

PERSONAL COMMUNICATIONS SERVICES

**ECE 525E – WIRELESS &
MOBILE COMMUNICATION
Wednesday, June 23, 2021**

MAJOR DEVELOPMENTS IN RADIO & MOBILE

- **1934** - Police Radio uses conventional AM mobile communication system.
- **1935** - Edwin Armstrong demonstrated FM.
- **1946** - First public mobile telephone service - Push-to-talk (Simplex).
- **1960** - Improved Mobile Telephone Service, IMTS - Full duplex.
- **1960** - Bell Lab introduce the concept of Cellular mobile system.
- **1968** - AT&T propose the concept of Cellular mobile system to FCC.
- **1976** - Bell Mobile Phone service Introduced. Has poor service due to call blocking.
- **1983** – Advanced Mobile Phone Service (AMPS)
- **1991** - Global System for Mobile (GSM)
- **1991** - U.S. Digital Cellular or Digital AMPS (DAMPS) IS-54, TDMA, DQPSK.
- **1993** - IS-95 CDMA QPSK, CDMA

DEFINITION OF PERSONAL COMMUNICATIONS SERVICES (PCS)

- Personal Communication Services (PCS) refers to a wide variety of wireless access and personal mobility services provided through a small terminal.
- There are two main categories of Personal Communication Systems:
 1. Low-tier PCS communication
 2. Cellular Telephone Systems

CELLULAR PERSONAL COMMUNICATION SYSTEMS

1. Advanced Mobile Phone Service (AMPS)
2. Global System for Mobile Communications (GSM)
3. Digital Advanced Mobile Phone Service (DAMPS)
4. Code Division Multiple Access - CDMA(IS-95)

ADVANCED MOBILE PHONE SERVICE (AMPS)

1. Advanced Mobile Phone System (AMPS) was the first cellular system.
2. Developed during the 1970s in the Bell Laboratories
3. From 1974 to 1978, a large scale AMPS trial was conducted in Chicago.
4. Commercial AMPS service became available since 1983.
5. It was used in Britain where it was called TACS and also in Japan where it was called MCS-L1
6. AMPS is based on ***frequency division multiple access*** (FDMA) technology for radio communications implemented with a frequency reuse scheme.
7. Voice channels are assigned to radio frequencies using FDMA.
8. AMPS operated in the 824-849 MHz (uplink) and 869-894 MHz bands (downlink).
9. Later systems (GSM and DAMPS) inherited many principles from AMPS

AMPS-TELEPHONE



AMPS-FREQUENCY PLAN

1. In AMPS, the **cells are typically 10 to 20 km across**; in later digital systems, the cells became smaller.
2. Each cell **uses a set of frequencies which are not used in the neighbouring cells**.
3. The design **objective was to give cellular systems far more capacity** than previous systems through the use of relatively small cells designed for frequency reuse.

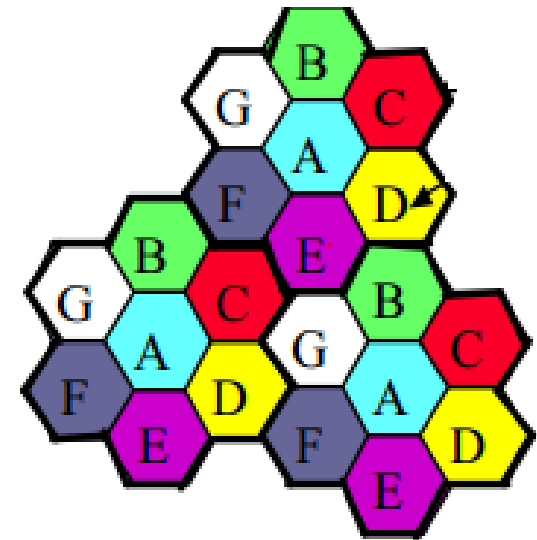


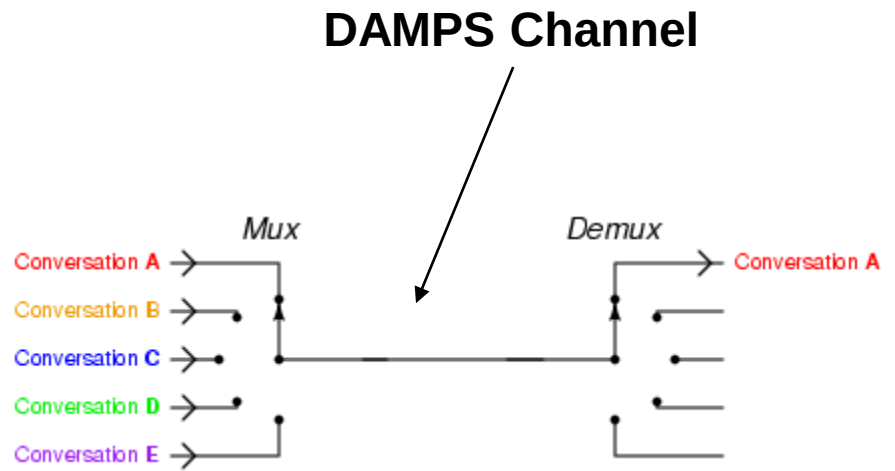
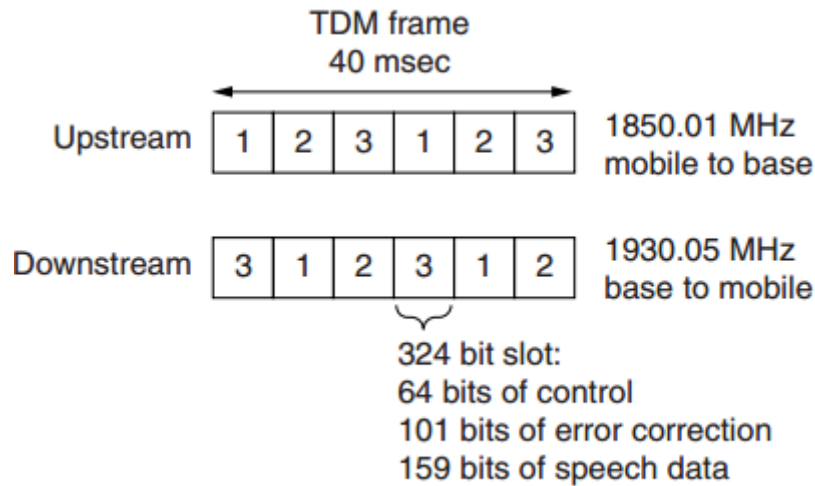
Fig. Frequency reuse.
Cells marked A used the same frequency. So do B, C, D, E and F

DIGITAL ADVANCED MOBILE PHONE SERVICE (DAMPS)

- DAMPS is a second generation AMPS that is fully digital but can co-exist with analogue AMPS
- DAMPS is uses both 850 MHZ and 1900 MHZ bands as follows:
 - **Up-link:** 824 – 849 MHz and 1850 – 1910 MHz
 - **Down-Link:** 869 – 894 MHz and 1930 – 1990 MHz

TIME DIVISION MULTIPLEXING IN DAMPS

- Three users can share a frequency channel in AMPS using TDM.

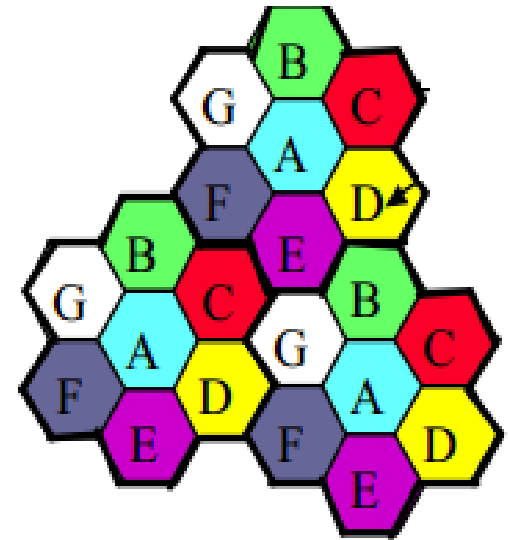


FIRST CELLULAR SYSTEM IN KENYA

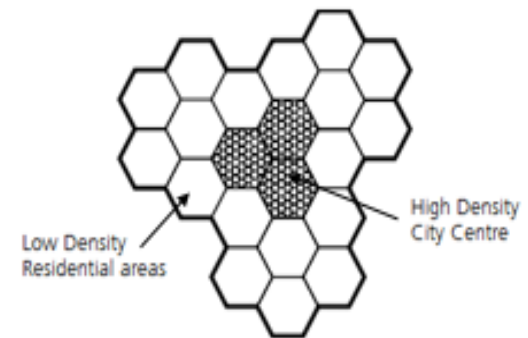
1. The first cellular system in Kenya was the Electronic Total Access Communication System (ETACS) which was introduced in 1992 by the Kenya Posts and Telecommunications (KPTC), the predecessor of Telkom Kenya.
2. ETACS was a British variant of AMPS.
3. The KPTC, ETACS was upgraded to GSM in 1996.

