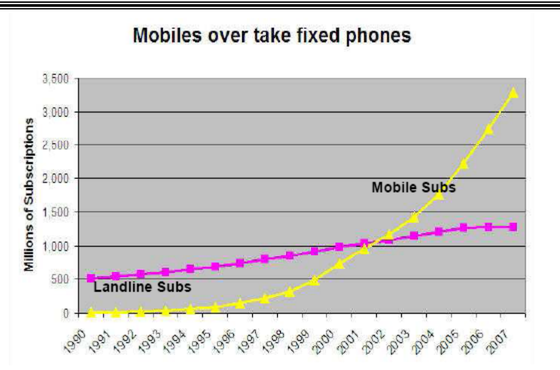
3G: UMTS overview

David Tipper
Associate Professor

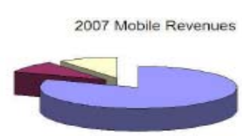
Graduate Telecommunications
and Networking Program
University of Pittsburgh
2700 Slides 8

3G Driving Factors

- Subscriber base continues to grow 1 billion wireless subscribers in 2002 (surpassed Landline)
- Predict 3 billion by 2008



800 Billion Mobile Revenues 2007
81%Voice, SMS 9.5%, All Other non-voice 9.5%



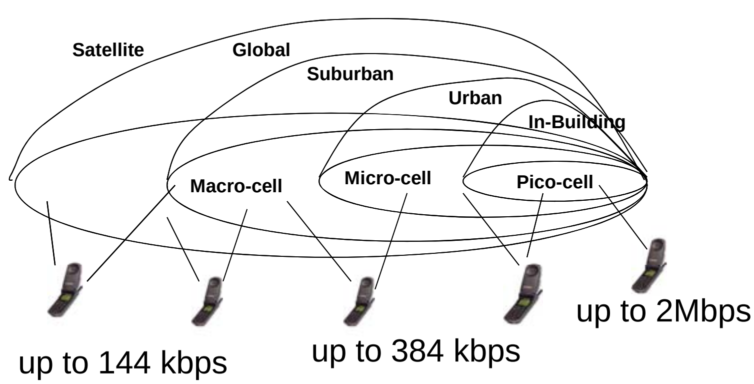
Source: Portio Research

3G Development

- 1986 ITU began studies of 3G as:
  - Future Public Land Mobile Telecom. Systems (FPLMTS)
  - 1997 changed to IMT-2000 (International Mobile Telecom. in Year 2000)
  - ITU-R studying radio aspects, ITU-T studying network aspects (signaling, services, numbering, quality of service, security, operations)
- IMT-2000 vision of 3G
  - *1 global* standard in *1 global frequency band* to support wireless data service
  - Spectrum: 1885-2025 MHz and 2110-2200 MHz worldwide
  - Multiple radio environments (phone should switch seamlessly among cordless, cellular, satellite)
  - Support for packet switching and asymmetric data rates
- Target data rates for 3G
  - Vehicular: 144 kbps
  - Pedestrian: 384 kbps
  - Indoor office: 2.048 Mbps → roadmap to > 10Mbps late
- Suite of four standards approved after political fight

3G Requirements

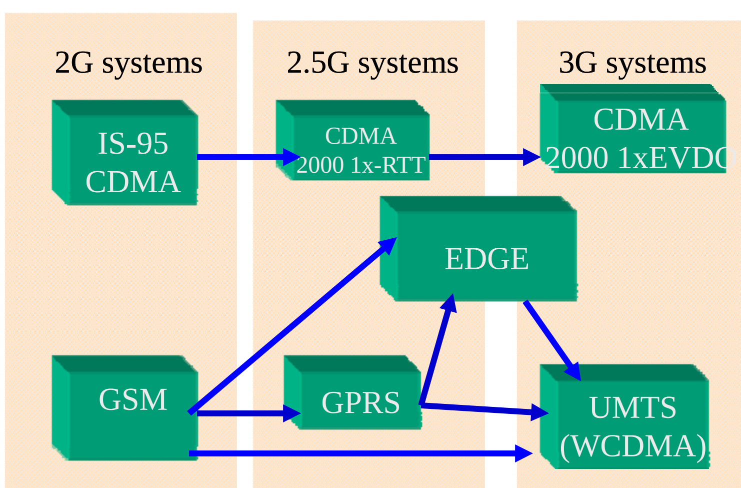
Seamless End to End Service with different data rates



