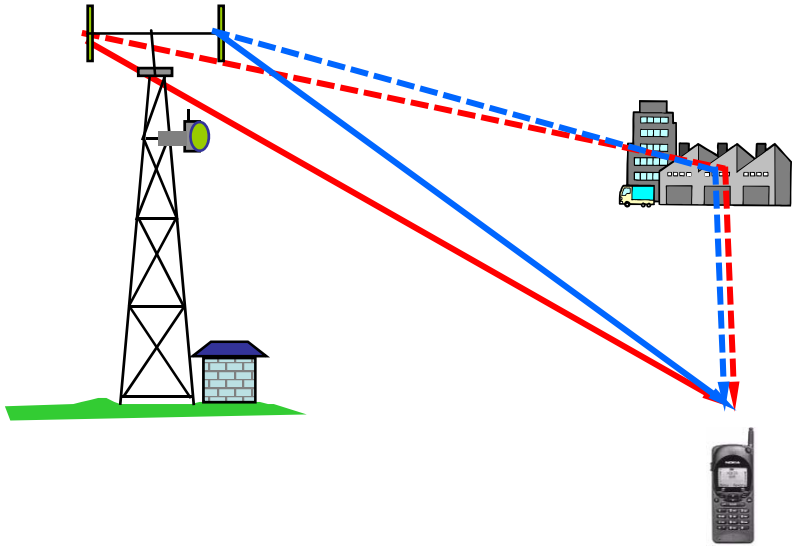
- This base station has 3 sectors each equipped with independent TRXs (transmitter/receivers)
- It has spaced pairs of antennas in each sector to provide diversity reception
- Microwave link antenna tot he network
- LNAs on the antennas (LNA=low noise amplifiers)

Diversity



Different phase relations will exist between the multipath rays from each antenna – so the interference will be different.

Diversity: Combining the signals

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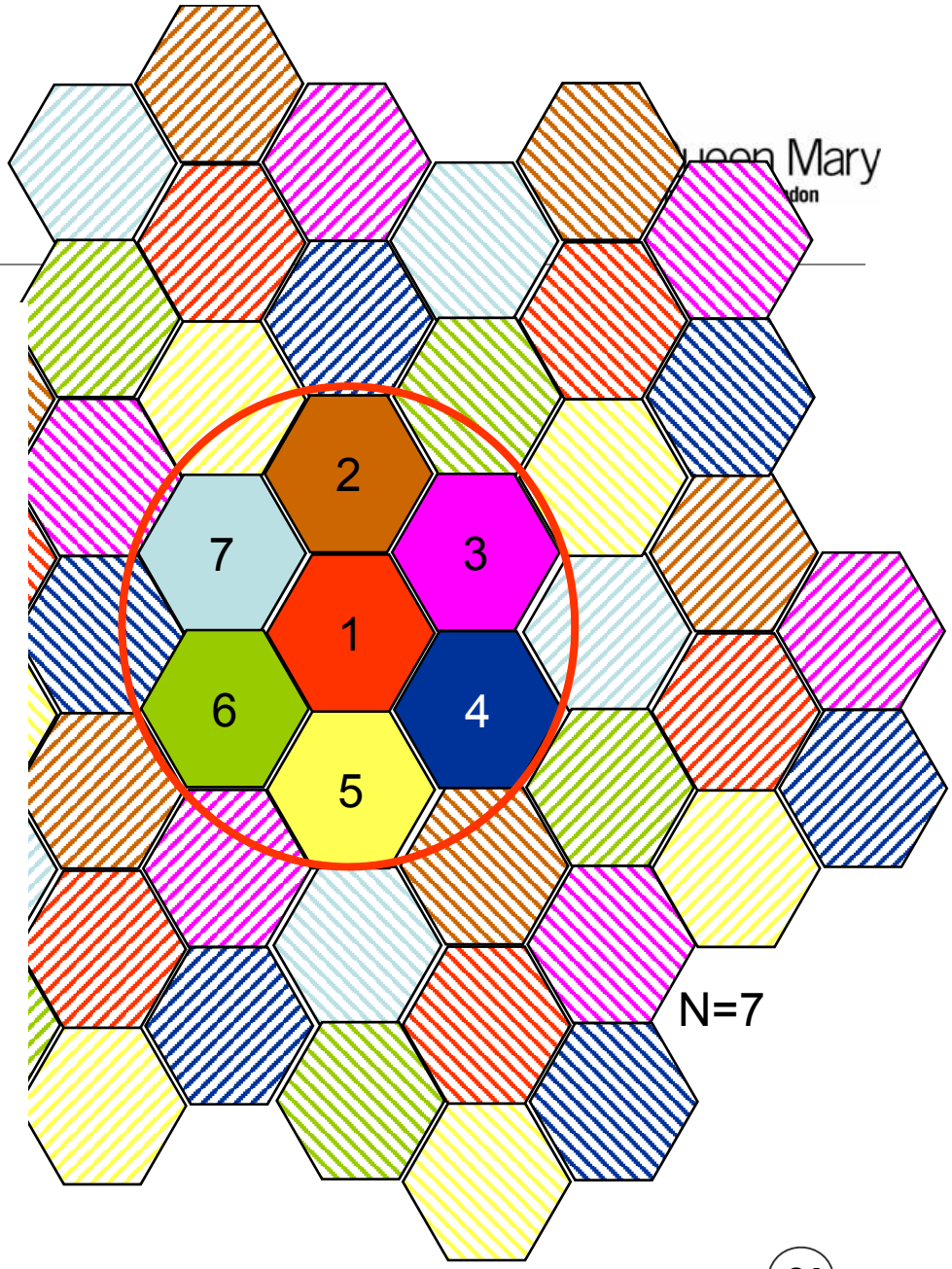
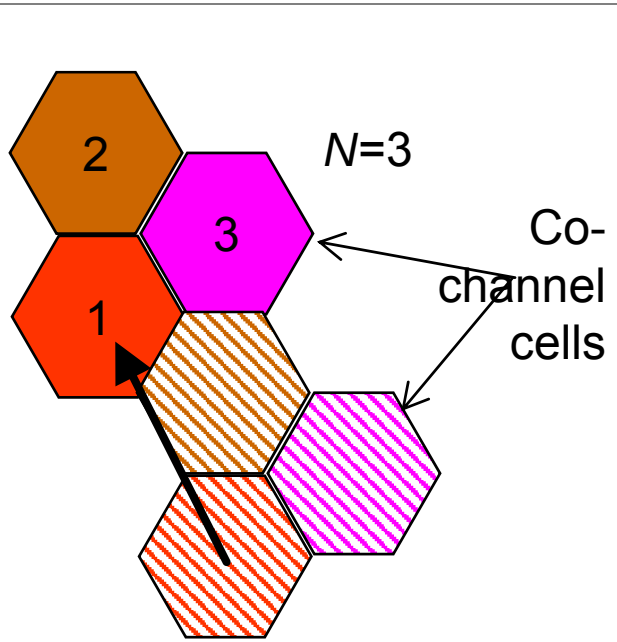
- Combine the signal from each branch and obtain a signal that is more reliable than any single branch
  - Switch diversity – when one is too low, try another
  - Selection diversity – choose the largest signal
  - Equal gain – signals equally weighted and added in phase
  - Maximal ratio – weight the power in the branches in proportion to their signal amplitude and add in phase
- Diversity gain = effective increase in signal power for some stated reliability. Typically 4–6dB depending on the environment.