FREQUENCY REUSE CONCEPT

- Cells are usually circular but are **more easily modelled as hexagons** as shown in the diagram
- Cells usually arranged in **clusters of 4, 7 or 12**.
- Each letter indicates a cell using a group of frequencies
- In this plan, there is **a buffer of two cells between any two frequencies**.
- In practice, **finding elevated sites at appropriate location is usually a big problem in network planning**.
- In areas where the number of users has increased, **cells are usually split into smaller ones** (micro and pico cells) and the power transmission levels are reduced.

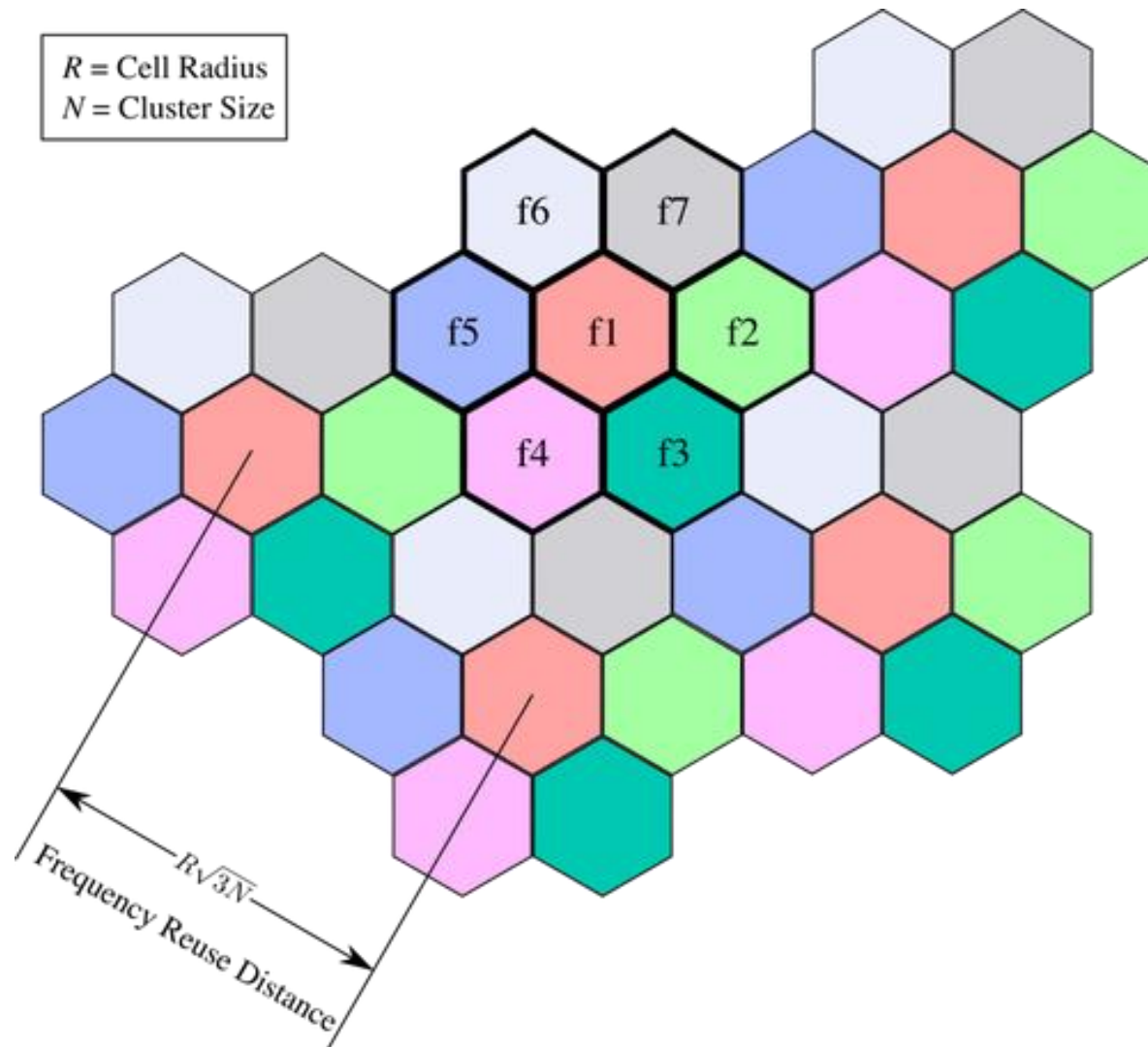


(a) 7-cluster cell arrangement



(b) Cell- splitting

FREQUENCY REUSE CONCEPT



PRACTICAL CELL PLANNING

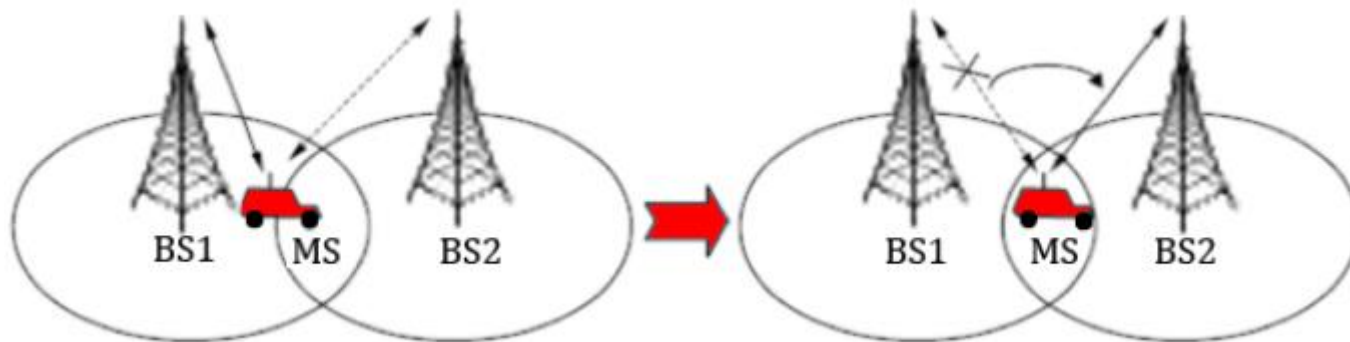
- In the practice of cell planning, cells are not hexagonal as in the theoretical studies.
- Computer methods are being used for optimised planning of base station location and cell frequencies.
- Path loss and link budgets are computed from the terrain features and antenna data.
- This determines to coverage of each base station and interference to other cells.

AMPS CHANNELS

- AMPS uses 832 full-duplex channels as follows:
 - **Up-link:** 824 – 849 MHz
 - **Down-Link:** 869 – 894 MHz
- Each simplex channel has a bandwidth of 30 KHz.
- The 832 channels are divided into four categories:
 1. Control to manage the system (downlink)
 2. Paging to alert mobile users on incoming call (downlink)
 3. Access to call set-up and channel assignment (bi-directional)
 4. Data (Voice, ~~fax~~ or data)

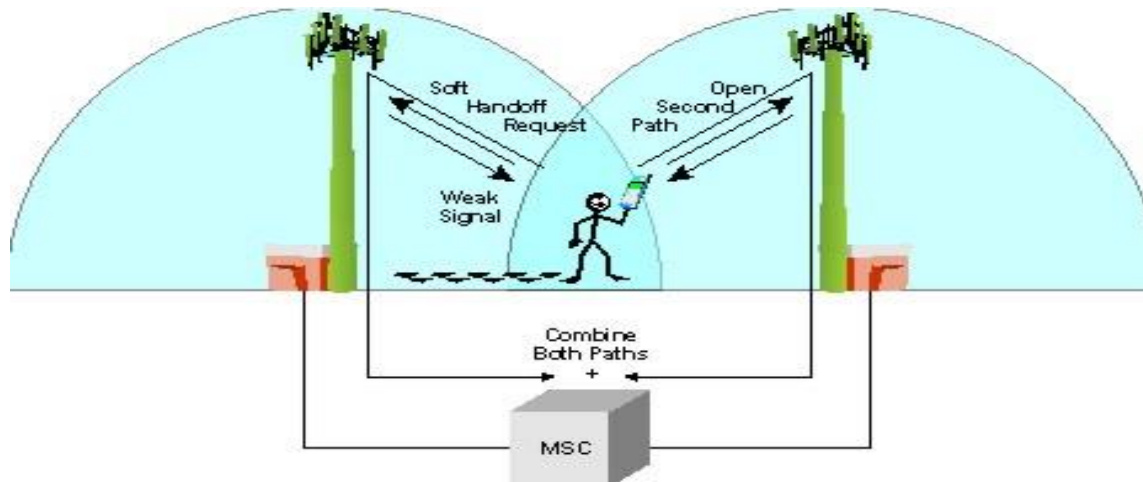
AMPS HANDOFF

- At any time each mobile is connected to one Base Station Transceiver (BTS).
- If the BTS notices that the signal is fading, then it requests the neighbouring base stations to measure the power from the mobile.
- Hand-over is then made to the base station reporting the highest power signal from the mobile.