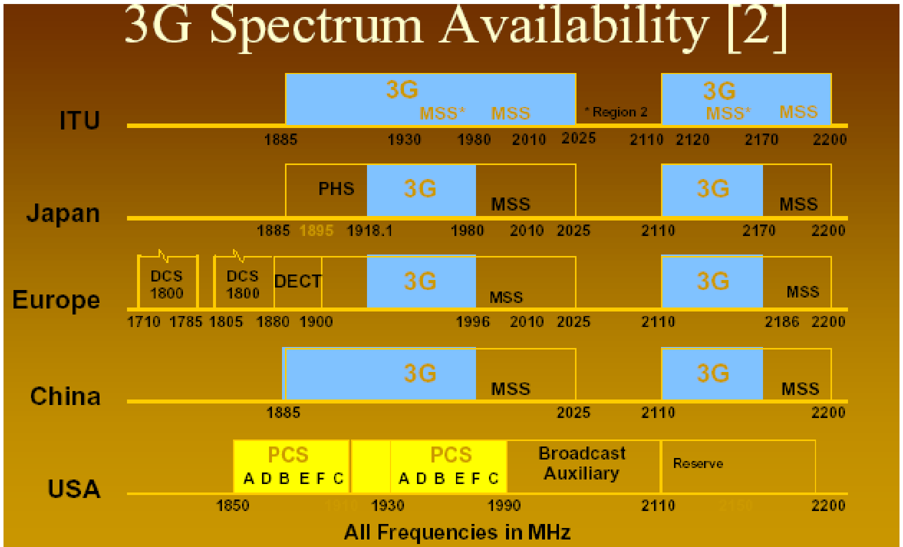
Third Generation Standards

- ITU approved suite of four 3G standards
- EDGE (Enhanced Data rates for Global Evolution)
  - TDMA standard with advanced modulation and combined timeslots
  - Provides unification of NA-TDMA and GSM
  - Only meets some of the 3G requirements (2.75G?)
- UMTS (Universal Mobile Telephone Service) also called WCDMA (wideband CDMA)
  - Dominant standard outside of US and leading standard for 3G worldwide
  - Viewed as 3G migration path for GSM/GPRS/EDGE systems
- CDMA 2000
  - Also called (3X and cdma three): competes directly with W-CDMA up to 2 Mb/s
  - Evolutionary path for IS-95 which is the dominant standard in the US
- TD-SCDMA : Stand alone standard developed in China

Evolution Path to 3G



3G Spectrum Allocations



Diverse 3G Spectrum

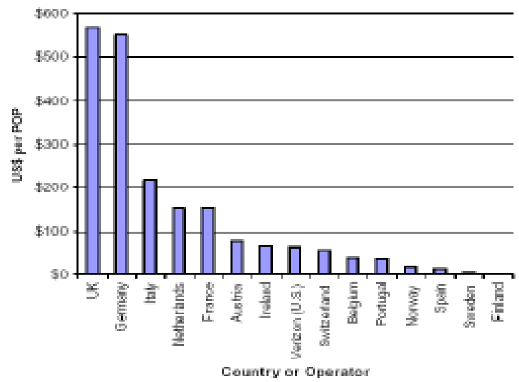
Bands	Frequencies (MHz)	Regions	GSM/ EDGE	UMTS/ 3GSM	CDMA 2000	TD-SCDMA
NMT/CDMA 450	460-493	EU, global			X	
GSM 450	450-467	EU, global	X			
GSM480	478-496	EU, global	X			
GSM 850 & CDMA 850	869-894	US	X		X	
GSM 900	925-960	EU, global	X			
DCS 1800	1805-1880	EU, global	X			
PCS 1900	1930-1990	US	X	X	X	
IMT 2000	1920-1980 & 2110-2170	EU, global		X		
China 3G	1880-1920 & 2010-2025 & 2300-2400	China				X
AWS	1710-1755 & 2110-2155	US		X	X	
700 MHz	746-764 & 776-794	US		X	X	
ITU Proposal	2500-2690	EU, global		X		

3G Spectrum Cost

Exhibit 1.11

COST OF 3G FREQUENCY PER POP

Country or Operator	Spectrum Cost / POP
UK	$570
Germany	$551
Italy	$218
Netherlands	$153
France	$152
Austria	$77
Ireland	$65
Verizon (U.S.)	$63
Switzerland	$55
Belgium	$39
Portugal	$36
Norway	$18
Spain	$12
Sweden	$5
Finland	$0



Source: Spectrum Strategy Consultants and QUALCOMM

Current status of 3G

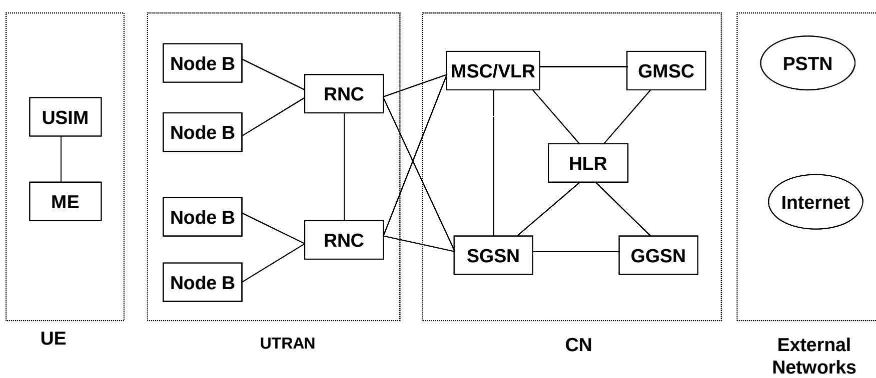
- Two partnership projects to harmonize and standardize the two main 3G standards
  - 3GPP that deals with the UMTS standard
    - http://www.3gpp.org
  - 3GPP2 that deals with the US cdma2000 proposal
    - http://www.3gpp2.org
  - 3G spectrum allocated in over 100 countries
    - spectrum not consistent throughout the world
  - Deployments occurring slower than expected
    - Service providers strapped for cash (spectrum expensive)
    - Equipment delays
    - Many carriers going went with 2.5 G first to build data market
- Subscribers (2Q 2008)

18% 3G, 82% 2G or 2.5G, 0.01% 1G
~30% 3G penetration rate in USA
GSM /GPRS/EDGE/UMTS 88% of all mobiles worldwide

UMTS

- Universal Mobile Telecommunication Services
- Often Called GSM 3
- UMTS is a complete system architecture
  - As in GSM emphasis on standardized interfaces
    - mix and match equipment from various vendors
  - Simple evolution from GPRS – allows one to *reuse/upgrade* some of the GPRS backhaul equipment
  - Backward compatible handsets and signaling to support intermode and intersystem handoffs
    - Intermode; TDD to FDD, FDD to TDD
    - Intersystem: UMTS to GSM or UMTS to GPRS
  - UMTS supports a variety of user data rates and both packet and circuit switched services
  - System composed of three main subsystems