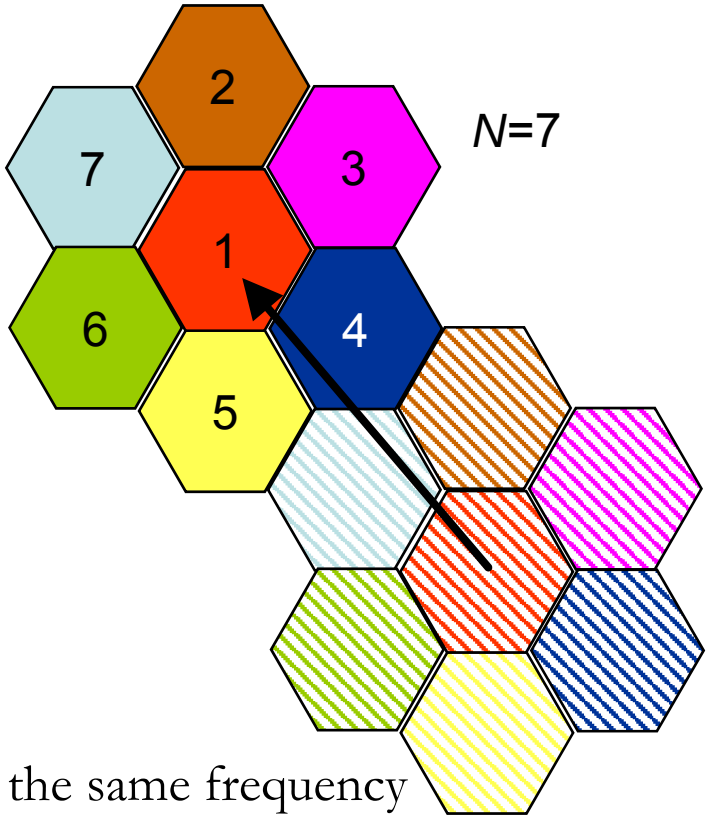
Frequency reuse

- Adjacent cells use different frequencies to avoid interference
- Cells sufficiently distant from each other can use the same channel (frequency)
- Reuse factor N: number of cells in a repeating pattern
- Control cell size by choosing BS power and antennas
  - Make use of topographical screening