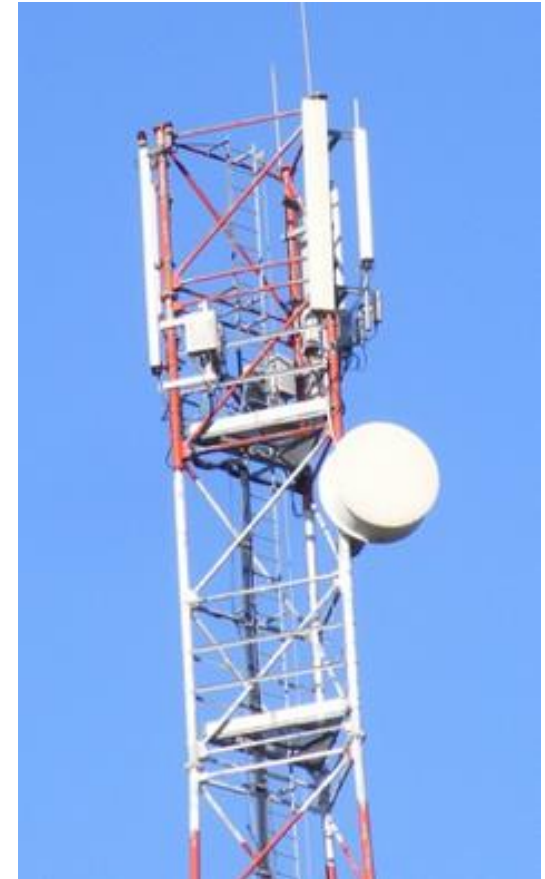
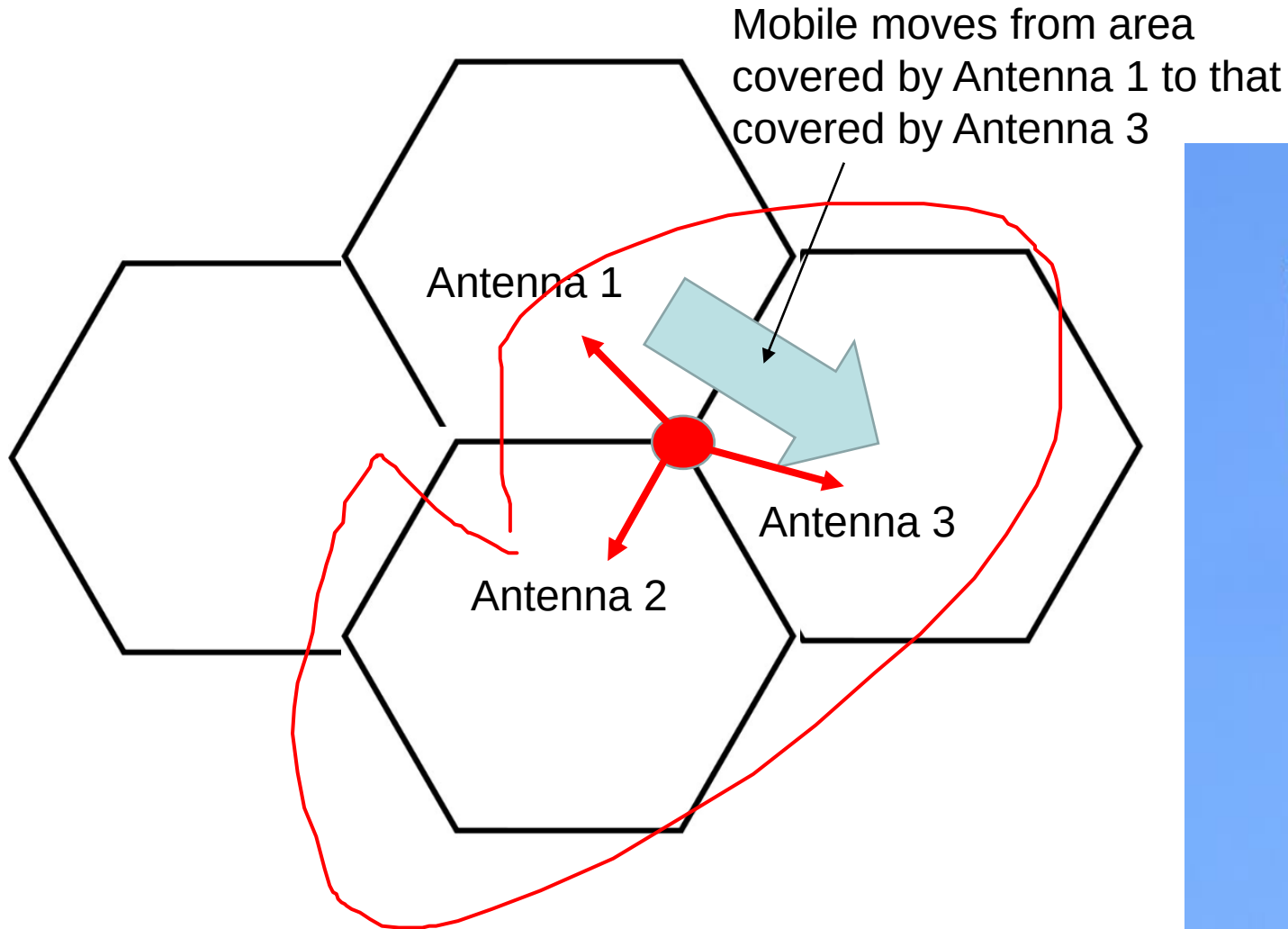


TYPES OF HAND-OFF

- There are three types of hand-offs, i.e.
 - **Hard Handoff** where the mobile disconnects from the BTS before acquiring the next BTS
 - **Soft handoff** where the mobile acquires the next BTS before the previous signs off (not available in 1st generation)
 - **Softer handoff** where handoff is between cells controlled from the same cell site



SOFTER HANDOFF



FACTS AT SAFARICOM.CO.KE ON 25/03/2017

1. As the biggest communication company in East and Central Africa.
2. Over 25.1 million subscribers.
3. Over 200,000 touch points
4. over 100 different products.
5. Annual revenues in excess of Kshs 150 Billion,
6. Invested Kshs 32.13 billion in infrastructure this year.
7. Provides over 95% of Kenya's population with 2G coverage
8. Provides over 78% of Kenya's population with 3G coverage

GLOBAL SYSTEM FOR MOBILE COMMUNICATION

1. GSM is a digital cellular system developed by **Groupe Special Mobile** of Conference Europeenne des Postes et Telecommunications (CEPT) and its successor **European Telecommunications Standard Institute (ETSI)**.
2. The goal of the GSM development process was to offer **compatibility of cellular services among European countries**.
3. GSM combines both time division multiple access (TDMA) and FDMA.

