

3G Networks

Lecture 3



First Generation – 1G Cellular Networks

- Advanced Mobile Phone Service (AMPS)
 - US trials 1978, deployed in Japan (1979) & US (1983)
 - 800 MHz frequency band
- Nordic Mobile Telephony (NMT)
 - Sweden, Norway, Denmark & Finland
 - Launched 1981
 - 450 MHz band, later at 900 MHz band (NMT900)
- Total Access Communications System (TACS)
 - British design; similar to AMPS; deployed 1985
 - 872 MHz band (872 MHz - 960 MHz)



Second Generation – 2G



▪ Digital systems

- Utilized technology to increase capacity
- Speech compression; digital signal processing
- Improved fraud prevention
- Added new services

➤ Multiple 2G systems:

- IS-54 North American TDMA
- iDEN
- DECT and PHS
- IS-95 CDMA (cdmaOne)
- GSM

IS 54 North American TDMA / PDC

- Speech coded as digital bit stream
 - includes compression plus error protection bits
- Uses Time division multiple access (TDMA), *like GSM*
 - 3 calls per radio channel using repeating time slices
- Deployed 1993 (deployed as **PDC** in Japan in 1994)
 - Developed throughout the 1980s
- Follows IS-54 / IS-136 standards in US



iDEN

- Used by Nextel
 - Motorola proprietary system
 - used time division multiple access (TDMA) technology
 - based on GSM architecture
- Uses a 800 MHz private mobile radio (PMR) spectrum
 - just below 800 MHz cellular band
- Special protocol supported fast “Push-to-Talk”



DECT and PHS

- Also utilizes TDMA
- Digital European Cordless Telephony
 - focused on business use
 - very small cells
 - high quality voice and data
 - deployed across Japanese cities (high pop. density)
 - Base stations on top of phone booths



North American CDMA (cdmaOne)

- Code Division Multiple Access
 - all users share same frequency band
 - CDMA is the basis for the 3G air interface

- Qualcomm demonstration in 1989
 - claimed improved capacity
 - First deployment in Hong Kong late 1994
 - Major success in Korea (1M subs by 1996, 20M by 2001)
 - Used by Verizon and Sprint in US



GSM

- Groupe Special Mobile, later changed to **Global System for Mobile**
 - joint European effort beginning in 1982
 - focus on seamless roaming across Europe

- Services launched in 1991
 - time division multiple access (8 users per frequency)
 - 900 MHz band; later extended to 1800MHz
 - added 1900 MHz (in US)



GSM

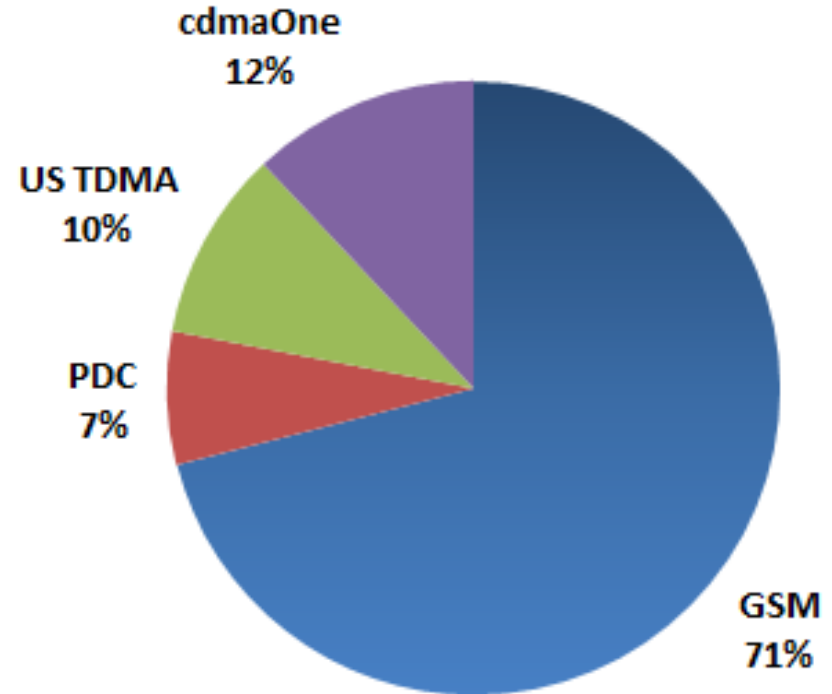
- **Global System for Mobile**

- GSM was A **dominant** world standard
- well defined interfaces; has many competitors



Distribution of GSM Subscribers (2001)

- GSM was used by 70% of subscribers worldwide
 - 800 M subs in July 2001
- Most GSM deployments in Europe and Asia
- ATT & Cingular deployed GSM in US