Effect of cluster size

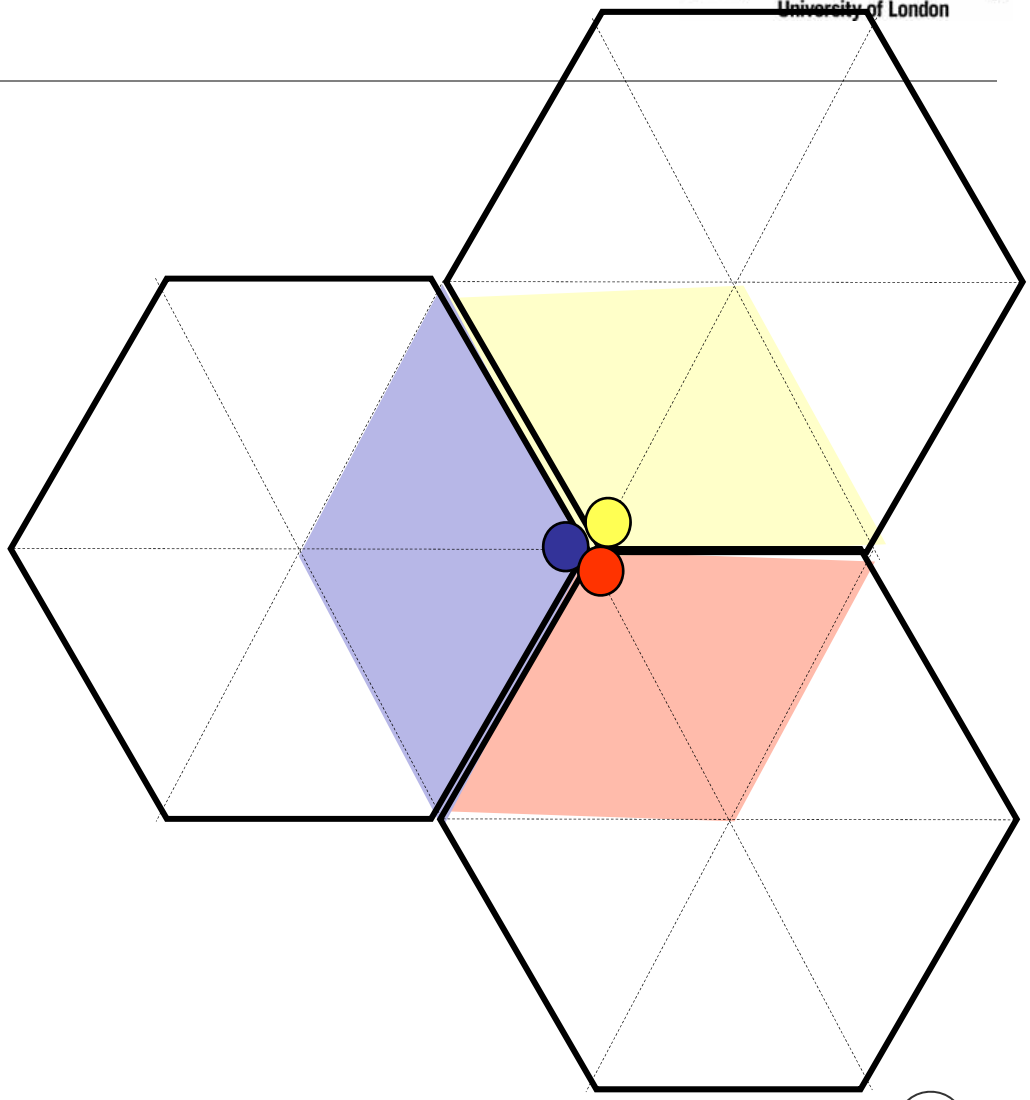


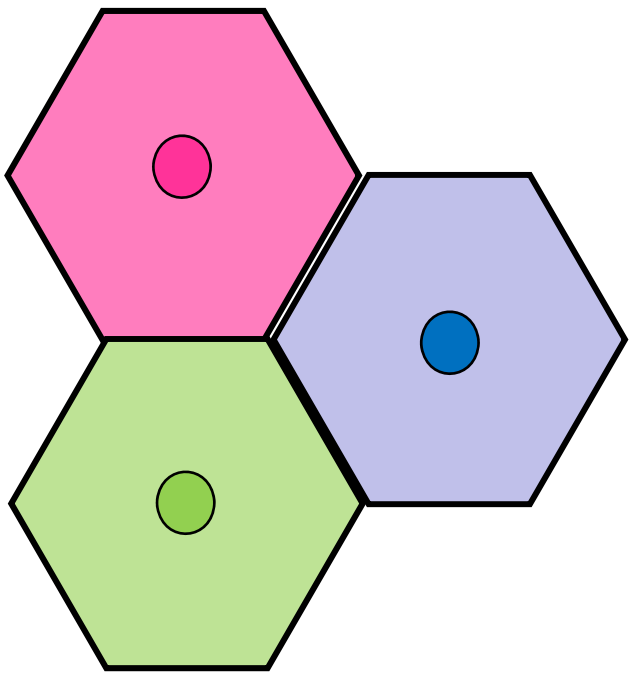


- Bigger cluster:
  - less interference from next cell using the same frequency
  - lower capacity – bandwidth available in cell is F_A/N
    (F_A is frequency spectrum allocated)

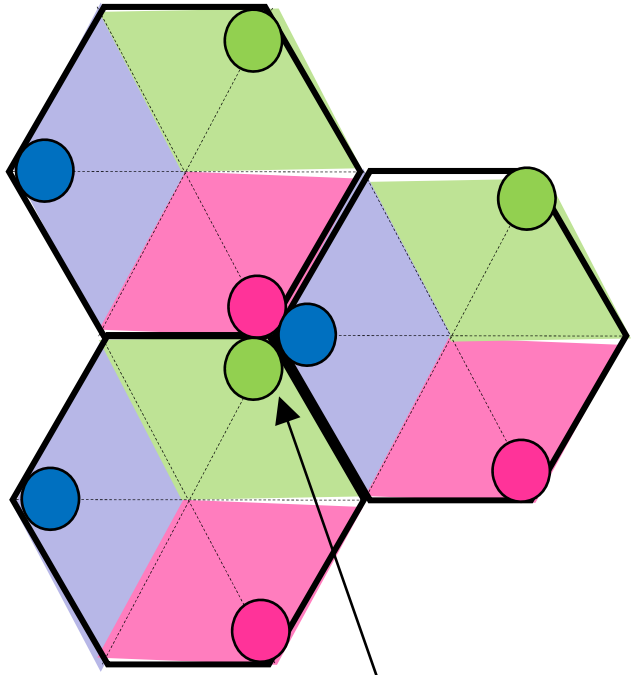
Sectoring

- Almost all mobile systems now operate with 3-sector cells
- Allows 3 different frequencies in the same cell
- It will take some time to figure out the best frequency plan – operators use computer tools





No sectorisation



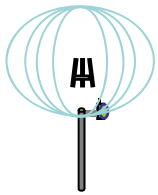
Sectors

3 antennas on one mast

Radio Resource Management (RRM)

- Power Control
- Handover Control
- Admission Control
- Load Control
- Packet Scheduling