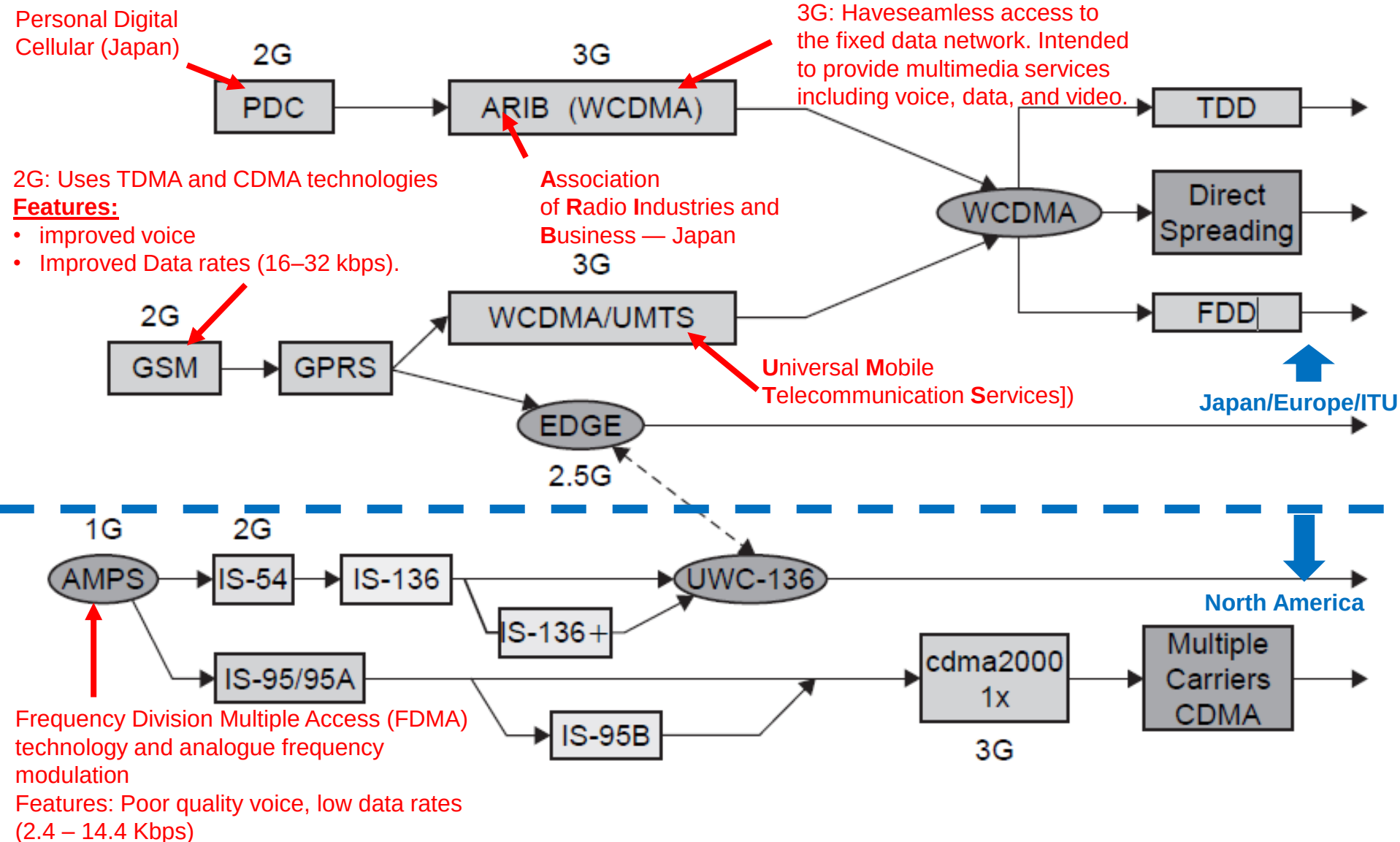
GLOBAL SYSTEM FOR MOBILE COMMUNICATION

1. The frequency carrier is divided into **eight time slots** where the speech coding rate is 13 Kbps.
2. A GSM base station, every pair of radio transceiver-receiver supports **eight voice channels**, whereas an DAMPS base station needs one such pair for three voice channel.
3. The **GSM Mobile equipment control their RF output** power to counter interference at low levels.
4. The GSM air interface has been evolved into **Enhanced Data Rate for GSM Evolution (EDGE)** with variable data rate and link adaptation.

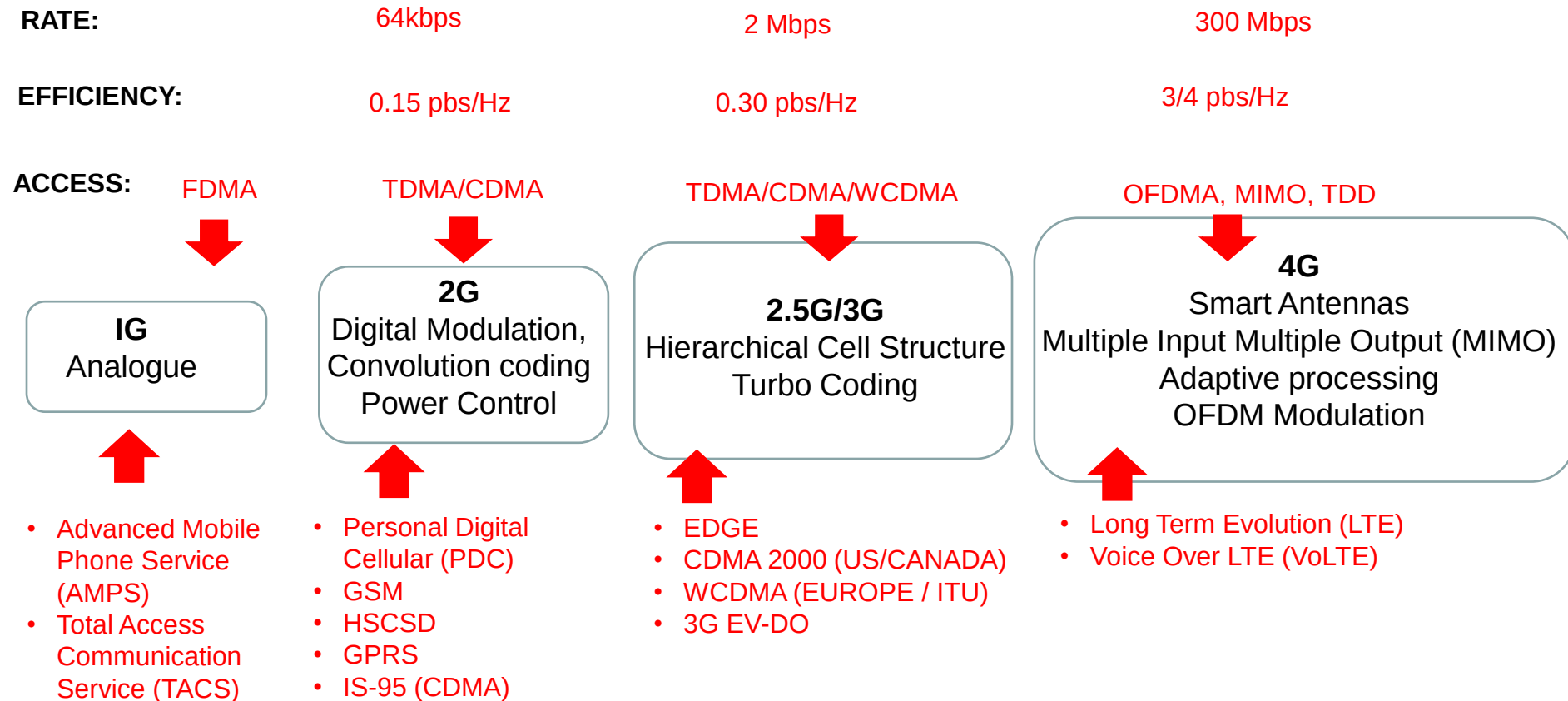
GENERATIONS OF MOBILE COMMUNICATION SYSTEMS

- **1st Generation:** Analogue systems, e.g. AMPS
- **2nd Generation:** Global System for Mobile Communication (GSM) designed for voice and low rate data services.
- **3rd Generation:** Higher system capacity with high speed data/internet access (> 2Mbps)