UMTS System Architecture

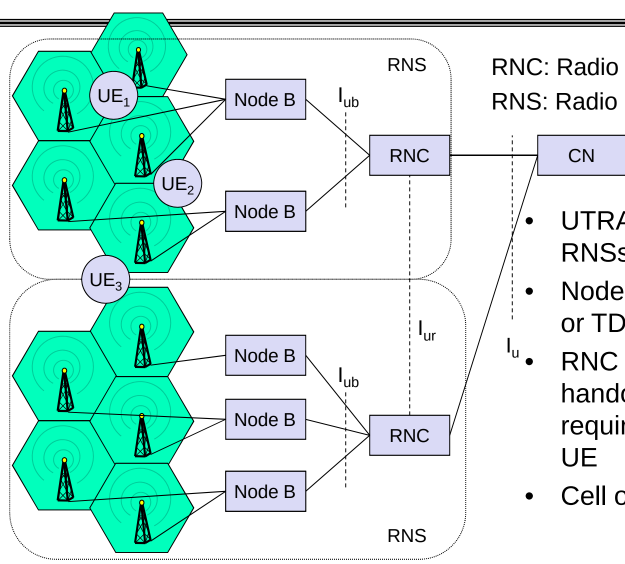


- UE (User Equipment) that interfaces with the user
- UTRAN (UMTS Terrestrial Radio Access Network) handles all radio related functionality – WCDMA is radio interface standard here.
- CN (Core Network) is responsible for transport functions such as switching and routing calls and data, tracking users

UMTS System Architecture

- UE
  - ME (Mobile Equipment)
    - is the single or multimode terminal used for radio communication
  - USIM (UMTS Subscriber Identity Module)
    - is a smart card that holds the subscriber identity, subscribed services, authentication and encryption keys
- UTRAN
  - Node B (equivalent to BTS in GSM/GPRS)
    - performs the air interface processing (channel coding, rate adaptation, spreading, synchronization, power control).
    - Can operate a group of antennas/radios
  - RNC (Radio Network Controller) (equivalent to GSM BSC)
    - Responsible for radio resource management and control of the Node Bs.
    - Handoff decisions, congestion control, power control, encryption, admission control, protocol conversion, etc.

UTRAN architecture



RNC: Radio Network Controller
RNS: Radio Network Subsystem

- UTRAN contains several RNSs
- Node B can support FDD or TDD or both
- RNC is responsible for handover decisions requiring signalingto the UE
- Cell offers FDD or TDD

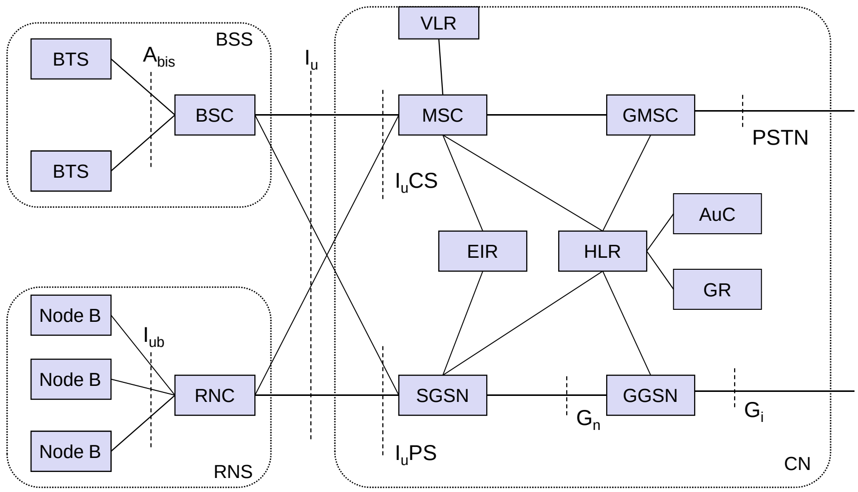
UMTS System Architecture

- Core Networks (CN)
  - *HLR (Home Location Register)*
    - database located in the user's home system that stores the master copy of the user's service profile. The HLR also stores the UE location on the level of MSC and SGSN,
  - *3G MSC / VLR*
    - Switch and database that serves the UE in its current location for Circuit Switched (CS) services. The MSC function is used to switch the CS transactions, and VLR function holds a copy of the visiting user's service profile, as well as more precise information on the UE's location within the serving system.
  - *3G GMSC (Gateway MSC)*
    - Switch at the point where UMTS is connected to external CS networks. All incoming and outgoing CS connections go through GMSC.
  - *3G SGSN (Serving GPRS Support Node)*
    - Similar to that of MSC / VLR but is used for Packet Switched (PS) services. The part of the network that is accessed via the SGSN is often referred to as the PS domain. Upgrade version of serving GPRS support node.
  - *3G GGSN (Gateway GPRS Support Node)*
    - Functionality is close to that of GMSC but is in the relation to PS services. Upgraded version of gateway GPRS support Node