Power Control



Node B

Power Control
Load Control

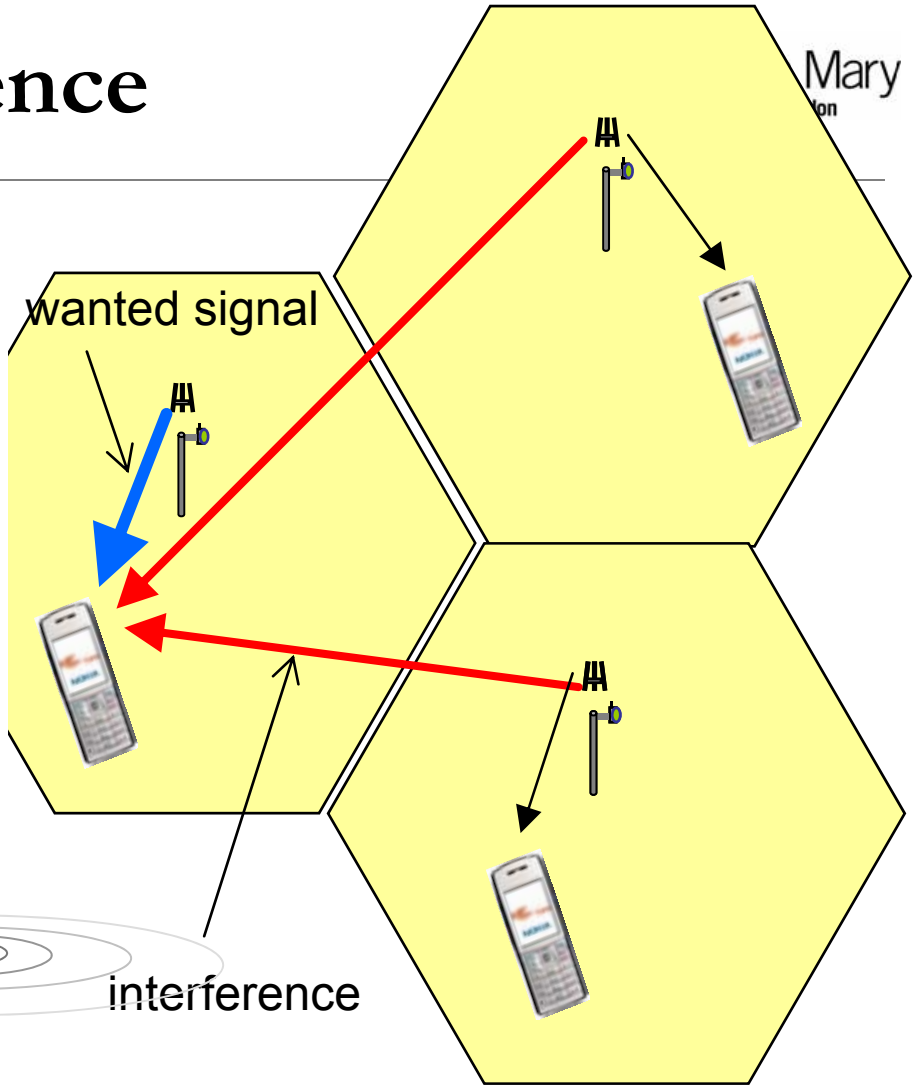
RNC

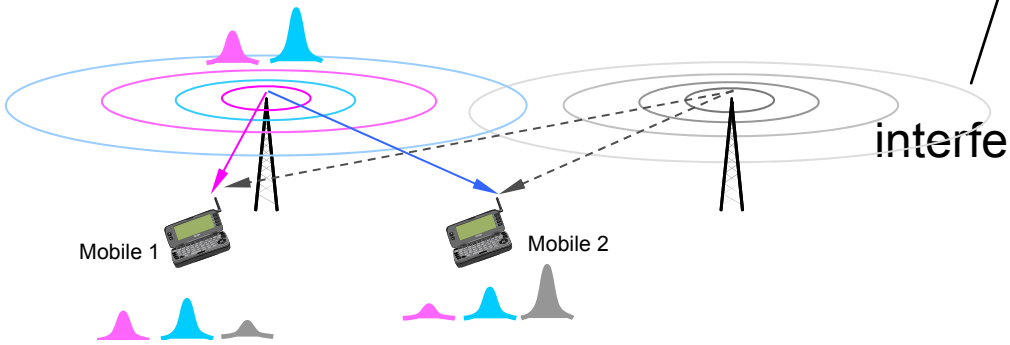
Power Control
Handover Control
Admission Control
Load Control
Packet Scheduling

Downlink interference

Power control:

- compensates for and minimises inter-cell interference
- aim is to minimise transmitted power yet still have a signal that is decodable