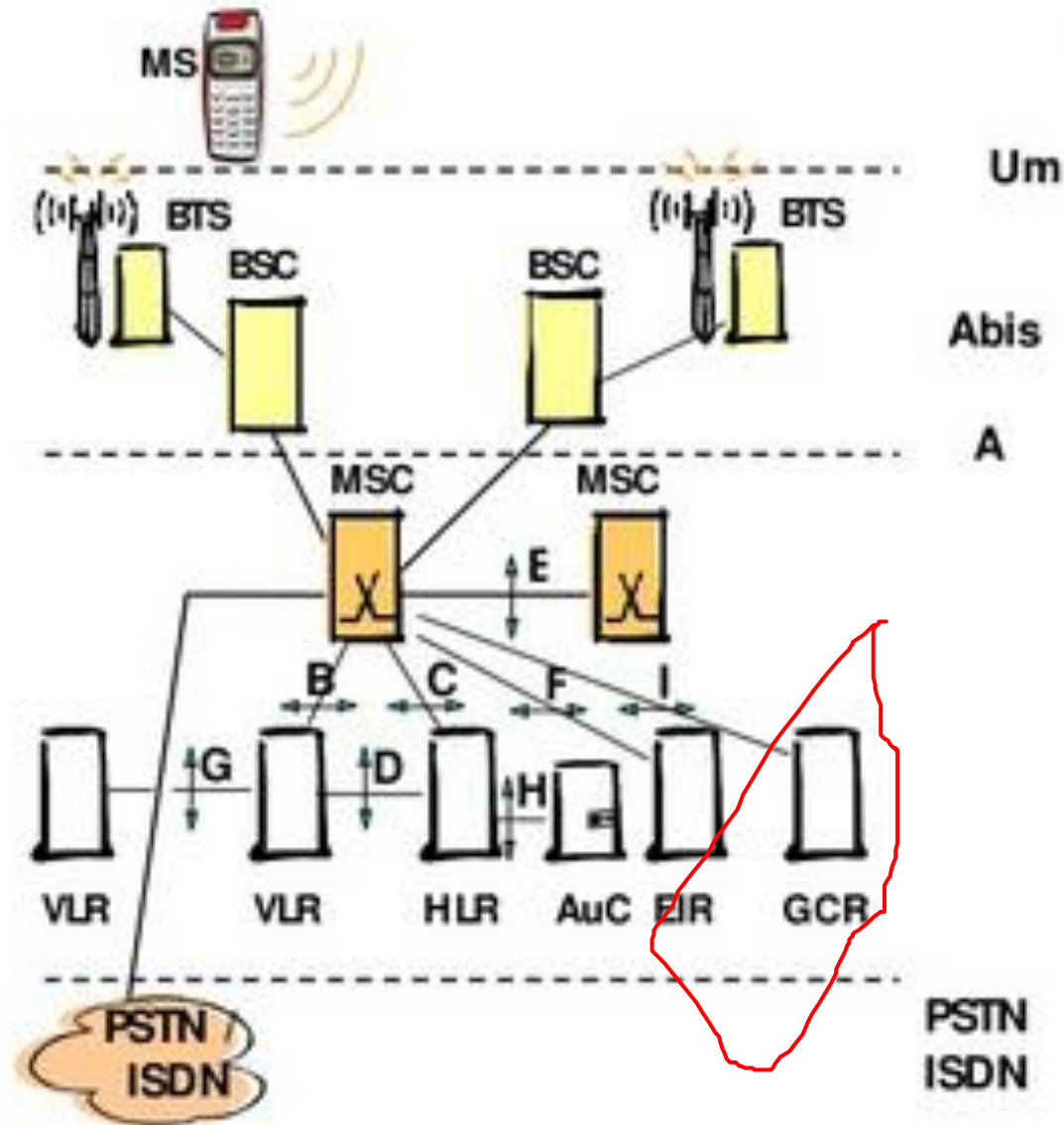
EVOLUTION OF WIRELESS WIDE AREA NETWORKS



EVOLUTION OF CELLULAR SYSTEMS



GSM NETWORK ARCHITECTURE

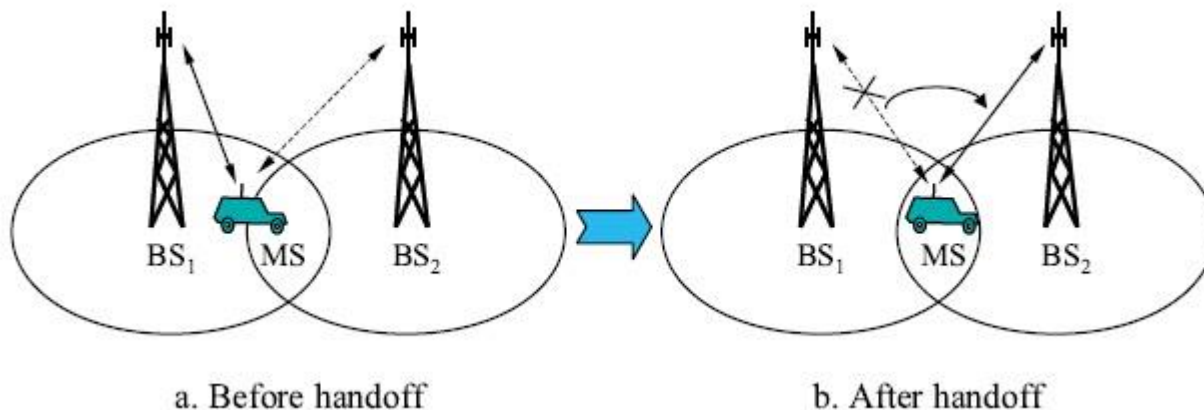


MOBILE STATION HAND-OFF STRATEGIES

- **Mobile-controlled handoff:** the MS continuously monitors the signals of the surrounding BSs and initiates the handoff process when some handoff criteria are met. Used in DECT and PACS.
- **Network-controlled handoff:** the surrounding BSs measure the signal from the MS, and the MSC initiates the handoff process when some handoff criteria are met. Used in CT-2 Plus and AMPS.
- **Mobile-assisted handoff:** the MSC asks the MS to measure the signal from the surrounding BSs. The MSC makes the handoff decision based on reports from the MS. Used in GSM and IS95 CDMA.

PROBLEMS WITH HAND-OFFS

1. Hand-offs are expensive to execute and should therefore be minimized.
2. If not properly executed then at the boundaries between cells, the calls may be handed over several times.
3. If the criteria is very conservative, then the call may be lost before handover.
4. Variations in the propagation environment due to such problems as multipath propagation may temporarily make a signal of a further BS appear stronger.
5. The problem becomes even more acute as more and more small sizes are used especially in urban areas.



MEASUREMENTS USED TO DETERMINE THE QUALITY OF THE HANDOVER

- **Word error indicator (WEI):** Metric that indicates whether the current burst was demodulated properly in the MS.
- **Received signal strength indication (RSSI):** Measure of received signal strength. The RSSI metric has a large useful dynamic range, typically between 80 to 100 dBm.
- **Quality indicator (QI):** Estimate of the "eye opening" of a radio signal which relates to the **signal to noise (S/N) ratio**, including the effects of dispersion. Q1 has a narrow range (from 5 dB -25 dB).

HAND-OFF FAILURES

1. No channel is available on target BS.
2. Handoff is denied by the network for reasons such as lack of resources, e.g. no bridge or no channel;
3. The MS has exceeded some limit on the number of handoffs that may be attempted in some period of time.
4. It takes the network too long to set up the handoff after it has been initiated.
5. The target link fails during the execution of handoff.

ASSIGNMENT I

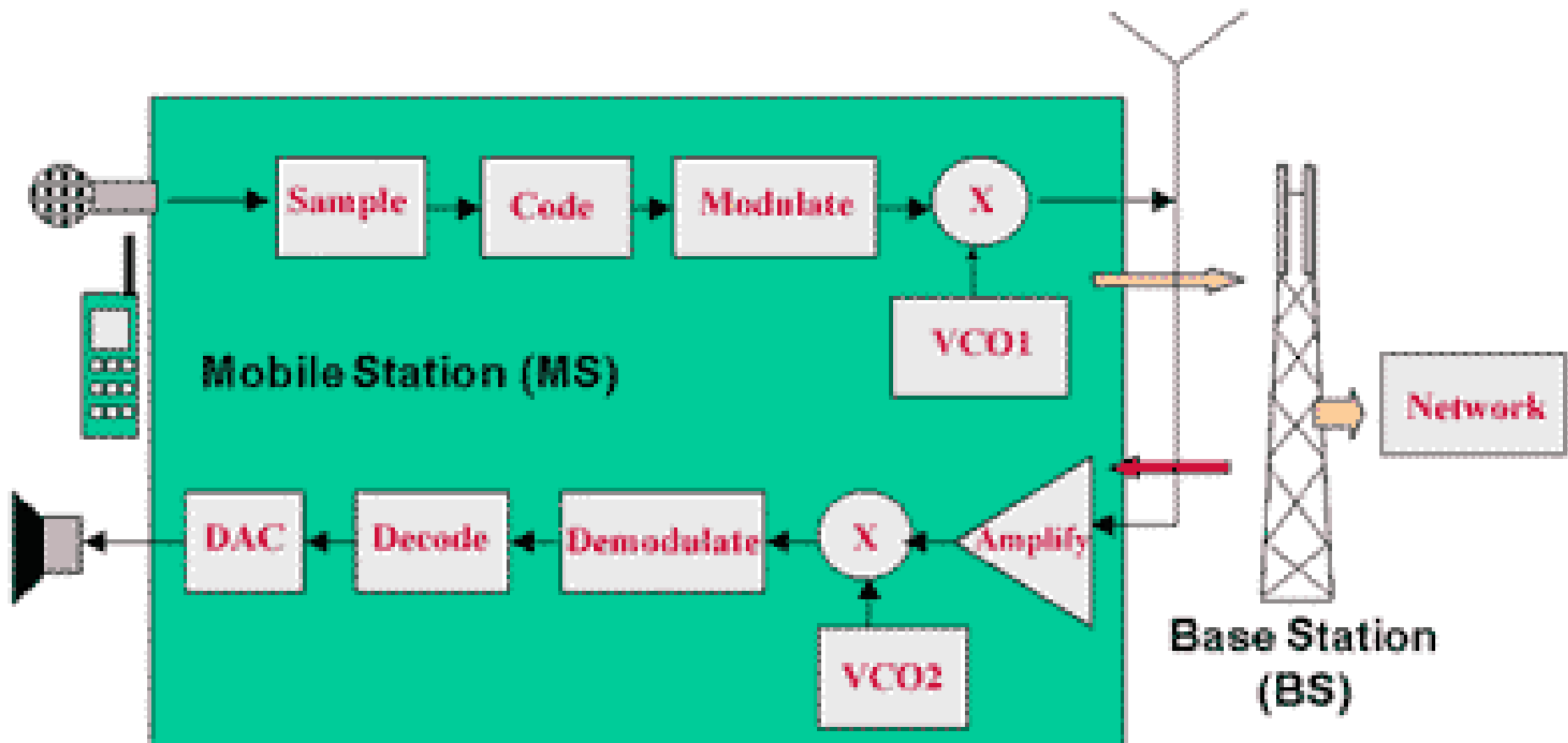
1. Why is the hexagon the most preferred model for a cell in cellular communications?
2. What are the three measurements that can be performed to decide on handoff?
3. What is distance-dependent fading?
4. Describe the **three** handoff detection strategies. What are the advantages and disadvantages of the three handoff detection strategies? For example, in terms of load balancing, Which handoff detection strategy is better?
5. Can you implement Mobile Controlled Hand-off (MCHO) or Mobile Assisted Hand-off (MAHO) on FDMA-based Systems?