1G – Frequency Division Multiple Access

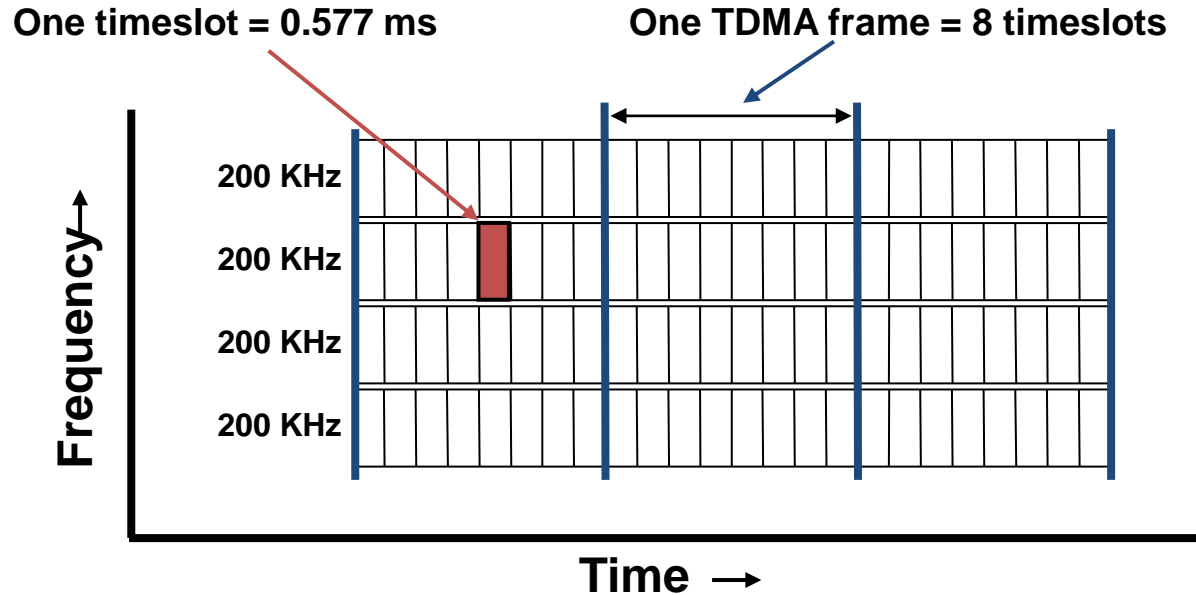


- FDMA permits individual allocation of a single frequency band (channel) or multiple frequency bands to the users. Allowed multiple users to access the network via different frequencies
- Main used in 1G networks (analog telecommunications standard) before the digital 2G networks

2G – Time Division Multiple Access



- GSM uses TDMA which divides the channel into time slots,



2G & 3G – Code Division Multiple Access



- **CDMA:**

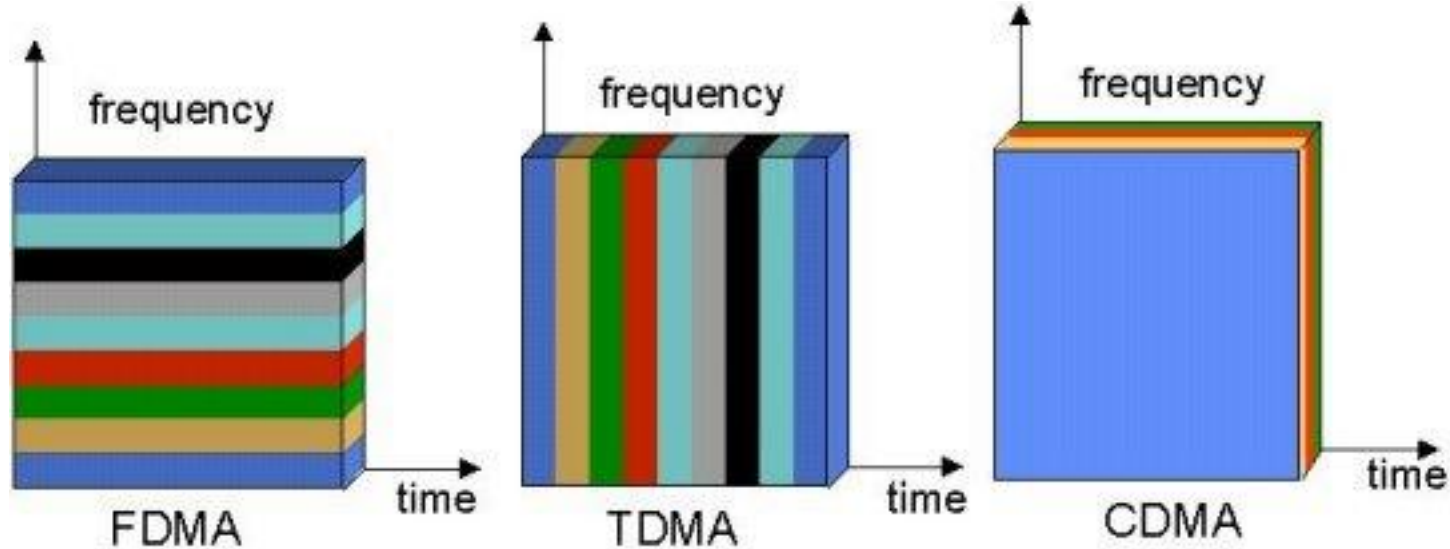
- CDMA utilizes a spread spectrum which assigns a **unique code** to each conversation and uses the full bandwidth of the channel.
 - An often-used analogy is the ability to detect one's own language in a room full of people speaking multiple languages
- **Spread spectrum** is a form of wireless communication in which the frequency of the transmitted signal is deliberately varied resulting higher bandwidth.