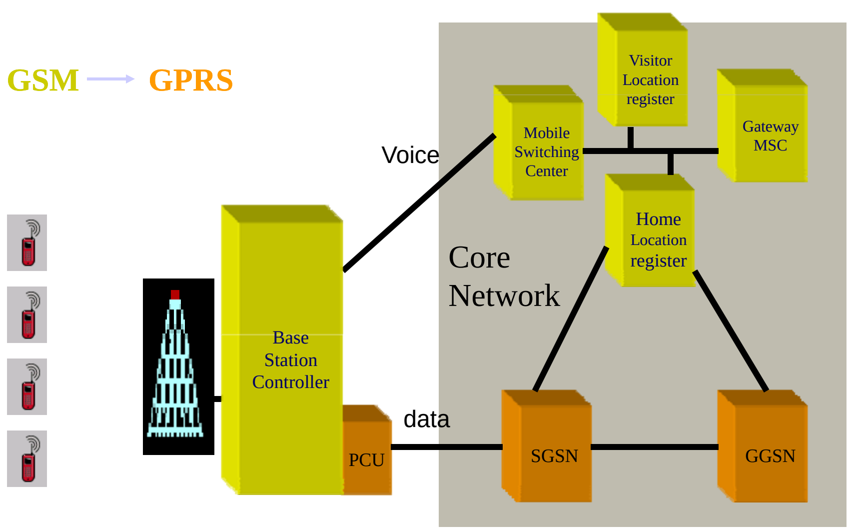
Core network

- The Core Network (CN) and the Interface I_u are separated into two logical domains:
- Circuit Switched Domain (CSD)
  - Circuit switched service including signaling
  - Resource reservation at connection setup
  - 3G versions of GSM components (MSC, GMSC, VLR, HLR)
  - I_uCS
- Packet Switched Domain (PSD)
  - Handles all packet data services
  - 3G versions of GPRS components (SGSN, GGSN)
  - I_uPS
- General approach of building on GSM/GPRS infrastructure ,helps to saves $ and faster deployment

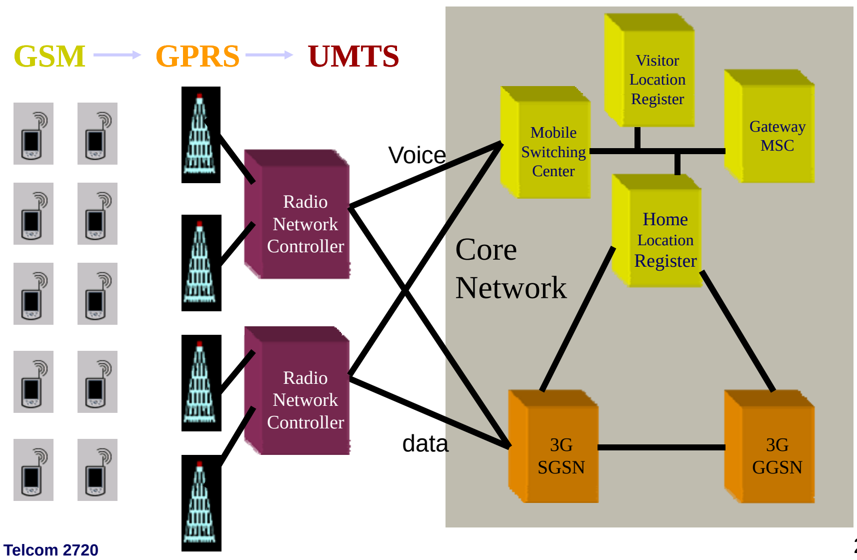
Core network: architecture



GSM → GPRS Evolution



GSM → GPRS → UMTS Evolution



WCDMA

- Wideband Code Division Multiple Access (WCDMA)
  - The air radio interface standard for UMTS
  - Wideband direct sequence spread spectrum
  - Variable orthogonal spreading for multiple access (OVSF)
- Three types of interface：
  - FDD: separate uplink/downlink frequency bands with constant frequency offset between them
  - TDD: uplink/downlink in same band but time-shares transmissions in each direction
  - Dual mode :supports FDD and TDD
- Wide range of data rates due to CDMA with variable spreading, coding and modes
  - Varying user bit rate is mapped to variable *power* and *spreading*
  - Different services can be mixed on a single carrier for a user

WCDMA

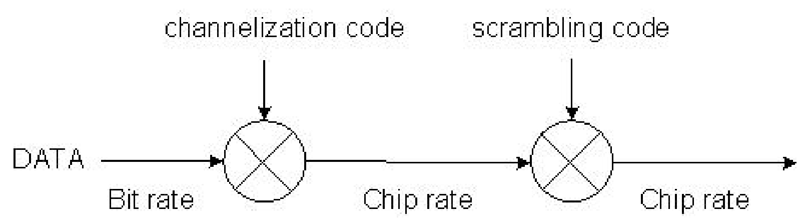
- 5-MHz Channel (25 GSM channels)
  - Each service provider can deploy multiple 5MHz carriers at same cell site
  - Each 5 MHz shared by multiple subscribers using CDMA
  - Maximum chip rate = 3.84 Mchips/sec
- Standard advantages of CDMA
  - Soft handoff
  - Frequency reuse cluster size of 1,
  - Better quality in multipath environment
  - RAKE receiver
- QPSK modulation

Scrambling and Channelization

- Channelization codes are orthogonal codes
  - Separates transmissions from the same source
  - Uplink: used to separate different physical channels from the same UE – voice and data session
  - Downlink: used to separate transmissions to different physical channels and different UEs
  - UMTS uses orthogonal variable spreading codes
- Scrambling (pseudonoise scrambling)
  - Applied on top of channelization spreading
  - Separates transmissions from different sources
  - Uplink effect: separate mobiles from each other
  - Downlink effect: separate base stations from each other

Physical Layer: Spreading

- Spreading of the low-bandwidth data signal to produce the wideband CDMA signal consists of two steps:
  - Channelization or spreading code to reach channel rate of 3.84 Mchips/s
  - Scrambling – to provide separation of transmissions