GLOBAL SYSTEM FOR MOBILE COMMUNICATION

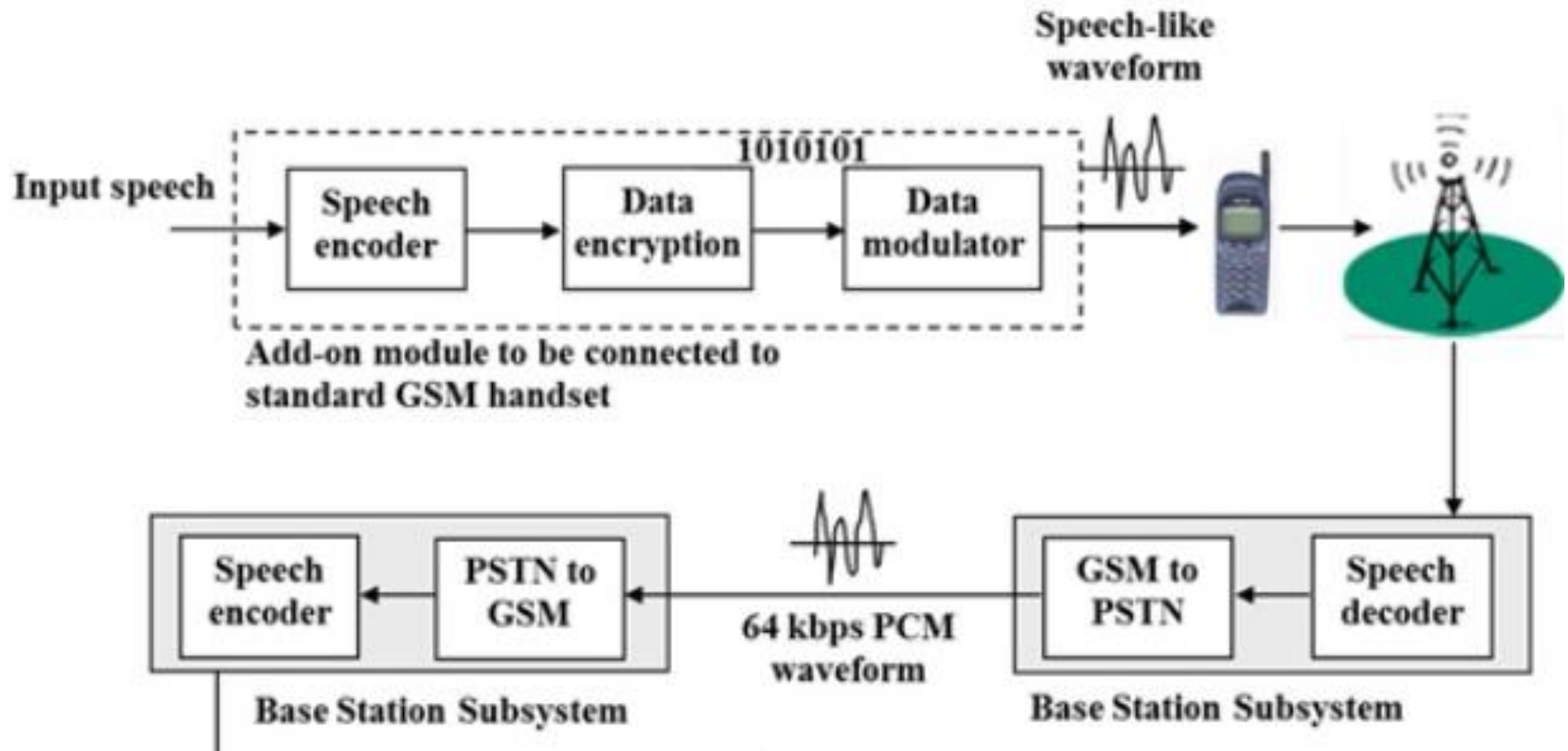
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Thursday, June 24, 2021

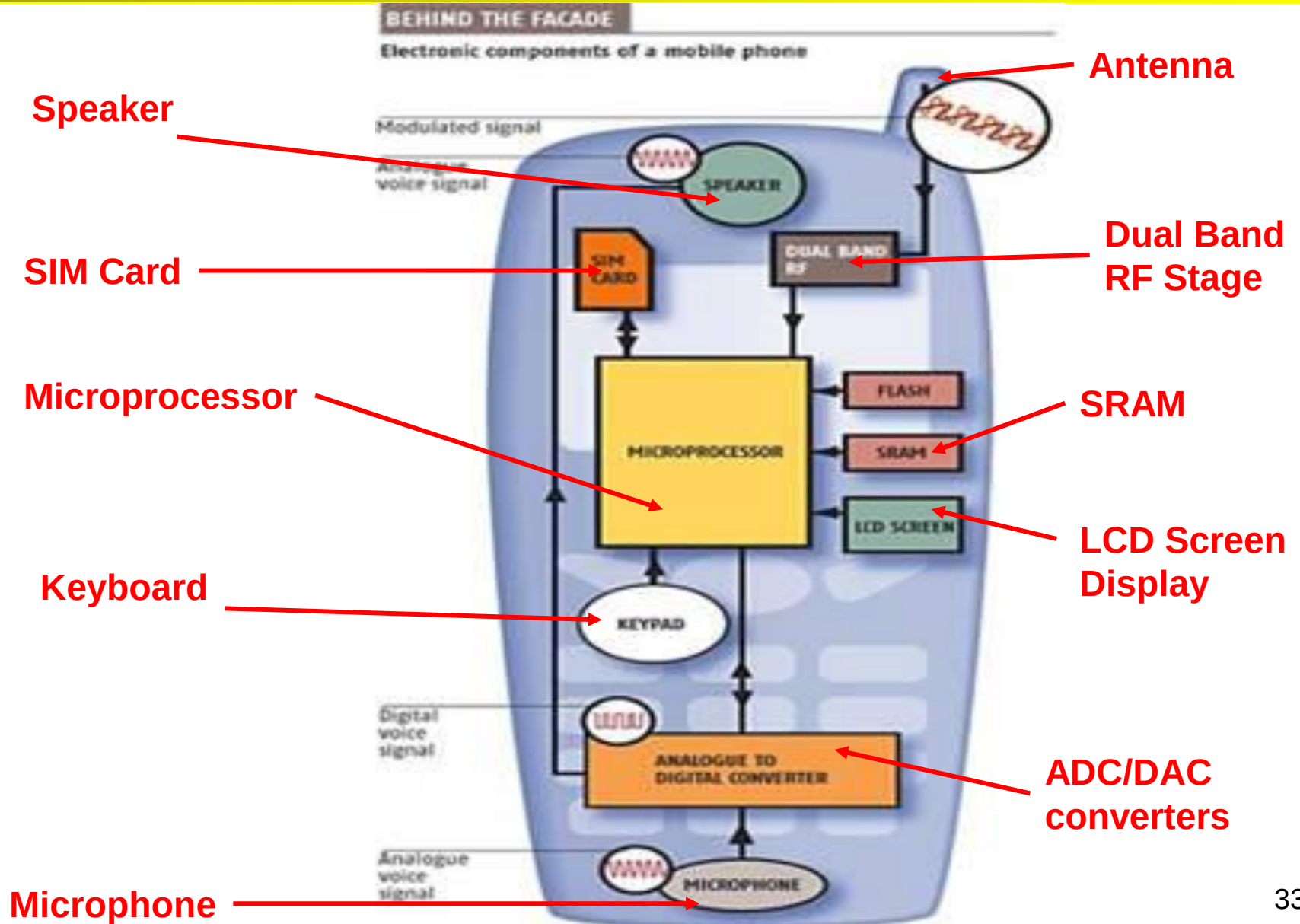
BASIC BLOCK DIAGRAM OF A SIMPLE GSM PHONE