2G & 3G – Code Division Multiple Access



- CDMA:
 - All users share the same large block of spectrum
 - Almost all accepted 3G radio standards are based on CDMA
 - CDMA2000, WCDMA and TD-SCDMA

Multi-Access Radio Techniques



- **CDMA:** The **spectrum of a signal** is the range of frequencies contained in the signal. The **bandwidth** is the difference between the lowest and highest frequency in the spectrum

CDMA



- CDMA provides up to 10 times the calling capacity of earlier analog networks (AMPS) and up to five times the capacity of GSM systems.
- CDMA is also the basis for the WCDMA and HSPA 3G technologies used by GSM carriers (operators)

International Standardization

- ITU (International Telecommunication Union)
 - develops radio frequency and spectrum standards

- IMT-2000
 - ITU's name for 3G which stands for International Mobile Telecommunications 2000



International Standardization

- 3G Partnership Projects
 - 3GPP
 - & 3GPP2
 - Focused on creating 3G core network

- Standards bodies collaborating in 3G partnership projects
 - ARIB, TTA, TTC, CWTS, T1, ETSI



3G Objectives



- Universal global roaming
- Multimedia mobile update (voice, data & video)
- Increased data rates
 - Data rate of **144 kbps** for access in a moving vehicle (cars)
 - **384 kbps** for access users walking (pedestrians)
 - **2 Mbps** for stationary users (homes)
- Increased capacity (more spectrally efficient)
- IP (Internet Protocol) architecture

3G Objectives

- To get the goal laid by IMT-2000 various technologies were proposed
 - ETSI agreed on the **WCDMA** solution using FDD
 - Japan utilized WCDMA with both FDD and TDD
 - In Korea two different types of solutions were proposed WCDMA and **CDMA2000**
- **This lead to 2 groups**
 - 3GPP – UMTS / WCDMA
 - 3GPP2 - CDMA2000



UMTS

- **Universal Mobile Telecommunications Service (UMTS)**
 - It is the group of radio technologies associated with third-generation (3G) cellular networks.
- Compared to its predecessors GSM and GPRS, UMTS offers:
 - greater bandwidth,
 - more efficient use of the radio spectrum,
 - and more advanced cellular capabilities (including Multimedia mobile updates)



UMTS

- Since UMTS uses Code Division Multiple Access (CDMA) technology but has wider bandwidth than other CDMA-based systems (like CDMA2000), it is also referred to as wideband **CDMA** or **WCDMA**



UMTS Speech Services

- UMTS uses Adaptive Multirate (AMR) speech coder
 - a standardized speech coding algorithm operating at eight bit rates in the range of 4.75 to 12.2 kbps and was specifically designed to improve network link strength
- UMTS provide the packet-switching services but voice remains circuit-switch like GSM and GPRS



UMTS Speech Services

- UMTS uses Adaptive Multirate (AMR) speech coder
 - AMR was initially developed for GSM systems
 - was standardized by ETSI and **adopted by the 3GPP** as the mandatory codec for 2.5G and 3G wireless systems based on the evolved GSM core network



WCDMA

- Wideband CDMA
- Proposed by Ericsson
- Channel spacing is **5MHz**
- In WCDMA multiple users send their data simultaneously using different chip rates (3.84×10^6 chips/second)



WCDMA

- WCDMA Chips
 - In CDMA, a bit's transmission time is subdivided into m short intervals called **chips**. Typically there are 64 or 128 chips per bit.
 - Each base station is assigned a unique m -bit chip sequence
 - To transmit a 1 bit, a station sends its chip sequence. To transmit a 0 bit, it sends the one's complement of its chip sequence. No other patterns are permitted.
 - For example for $m = 8$, if station A is assigned the chip sequence 00011011, it sends a 1 bit by sending 00011011 and a 0 bit by sending 11100100.

As such multiple users can transmit (and receive) data through the use of transmitted codes on a CDMA network

WCDMA

- **Direct Sequence Spread Spectrum (DSSS)**
 - DSSS multiplies the data bits by a very fast pseudo-random bit pattern (PN sequence) that "spreads" the data into a large coded stream that takes the full bandwidth of the channel
DSSS is the basis for **CDMA cellphones** and **802.11 Wi-Fi** wireless transmission.



FHSS

- **Frequency Hopping Spread Spectrum (FHSS)**

- A transmission technology in which the data signal is modulated by a narrowband signal which changes frequency ("hops") over a wide band of frequencies.
- The hopping seems random but is prescribed by an algorithm known to the receiving system.
- Because a fixed frequency is not used, illegal monitoring of spread spectrum signals is highly difficult.
- FHSS is the transmission technology in **Bluetooth**.



FHSS vs DSSS

- The difference between FHSS and DSSS is their different ways of transmitting the information into a wider bandwidth.
- They both utilize spread spectrums, however with different processes: FHSS uses the process of “hopping” while DSSS connects the signals through **pseudo-noise** (i.e. the inclusion of a unique code to the data)



WCDMA (3G)

- WCDMA – FDD (Frequency Division Duplexing)
 - method for establishing a **full-duplex** communication link that uses two different radio frequencies for the transmitter and the receiver
- WCDMA – TDD (Time Division Duplexing)
 - Full-duplex communication using time (slots) rather than frequency, whereby separate timeslots are used for the transmission and reception of the signals



CDMA2000 (3G)

- Proposed by Qualcomm
- 5 MHz **bandwidth** (channel spacing)
- Doesn't inter-network with GSM (no handoff to GSM)

- US: **IS-95 (cdmaOne) switched to CDMA2000** ... Qualcomm
- Europe: **GSM switched to WCDMA** ... Ericsson



CDMA2000 (3G)