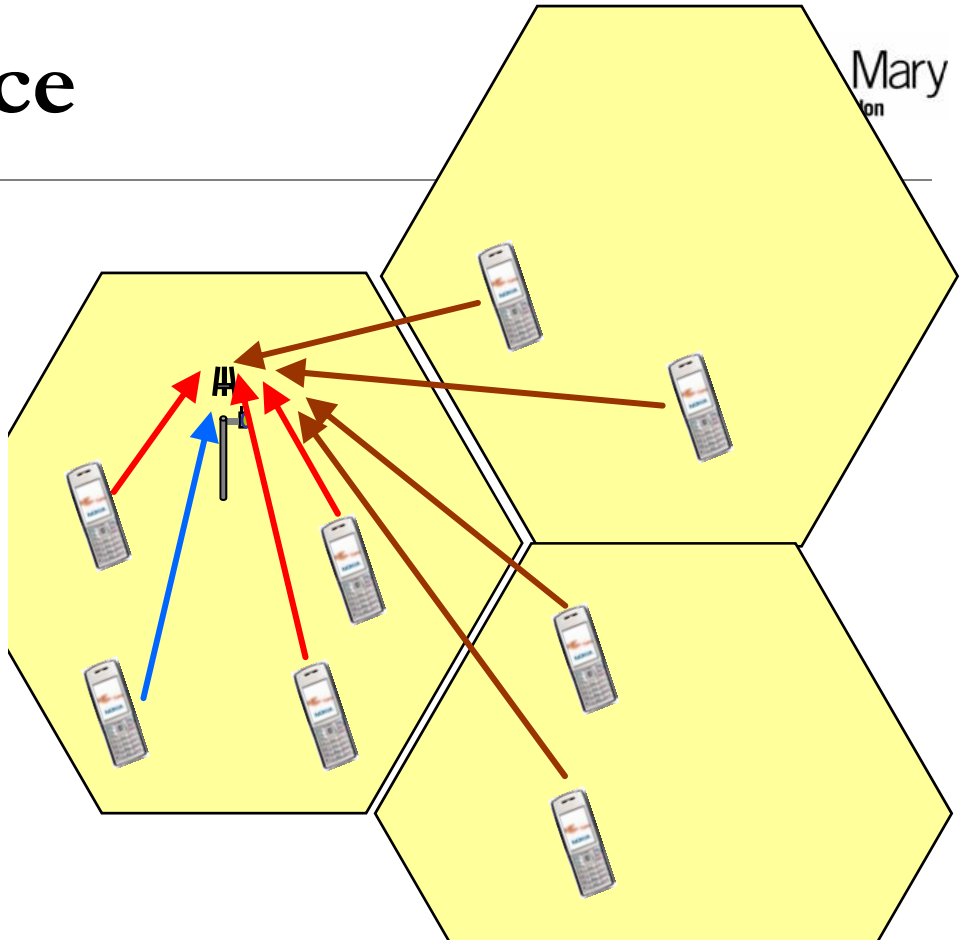




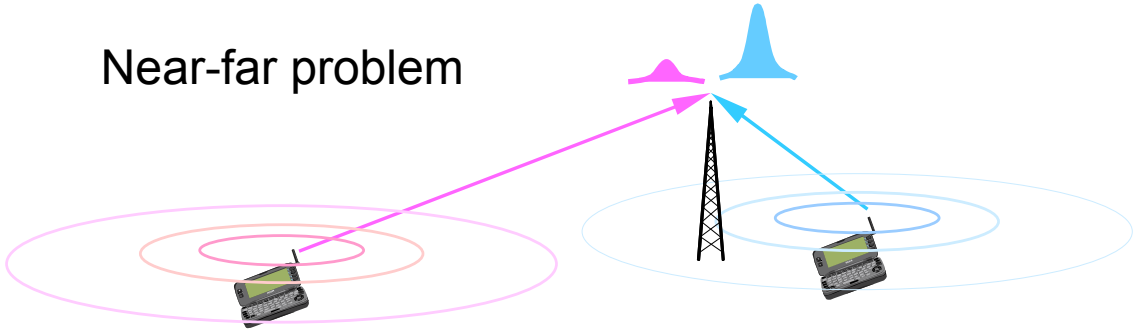
Uplink interference

Power control:

- Overcomes near-far problem Optimises system capacity by controlling interference
- Maximises battery life of mobile terminals

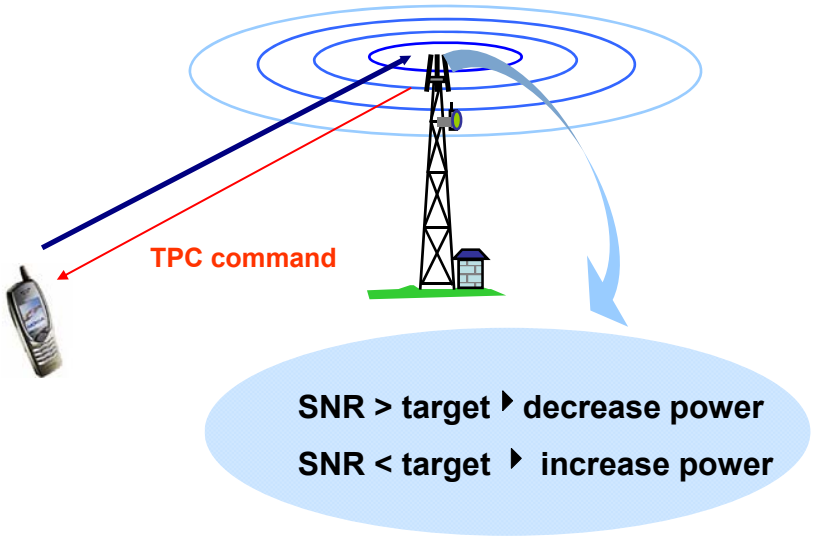


Near-far problem

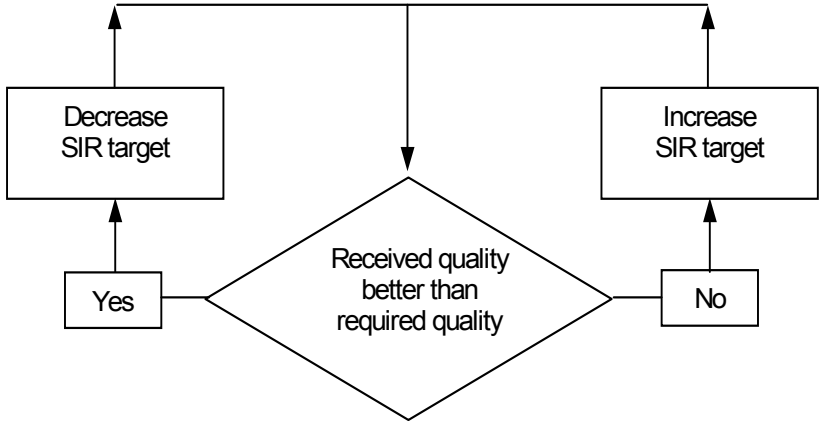


Types of power control

- Open-loop PC: used as initial power setting
- Closed-loop PC: fast power control loop (1.5 KHz)
- Outer-loop PC: set target for closed-loop PC.