Channelization Spreading

UMTS uses variable spreading and power levels to provide different user data rates. In FDD mode 10 msec frames are used

The number of chips per bits is called the Spreading Factor (SF) and define the data service required for the user:

$$T_{bit} = SF \times T_{chip}$$

For UMTS:

Bit Rate x SF = 3.84 Mchips/s (Chip Rate)

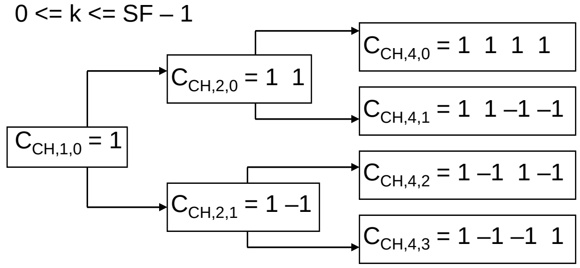
SF can change in every 10 msec frame

Service	Bearer Date Rate (kbps)	SF	Modulation Rate (Mchips/s)
Speech	30	128	3.84
Packet 64 kbps	120	32	3.84
Packet 384 kbps	960	4	3.84

WCDMA Variable Spreading

The channelization codes are Orthogonal Variable Spreading Factor codes that preserves the orthogonality between a user's different physical channels. The OVSF codes can be defined using a code tree.

In the code tree the channelization codes are uniquely described as $\mathbf{C_{CH,SF,k}}$ where SF is the Spreading Factor of the code and k is the code number, $0 <= k <= SF – 1$

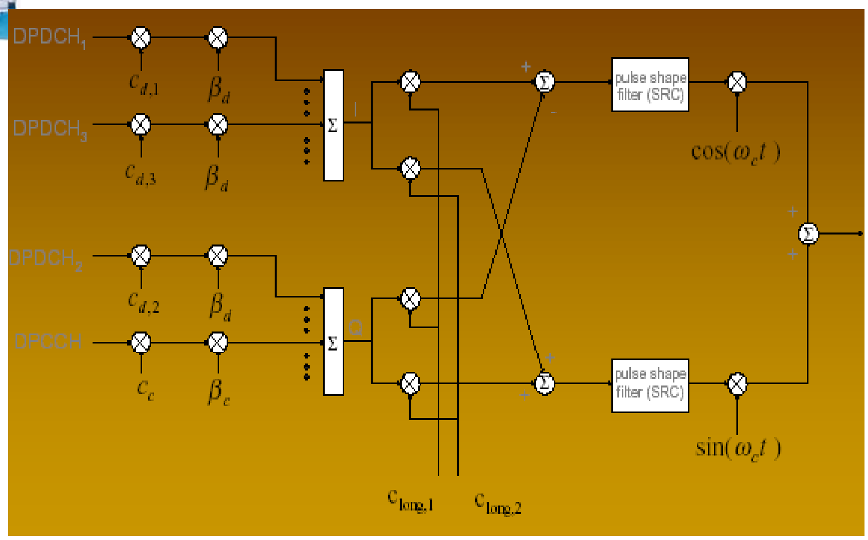


SF = 1 SF – 2 SF = 4 SF between 4 and 512 on DL between 4 and 256 on UL

Scrambling and Channelization Codes

	Channelization code	Scrambling code
Usage	Uplink: Separation of physical data and control channels from same terminal	Uplink: Separation of terminals
	Downlink: Separation of downlink connections of different users within one cell	Downlink: Separation of sectors (cells)
Length	4-256 chips (1.0-66.7 μs) Downlink also 512 chips	Uplink: 10 ms 38400 chips or 66.7 μs = 256 chips Downlink: 10 ms = 38400 chips
Number of codes	Number of codes under one scrambling code = spreading factor	Uplink: Several millions Downlink: 512
Code family	Orthogonal Variable Spreading Factor (OVSF)	Long: Gold code Short: Extended S(2) family
Spreading	Yes, increases transmission bandwidth	No, it does not affect transmission bandwidth

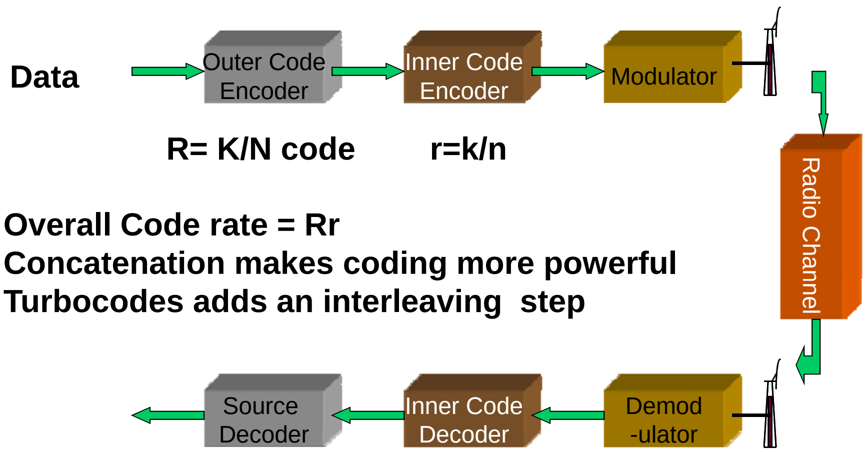
WCDMA QPSK Modulator



Turbocodes

- Used in 3G cellular (UMTS) standard
- TurboCode: Concatenation of codes with interleaving - followed by an *iterative* algorithm for decoding
- Instead of counting differences in bit positions, distance probabilities are used – pick max probability to decode word
- Iterative decoding allows one to tradeoff delay vs. accuracy