- Better migration story from 2G to 3G (than GSM and WCDMA)
 - cdmaOne operators don't need additional spectrum (frequency changes)
 - claimed 3x higher data rates than UMTS, i.e. WCDMA
- Has better spectral efficiency than WCDMA

WCDMA (UMTS) continued



- WCDMA was the committed standard for Europe and the migration path for GSM operators
 - **utilized GSM's dominant position**, as such WCDMA became a dominant 3G Network technology
- Legally mandated in Europe and elsewhere

Mobile Wireless Spectrum



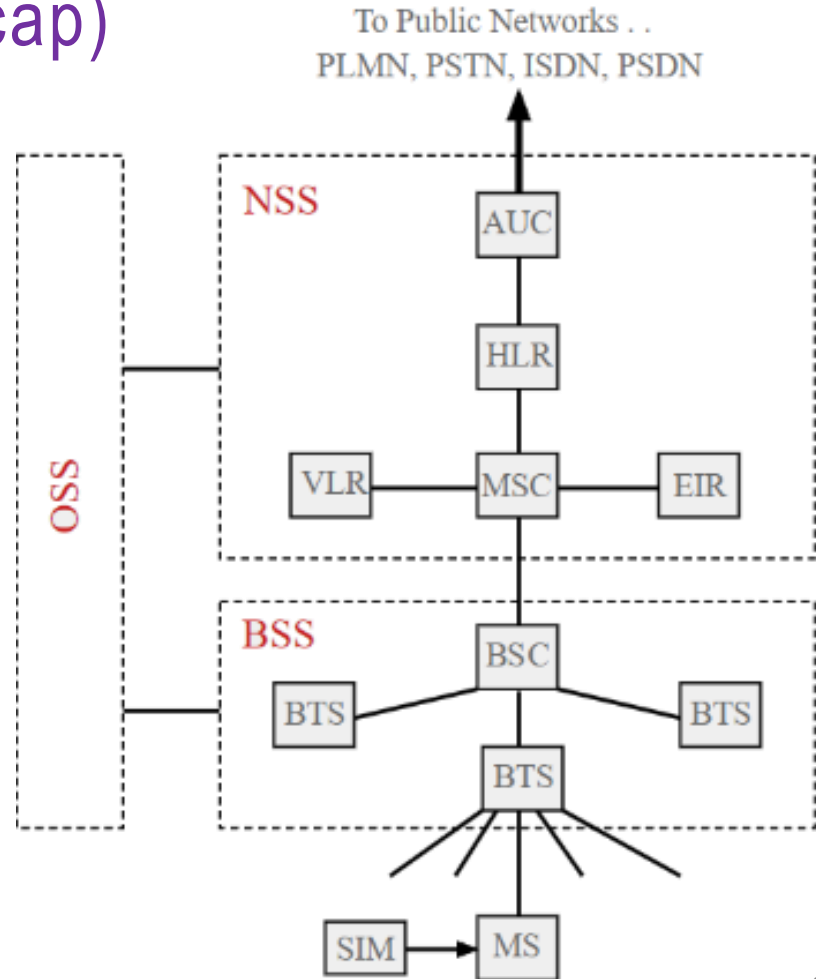
Bands (MHz)	Frequencies (MHz)	Regions	GSM/ EDGE	WCDMA	CDMA2000
450	450-467	Europe	x		x
480	478-496	Europe	x		
800	824-894	America	x		x
900	880-960	Europe/APAC	x		x
1500		Japan PDC			x
1700	1750-1870	Korea			x
1800	1710-1880	Europe/APAC	x	x	x
1900	1850-1990	America	x	x	x
2100	1885-2025 & 2100-2200	Europe/APAC		x	x
2500	2500-2690	ITU Proposal			x

*Note that initially WCDMA uses frequency bands that are **5MHz** wide, while CDMA2000 used bands that are **1.25MHz** wide (regarding channel spacing)*

GSM - 2G Architecture (Recap)



- **NSS**
 - MSC - Mobile Switching Controller
 - VLR - Visitor Location Register
 - HLR - Home Location Register
 - AuC - Authentication Center
- **BSS**
 - BTS - Base Transceiver Station
 - BSC - Base Station Controller
 - MS - Mobile Station
- **OSS**
 - OMC - Operation and maintenance center
 - Operator dependent various setups



GPRS – 2.5 G Architecture (Recap)