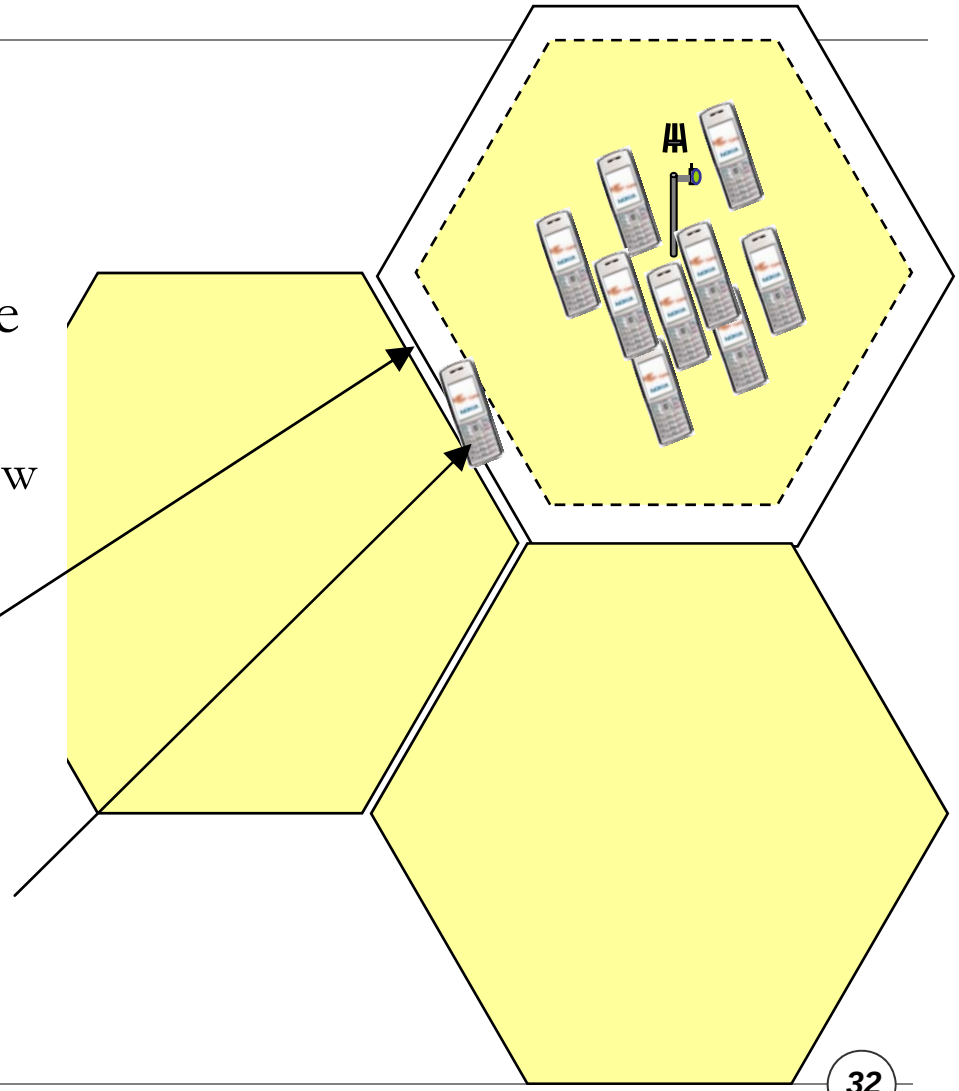
UL closed-loop PC



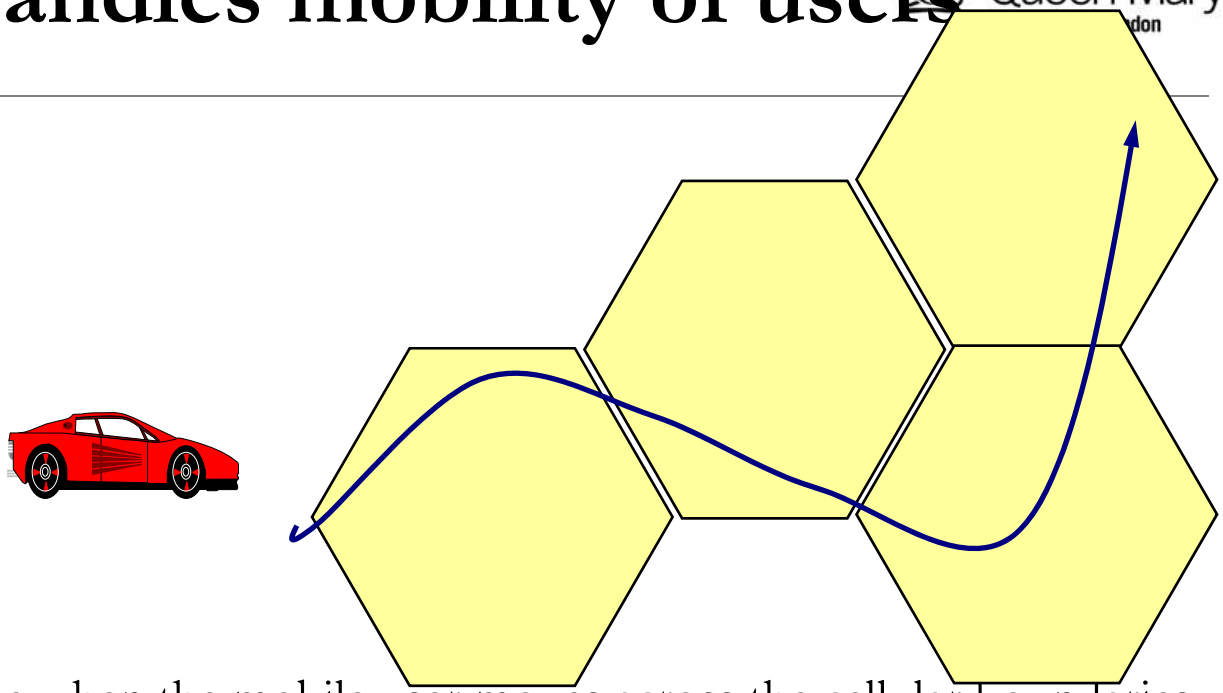
Outer-loop PC

Cell breathing in CDMA

- With very heavy traffic near the centre of the cell the power control may make the cell effectively "shrink"
  - signal power becomes very low near the edge
- If not planned properly this can cause "gaps" and a mobile might not get sufficient signal.