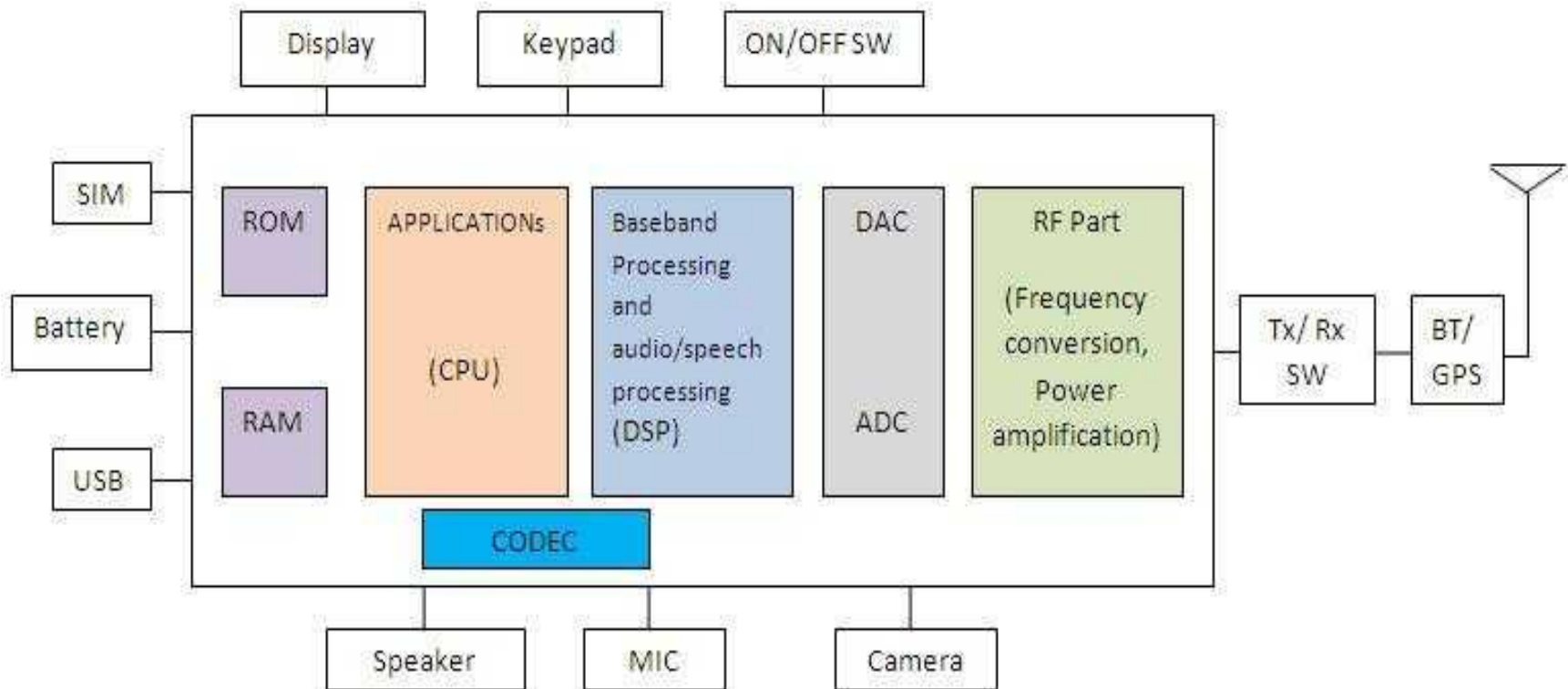
BASIC BLOCK DIAGRAM OF A SIMPLE GSM PHONE WITH ENCRYPTION



INSIDE THE MOBILE PHONE



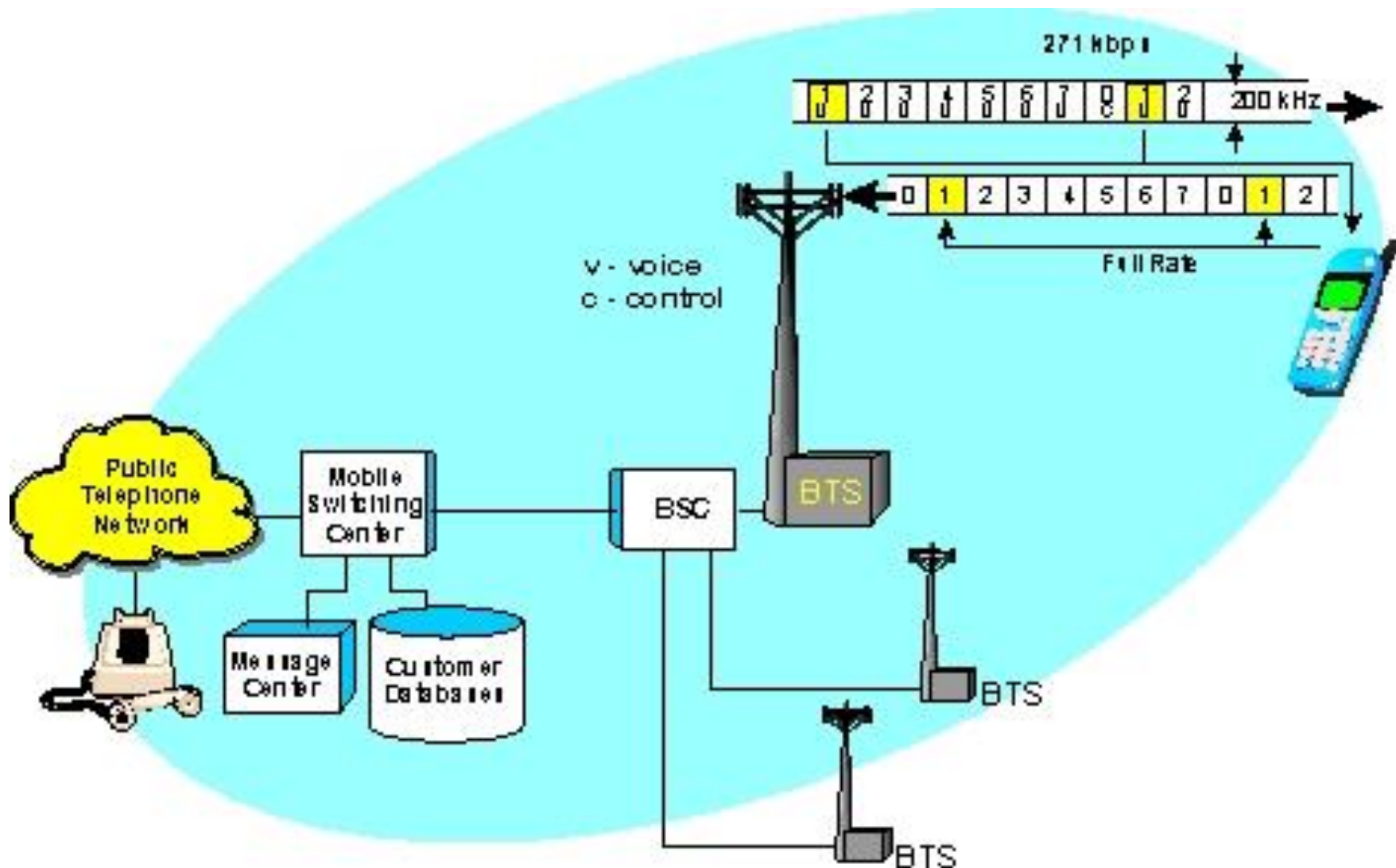
INSIDE SMART GSM PHONE



Commonly used antennas in the mobile phone are

1. Microstrip
2. helix type,
3. planar inverted F type,
4. whip

BASIC BLOCK DIAGRAM OF A SIMPLE GSM NETWORK



SIM CARD

1. Personal Identity Number (PIN)

- 4-8 Digit
- Initially loaded by the network operator
- Can be deactivated or changed by operator
- Contains:
 - Name of Home Network
 - SMS Received
 - Dial/Received/Missed Numbers

2. Pin Unlocking Key (PUK)

- 8-digit

Modification of the SIM Contents

- User using keyboard
- User using Computer connected to the serial port
- Over the air by an operator using a SIM toolkit

BASE STATION SYSTEM (BSS)

1. Base Station Transceiver Station contains:
 - Transmitter, receiver and signalling specific to the radio interface
 - Transceiver Rate Adapter Unit (TRAU) for GSM encoding and decoding
2. Base Station Controller:
 - Connects to one or more BTS
 - Performs switching function within the BSS
 - Connection to MSC in the Network and Switching Subsystem (NSS)
 - Radio Channel Allocation/Release and handover management.