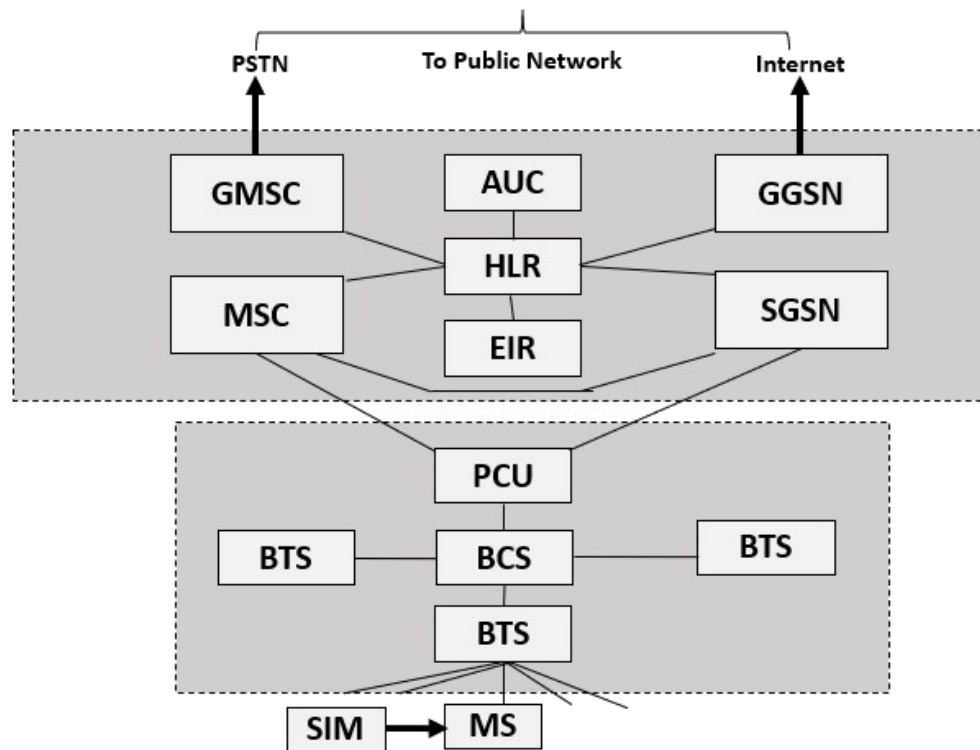


- **Gateway GPRS Support Node (GGSN)**

- connects GPRS and the Internet

- **Serving GPRS Support Node (SGSN)**

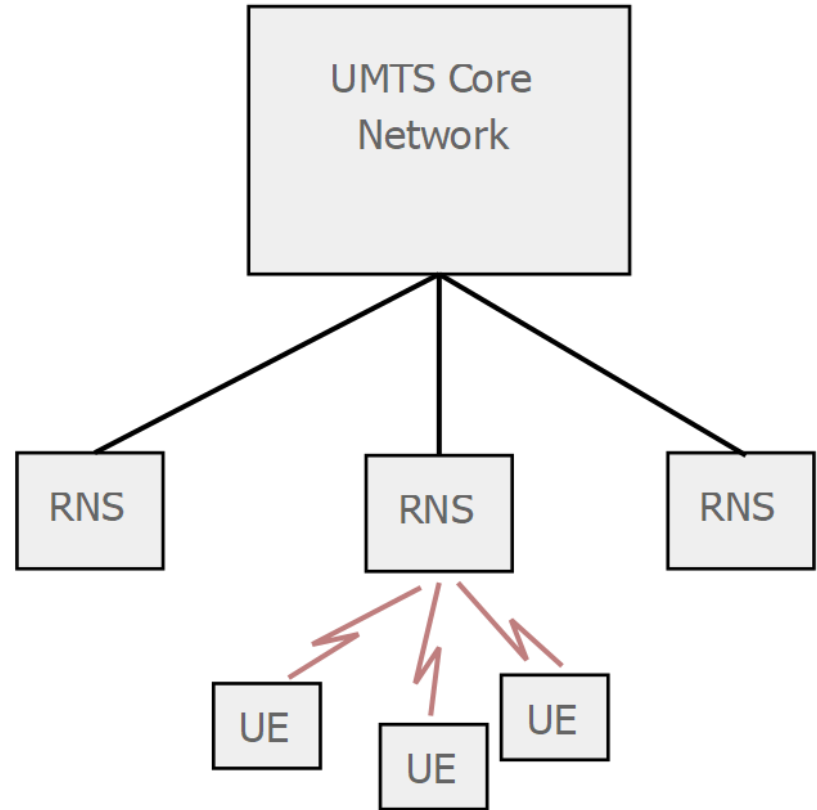
- provides packet switching, security and authentication for GPRS users



many components of a GSM network are used within a GPRS network with some additionally components