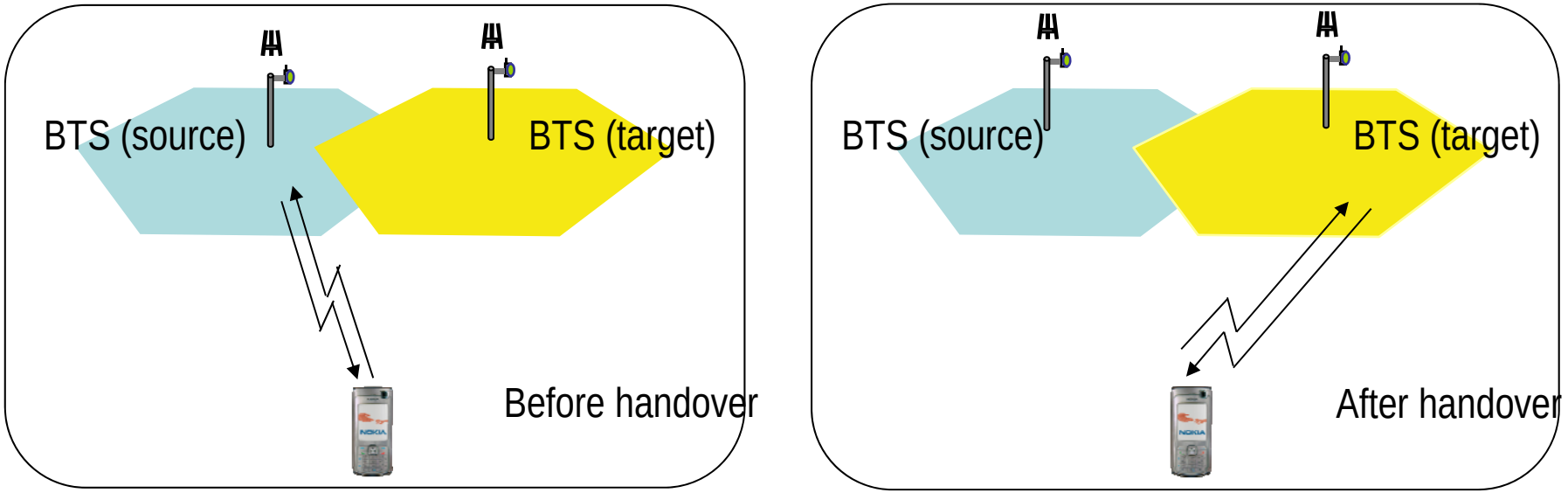


Handover handles mobility of users



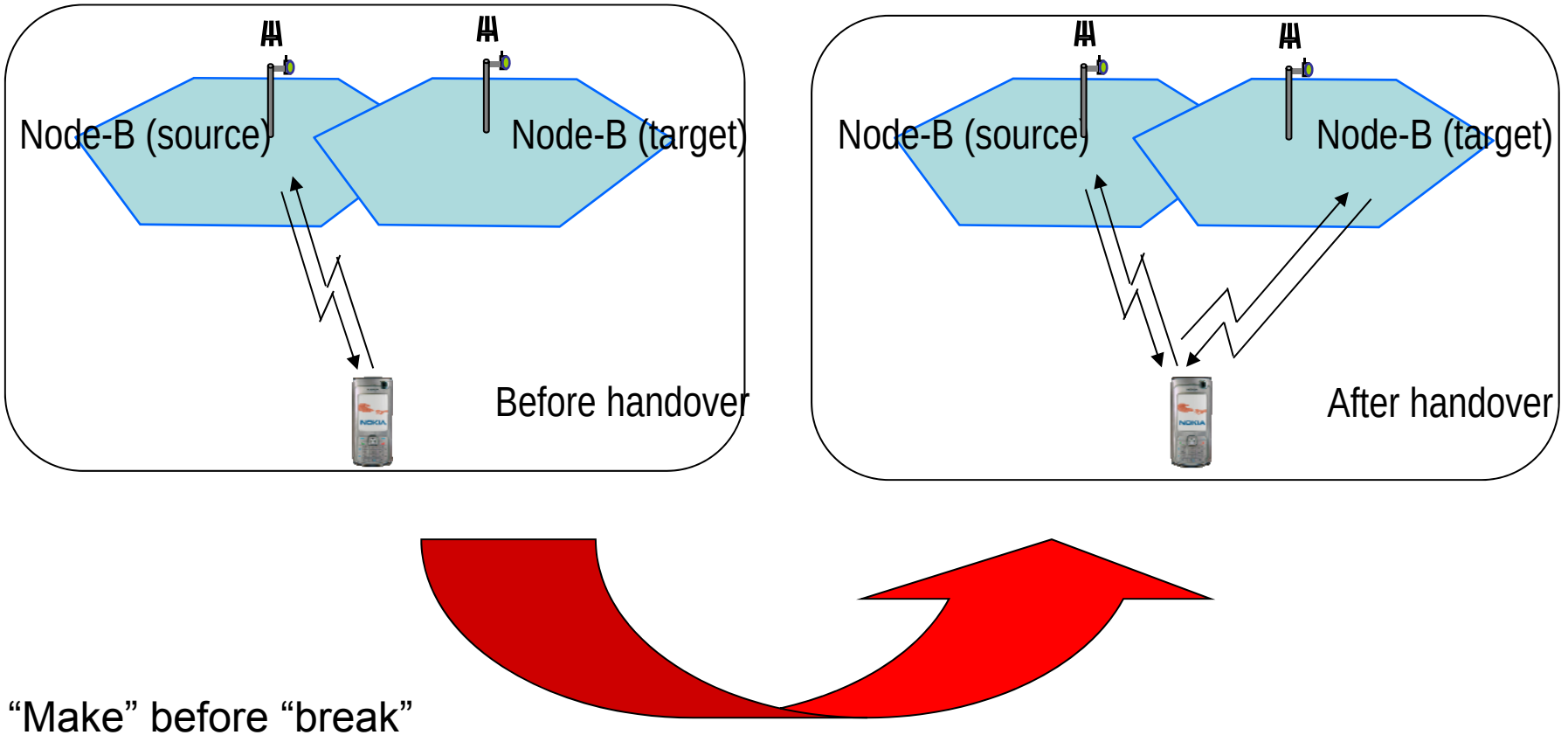
- Keeps wireless service when the mobile user moves across the cellular boundaries
- Keep required QoS
- Minimises interference level of the whole system by keeping the mobile attached to the strongest BS or BSs.
- Roaming between different networks
- Distributing load from hot spot areas (load balancing)