NETWORK & SWITCHING SUBSYSTEM (NSS)

1. NSS Supports:

- Switching functions
- Subscriber profiles (HLR and VLR)
- Mobility Management
- Security data management using the Authentication Centre (AUC)

2. Communicates with other external systems, e.g Other MSCs, PSTNs

RADIO INTERFACE (900 MHz)

1. Radio Interface uses both FDMA and TDMA technologies.
2. Up-link frequency: 890 – 915 MHz
3. Down-Link Frequency: 935-960 MHz
4. Many countries including Kenya have 10 MHz Extended GSM band in the 900MHz Band.
5. The Extended 900MHz band is 880-915MHz (uplink) and 925-960MHz (Downlink).
6. The Standard 900MHz frequency band is divided into 124 pairs of frequency duplex channels with 200 KHz carrier spacing.

RADIO INTERFACE

1. **Note:** For a given distance, less power is required to transmit a signal over a lower frequency.
2. Therefore to save mobile power, uplink frequencies in a mobile system are always lower than the downlink frequency.

INTERNATIONAL MOBILE SUBSCRIBER NUMBER (IMSI)

- IMSI - International Mobile Subscriber Identity

254-07-1234567890

- Mobile Country Code (MCC), 3 digits
example: **+254**
- Mobile Network Code (MNC), 2 digits
example: **07**
- Mobile Subscriber ID Number (MSIN), up to **10 digits**

WHERE TO GET MNC FOR GSM OPERATORS

www.itu.int/dms_pub/itu-t/opb/sp/T-SP-E.212B-2013-PDF-E.pdf

*Annex to ITU Operational Bulletin
No. 1019 – 01.I.2013*



INTERNATIONAL TELECOMMUNICATION UNION

Kenya		
	Safaricom Ltd.	639 02
	Kencell Communications Ltd.	639 03

TSB
TELECOMMUNICATION
STANDARDIZATION BUREAU
OF ITU

**Mobile Network Codes (MNC) for the international
identification plan for public networks and subscriptions
(According to Recommendation ITU-T E.212 (05/2008))**

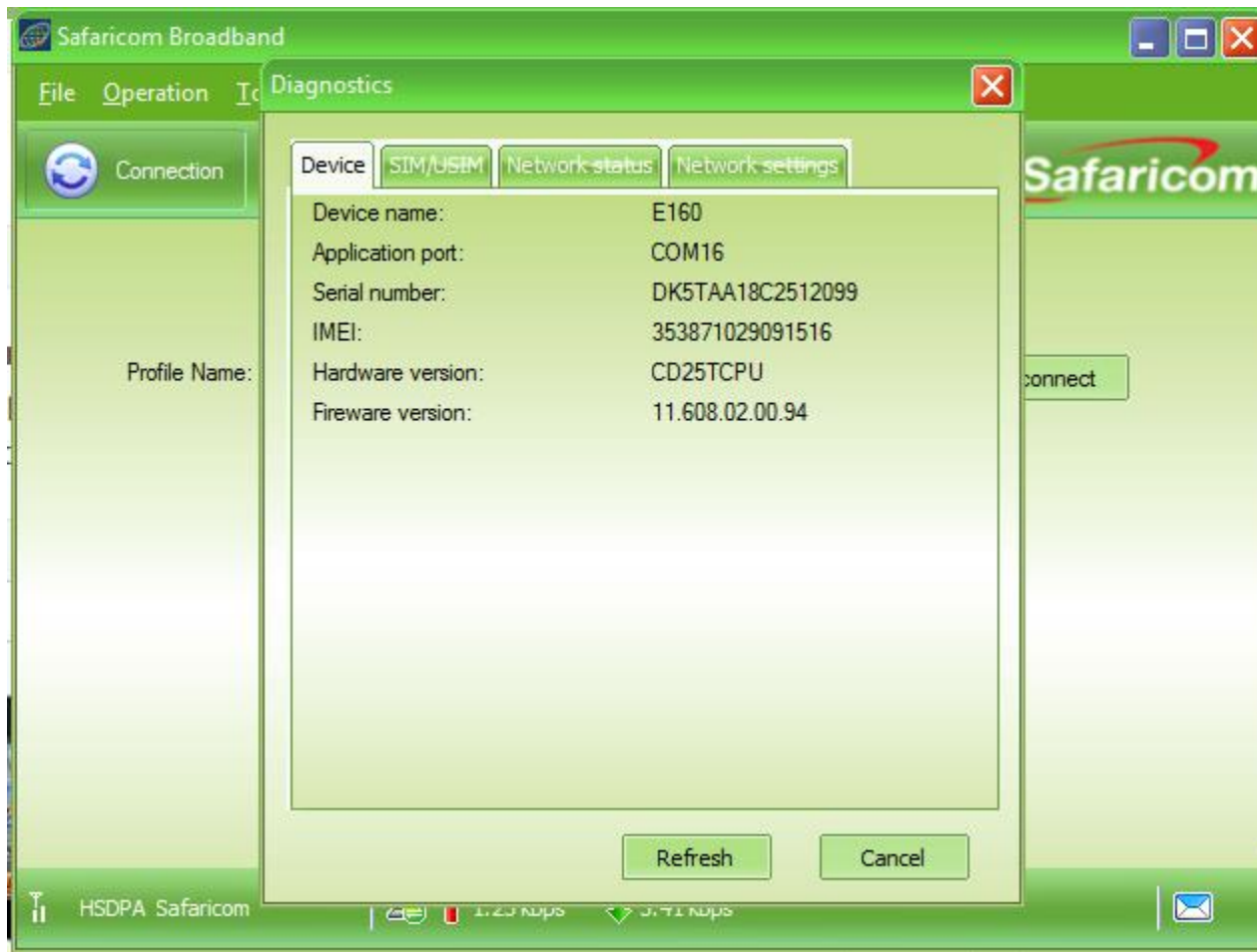
IMEI NUMBER

- IMEI – **International Mobile Equipment Identity** used to identify 2G and 3G mobile terminals.
 - **Fifteen digits stored in the firmware of the phone.**
 - **Used to track stolen/malfunctioning terminals and for enabling network and security features.**
- The IMEI is only used for identifying the device and has no permanent or semi-permanent relation to the subscriber.
- The IMEI (15 decimal digits: 14 digits plus a check digit) includes **information on the origin, model, and serial number of the device.**

IMEI AND THE LAW

- Many countries have acknowledged the use of the IMEI in reducing mobile phone theft.
- For example, in Kenya and UK, changing the IMEI of a phone, or possessing equipment that can change it, is a criminal offence.
- When mobile equipment is stolen or lost the owner can contact their operator with a request that it should be blocked from the operator's network

IMEI OF A SAFARICOM MODEM



TEMPORARY MOBILE SUBSCRIBER IDENTITY (TMSI)

- The Temporary Mobile Subscriber Identity (TMSI) is the identity that is most commonly sent between the mobile and the network.
- TMSI is randomly assigned by the VLR to every mobile in the area, the moment it is switched on.
- The number is local to a location area, and so it has to be updated each time the mobile moves to a new geographical area.

REVIEW QUESTIONS

1. Describe the main parts of a mobile station in a GSM system
2. Describe the possible connection configurations of BTSs and BSCs in the GSM system.
3. What is AUC in the GSM System?
4. GSM uses both FDMA and TDMA. Explain