WCDMA – 3G Architecture

- Subsystems:
 - UMTS Core Network
 - Radio Network Subsystem

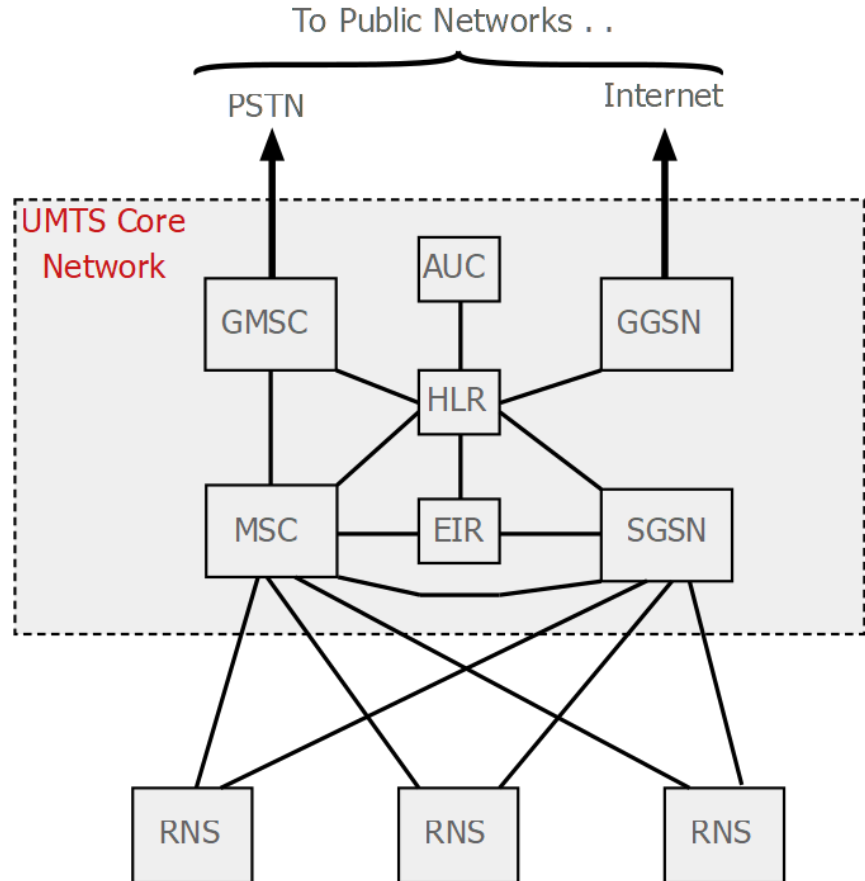


WCDMA – 3G Architecture

■ UMTS Core Network

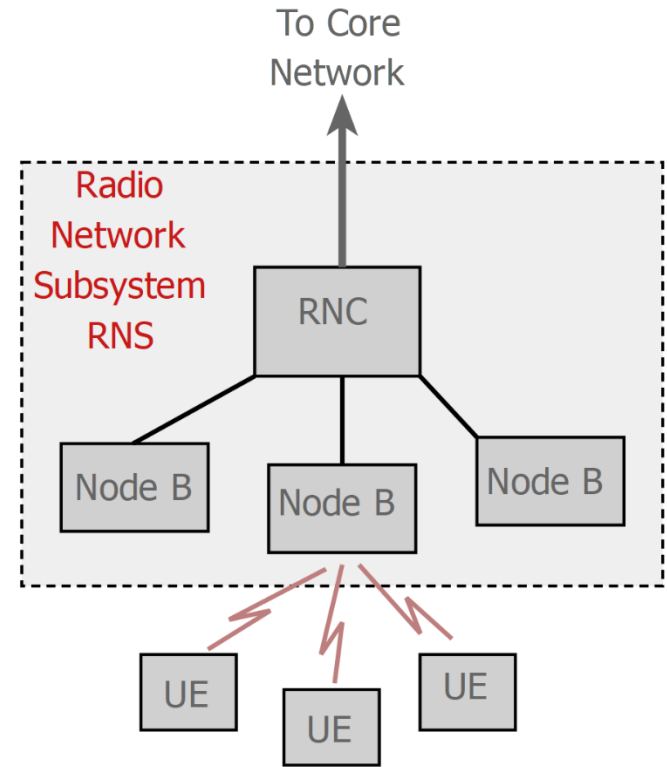
Has similar components of GSM / GPRS NSS with similar functions:

- Controls setting up calls and controls handoffs
- connecting to other MSCs
- connecting the wireless network with other networks (such as telephone networks and the Internet)



WCDMA – 3G Architecture

- **Radio Network Subsystem (RNS)**
 - Radio Network Controller (RNC)
 - Responsible for controlling the Node Bs, encrypts data before it is sent to a UE
 - Node B
 - WCDMA/UMTS term for a **radio base station receiver**, as defined by the 3GPP. It provides radio coverage and converts data between the radio network and the RNCs



*ie RNC operates like a BSC (from GSM)
and a Node B operates like a BTS (from GSM)*

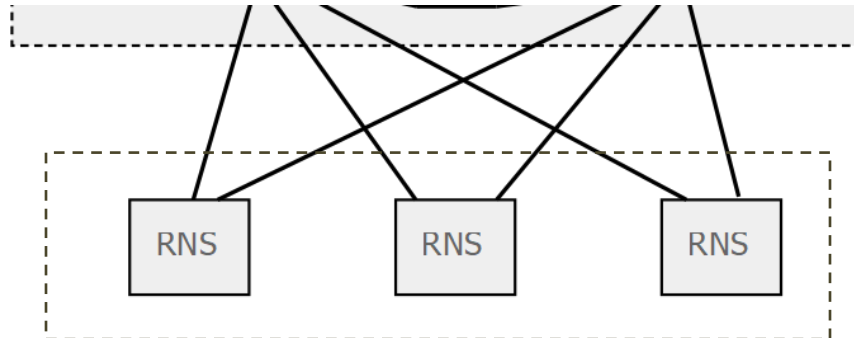


WCDMA – 3G Architecture

- **Radio Network Subsystem (RNS) and UTRAN**

- The UMTS Terrestrial Radio Access Network (**UTRAN**)