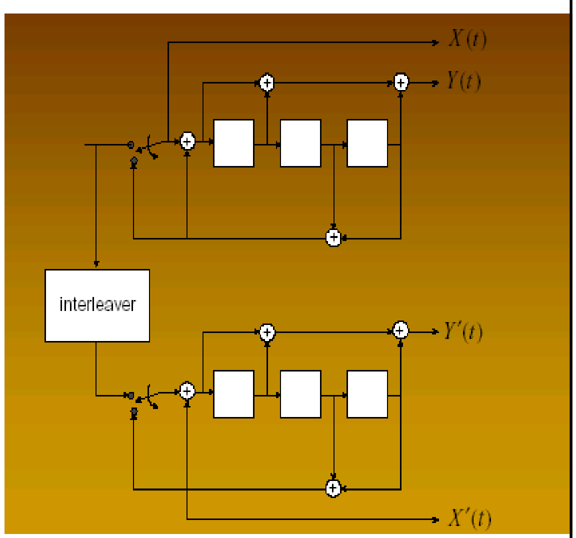
Concatenated Code System



Overall Code rate = Rr
Concatenation makes coding more powerful
Turbocodes adds an interleaving step

WCDMA Forward Error Control

- Convolutional Coding: for voice and control info
  - ½ rate and 1/3 rate codes with constraint length 8
- Block Interleave over 10, 20, 40, or 80 ms
- Turbo Coding for data and some control info
  - Two parallel rate 1/3 convolutional codes constraint length 3 with interleaving – block length 320 – 5120 bits
  - Iterative decoding to improve BER in poor channel environments.



Turbocode Performance

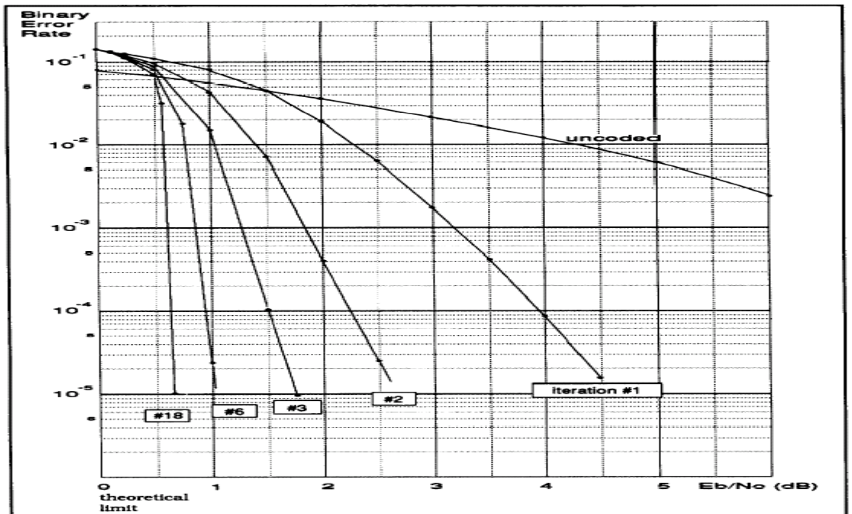
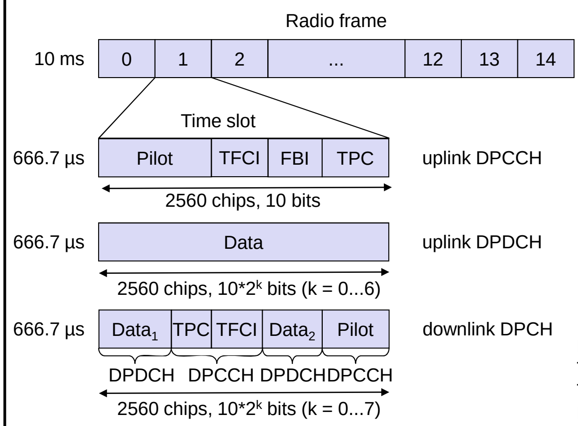


Fig. 5 Binary error rate given by iterative decoding (p=1,...,18) of code of fig. 2 (rate:1/2); interleaving 256x256.

WCDMA Parameters

Channel bandwidth	5.MHz
Downlink RF channel structure	Direct spread spectrum QPSK modulation
Chip rate	3.84 Mcps
Frame length	10ms/20ms (optional TDD mode)
Handover	Softer handover, soft handover and interfrequency handover

UMTS FDD frame structure

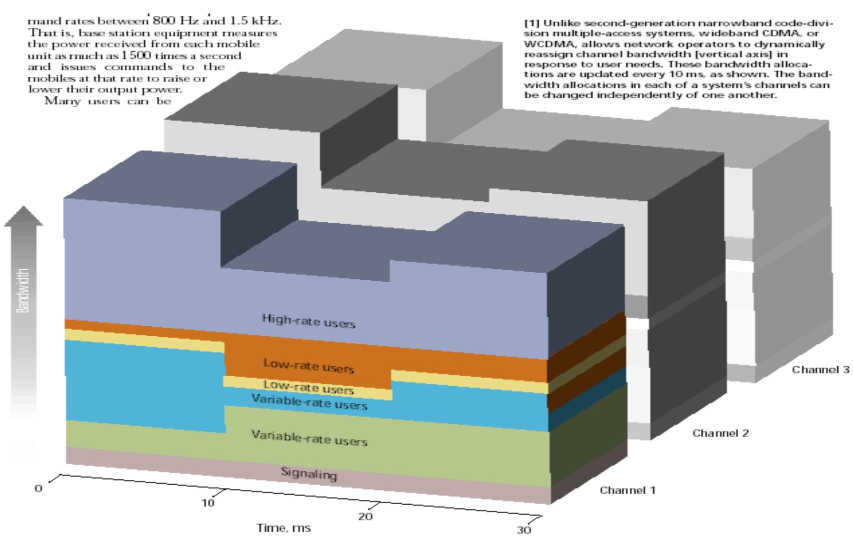


FBI: Feedback Information
TPC: Transmit Power Control
TFCI: Transport Format Combination Indicator
DPCCH: Dedicated Physical Control Channel
DPDCH: Dedicated Physical Data Channel
DPCH: Dedicated Physical Channel

Slot structure NOT for user separation but synchronisation for periodic functions!