Hard Handover (GSM)



Can also be used for CDMA
"Break" before "make"
MT has to switch frequency

Soft Handover (W-CDMA)



"Make" before "break"
Each cell uses same frequency

Soft handover benefits/disadvantages

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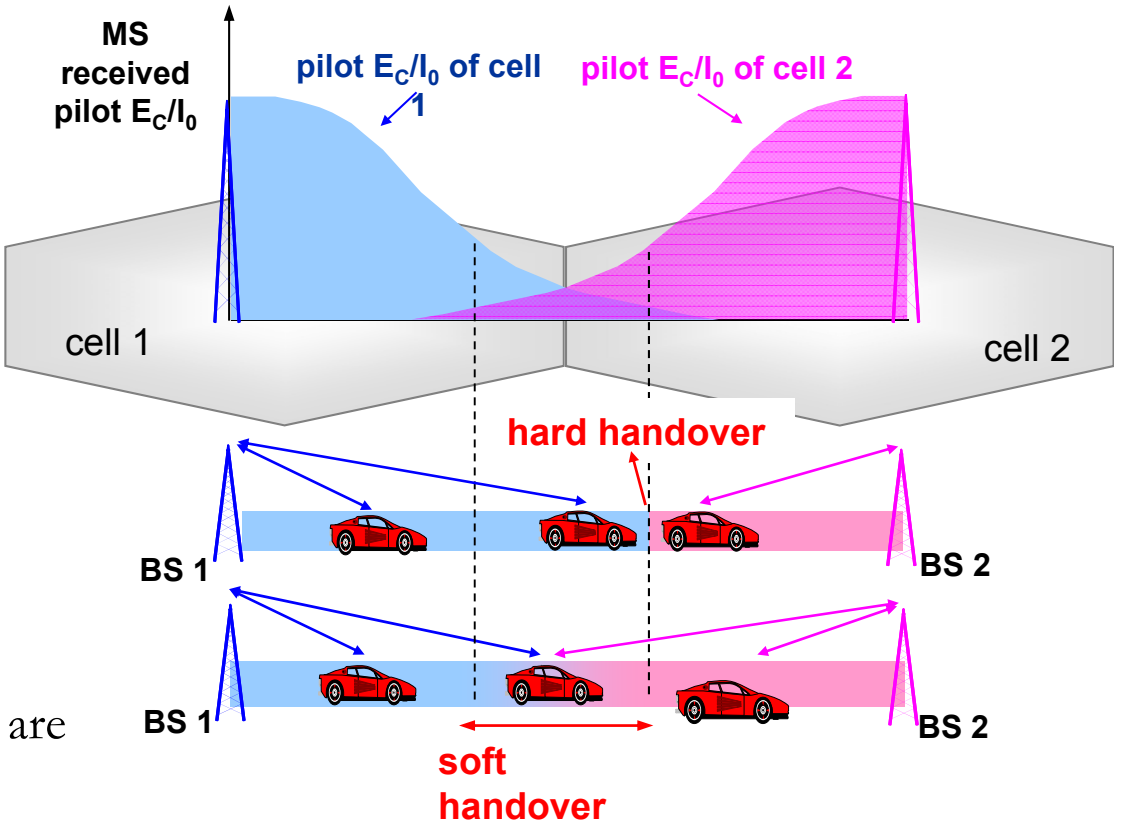
Advantages:

- Less the "ping-pong" effect
- Smoother transmission
- No hysteresis margin
- Macrodiversity gain
- Reduced overall uplink interference

Disadvantages:

- More complexity
- Additional network resources are consumed in the downlink direction (code resource and power resource)



Challenges of wireless

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- Limited resources: finite radio spectrum
  - Frequency reuse, breaking cells into smaller cells, more efficient medium access technology, e.g. CDMA…
- Supporting mobility - Location management, handover, …
- Maintaining Quality of Service (QoS) over unreliable wireless links
  - Radio propagation attenuation: path loss, shadowing, multipath fading.
- Connectivity and coverage - roaming and internetworking
- Security
  - Wireless channels are "open"
  - Certification and authentication
- Integrated services (voice, data, multimedia, etc.) over a single network
  - service differentiation, priorities, resource sharing,...
- Mobile terminal battery life
- Can you think more?

How does communications everywhere affect the global economy?

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- Increasingly reliant on communications technology for business
- Variety of actors with competing interests
- Communications systems becoming the target of cyber-terrorist attacks
- Communications networks now part of the national large-scale critical infrastructure.