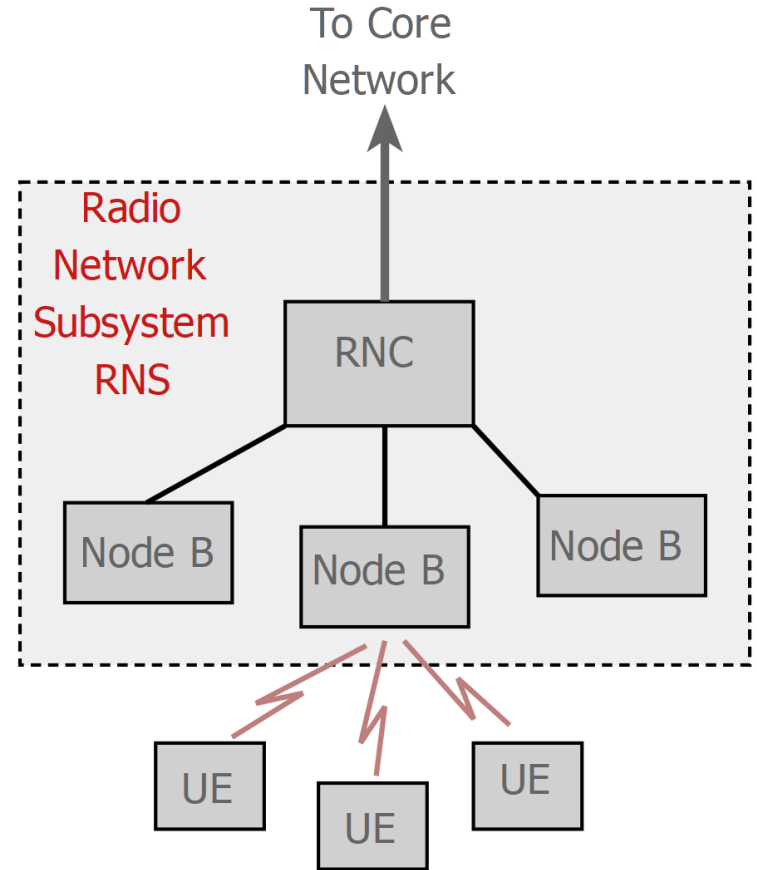
- consists of one or more RNS (Radio Network Subsystem). Each RNS control the allocation and the release of specific radio resources to establish a connection between a UE (User Equipment) and the UTRAN.



WCDMA – 3G Architecture

- **User Equipment (UE)**

- The name given to what was previous termed the mobile station, mobile, or cellphone



WCDMA - 3G Media Gateway



- **Media gateway**

- translation device or service that converts media streams between different technologies such as SS7, 2G, 2.5G and 3G radio access networks or PBX systems

- Media gateways (such as GMSC and GGSN) enable communications across packet networks by converting information between different transmission and coding techniques

3G Partnership Project (3GPP) – Releases

3GPP continuously updates with releases that contain new features:

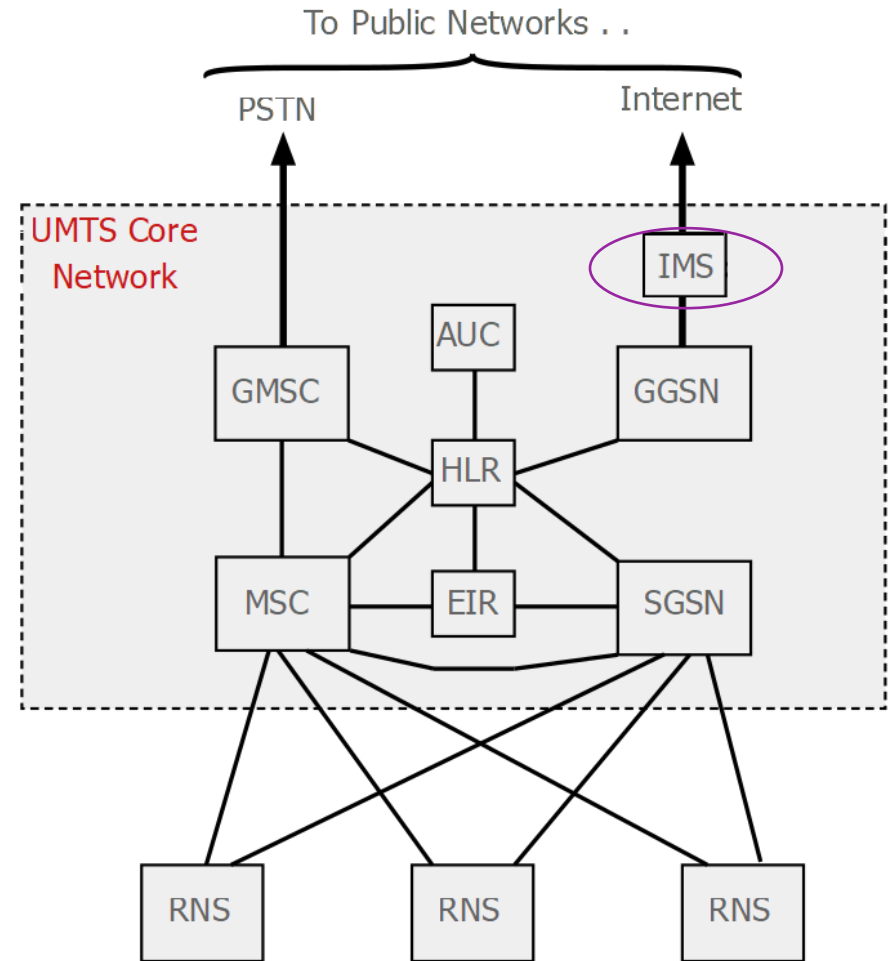
- **3GPP Release 96** (named after the year 1996)
 - Q1 1997
 - GSM Updates, 14.4 kbps user data rate

- **Release 97**
 - Q1 1998
 - GSM additional features, inclusion of GPRS

Note: our scope will focus on specific 3GPP releases, use the link below for more information on all 3GPP releases: <https://www.electronics-notes.com/articles/connectivity/3gpp/standards-releases.php>