UMTS

- Data rate adjusted every 10 msec by variable spreading and power



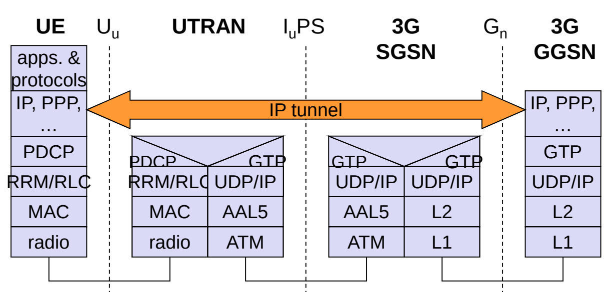
UMTS

- Protocol Stack
  - User Plane
    - Radio Link Control (RLC)
      - Presents a reliable channel to higher layers by retransmitting erroneous packets
    - Medium Access Control (MAC)
      - Channel access, multiplexing traffic streams, scheduling priority flows
    - Physical Layer
      - Measurements, power control algorithms
  - Control Plane
    - Radio Resource Control (RRC)
      - Connection and QoS management
    - Radio Resource Management (RRM)
      - Algorithms for admission control, handovers

UMTS protocol stacks (user plane)

Circuit Switched Domain — Uses same protocols as GSM

Packet Switched Domain Builds on GPRS Stack



RLC Functions

- Segmentation and reassembly
- Concatenation
- Padding
- Transfer of user data
- Error correction
- In-sequence delivery
- Duplicate detection
- Flow control
- Sequence number check (UM)
- Protocol error detection and recovery
- Ciphering
- Suspend/resume function for data transfer

MAC Functions

- Mapping of logical channels onto transport channels
- Selection of transport format for each transport channel
- Priority handling between data flows of one MS
- Priority handling between MSs by means of dynamic scheduling
- Identification of MSs on common transport channels
- Multiplexing/demultiplexing of higher layer PDUs into/from transport blocks to/from the physical layer
- Traffic volume monitoring
- Dynamic transport channel type switching
- Ciphering
- Access service class selection for RACH transmissions

MAC: Logical Channels

- Builds on GSM/GPRS structure
  - Control channels:
    - Broadcast control channel (BCCH)
    - Paging control channel (PCCH)
    - Dedicated control channel (DCCH)
    - Common control channel (CCCH)
    - random access channel (RACH)
  - Traffic channels:
    - Dedicated traffic channel (DTCH)
    - Common traffic channel (CTCH) (broadcast or multi-cast traffic)
  - Control and traffic channels are per UMTS frequency channel (5MHz channel) in fashion similar to cdmaone

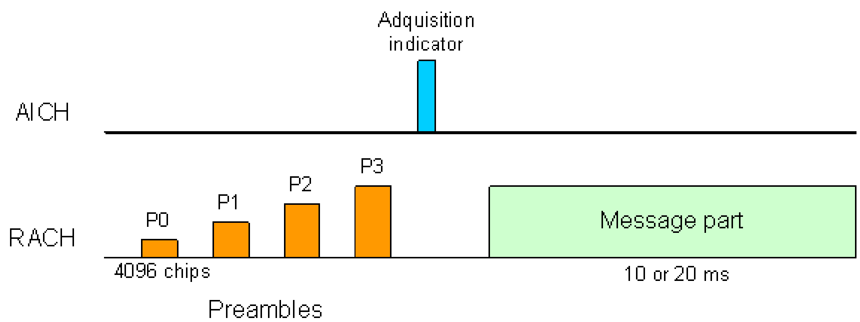
MAC Entities

- **MAC-b** handles the following transport channels:
  - broadcast channel (BCH)
- **MAC-c/sh** handles the following transport channels:
  - paging channel (PCH)
  - forward access channel (FACH)
  - random access channel (RACH)
  - common packet channel (UL CPCH). The CPCH exists only in FDD mode.
  - downlink shared channel (DSCH)
- **MAC-d** handles the following transport channels:
  - dedicated transport channels (DCH)