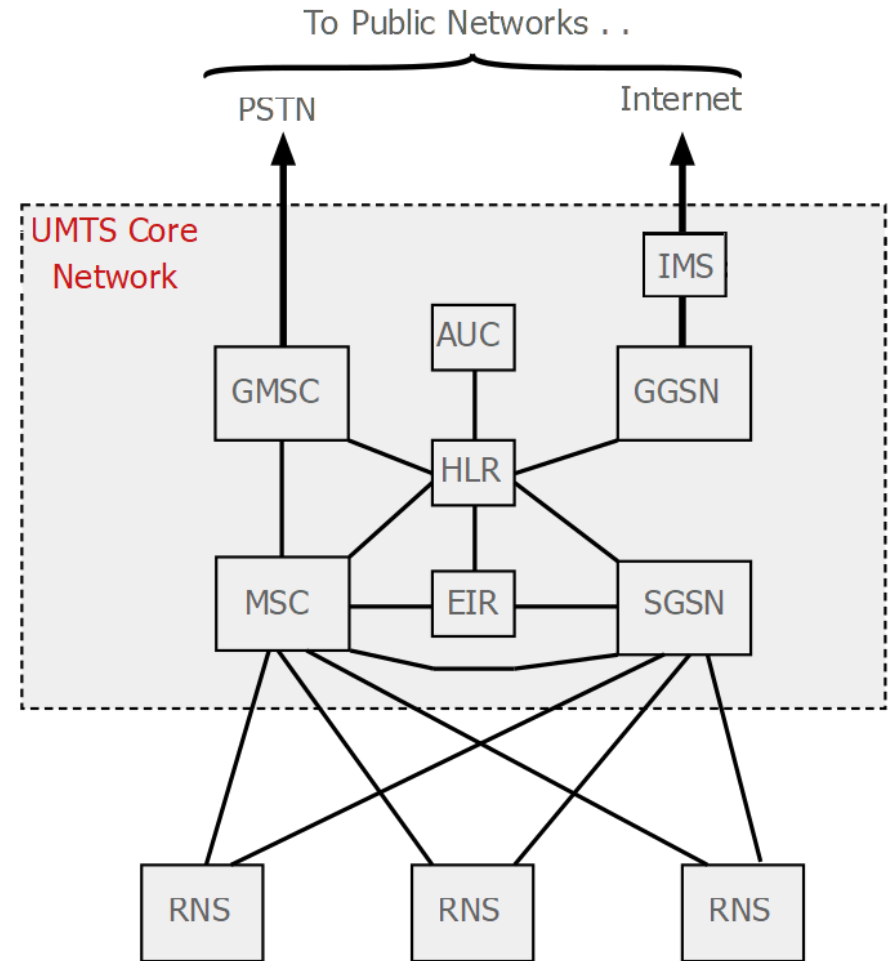
3GPP – Releases

- **3GPP Release 4**
 - Q2 2001
 - UMTS all-IP Core Network
- **3GPP Release 5**
 - Q1 2002
 - Inclusion of **IMS** and **HSDPA**



3GPP – Releases

- IP Multimedia Subsystem (IMS)
 - the standard for a telecommunication system which controls multimedia services across different networks
 - The IP Multimedia Subsystem is based on the All-IP network
 - IMS connects the Internet to cellular network for an all IP core network



3.5G (HSPA)



- High Speed Packet Access (HSPA)
 - a combination of two mobile telephony protocols
 - High Speed Downlink Packet Access (HSDPA)
 - and High Speed Uplink Packet Access (HSUPA)

 - extends and improves the performance of existing WCDMA protocols

 - 3.5G introduces new features that enhances the UMTS
 - HSDPA allowed data rate speeds reaching 3.6Mbps and 7.2Mbps (depending on mobile operator)

3G Mobile Services



- SMS, EMS, MMS
 - Introduction of Enhanced Messaging Service (EMS)
 - and Multimedia Messaging Service (MMS)
- Location-based services
 - UEs with location information and location requests
- 3G-324M Video
 - 3G support of video clips, video streaming and live video conversations
 - Deployed by DoCoMo in Japan

**Exercise: find out the difference between EMS and MMS*

3G Mobile Services



- VoIP w/o QoS; Push-to-Talk
- IP Multimedia Services (w/ QoS)
 - Voice and video over IP with quality of service guarantees
 - IP Multimedia Subsystem (IMS) – 3GPP
 - Multi-Media Domain (MMD) – 3GPP2

**Exercise: find out more about 3G VOIP (w/o QoS), Push-to-Talk and IP Multimedia Services (w/ QoS)*

3GPP – Releases

- **3GPP Release 8**
 - Q4 2008
 - **Introduction of LTE (4G Networks)**

- **3GPP Release 15**
 - Q4 2018
 - **5G Phase 1 Specification**

- **3GPP Release 16**
 - Q2 2020
 - **5G Phase 2 Specification**

As of December 2020:

- More 5G system enhancements are set to follow in 3GPP Release 17



3G Networks Shutting Down



- **Carriers are shutting down older 3G networks (2021)**
 - As a result of this, older phones will no longer be usable, eventually
 - Other UE affected:
 - cars with 3G systems
 - security cameras and other devices.

3G Networks Shutting Down



- Carriers are shutting down older 3G networks (cont.)
 - Phone companies (carriers) have to keep up with the latest technology
 - carriers don't want to maintain older technologies that aren't used much.
 - Older equipment costs money to maintain, and use space that can be better utilized for newer hardware.
 - Removing older equipment makes space for 5G equipment and simplifies network management
 - Additionally some 3G spectrum can be better used for 4G data