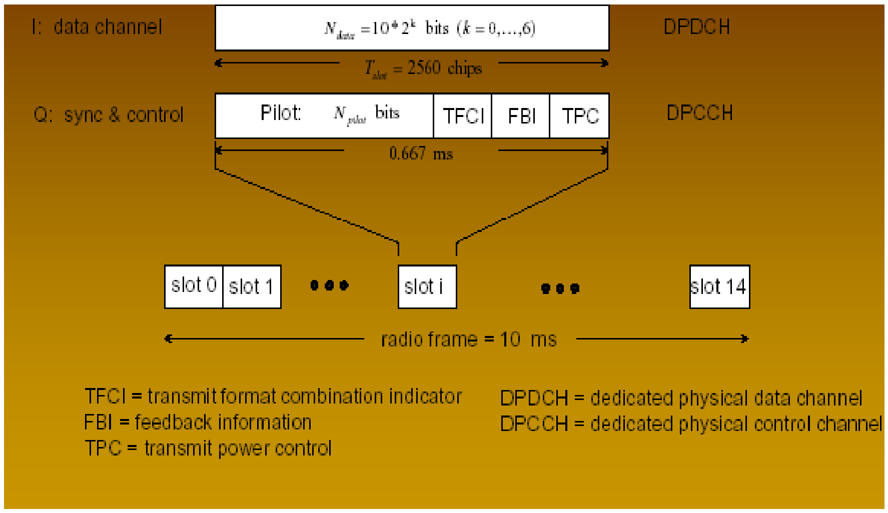
Physical Channels

- Primary Common Control Physical Channel (PCCPCH)
- Secondary Common Control Physical Channel (SCCPCH)
- Physical Random Access Channel (PRACH) (RACH in MAC layer)
- Dedicated Physical Data Channel (DPDCH)
- Physical Downlink Shared Channel (PDSCH)
- Physical Common Packet Channel (PCPCH)
- Synchronization Channel (SCH)
- Common Pilot Channel (CPICH)
- Acquisition Indicator Channel (AICH)
- Paging Indication Channel (PICH)
- CPCH Status Indication Channel (CSICH)
- Collision Detection/Channel Assignment Indicator Channel (CD/CA-ICH)

Physical Channels – Physical Random Access Channel (PRACH)

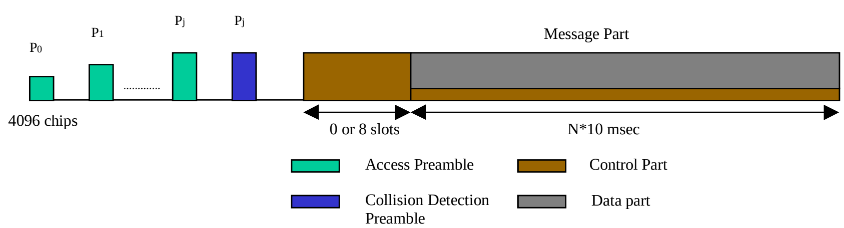


Physical Channels – Dedicated Uplink Physical Channel

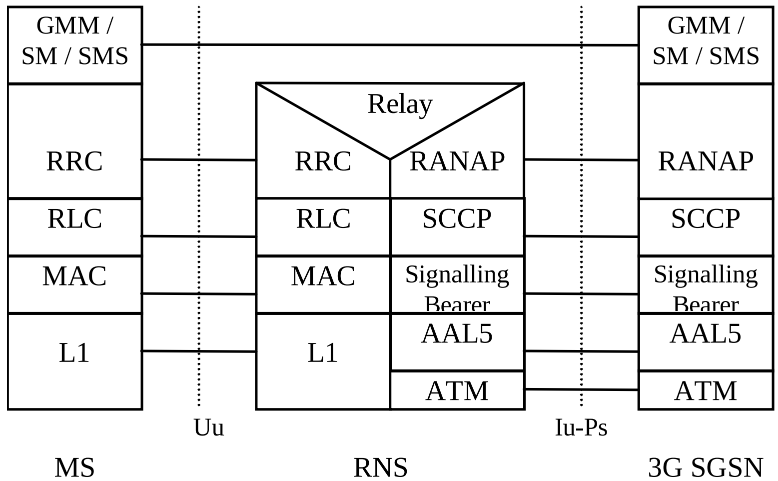


Physical Channels – Physical Common Packet Channel (PCPCH)

Uplink packet transmission



UMTS Architecture: Control Plane



[2]

RRC: Functions and Signaling Procedures

- Broadcast of information related to the non-access stratum (Core Network)
- Broadcast of information related to the access stratum
- Establishment, maintenance and release of an RRC connection between the UE and UTRAN
- Establishment, reconfiguration and release of Radio Bearers
- Assignment, reconfiguration and release of radio resources for the RRC connection
- RRC connection mobility functions
- Control of requested QoS
- UE measurement reporting and control of the reporting
- Outer loop power control
- Control of ciphering
- Paging
- Initial cell selection and cell re-selection
- Arbitration of radio resources on uplink DCH
- Timing advance (TDD mode)

UMTS Diversity

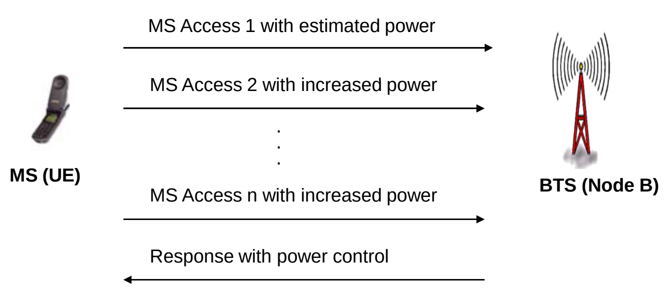
- UMTS – DS- CDMA support multi-path diversity
  - Note can tolerate a wider range of multi-path delay spread than IS-95 due to greater spreading
- UMTS supports macro-diversity.
  - Allows UE to transmit the same signal via 2 or more cells, in order to counteract interference problems.
- When macro-diversity is used, and when 2 cells are belonging to 2 Node Bs, that are belonging to 2 different RNCs, these RNCs have a specific functionality:
  - Serving RNC (SRNC): The SRNC is in charge of the radio connection between the UE and UTRAN.
  - Drift RNC (DRNC): A RNC, that supports the SRNC with radio resources when the connection between the UTRAN and the UE needs to use cell(s) controlled by this RNC, is referred to a Drift RNC.

Power Control

In order to maximize the cell capacity, it has to equalize the received power per bit of all mobile stations at all times.

Open loop power control

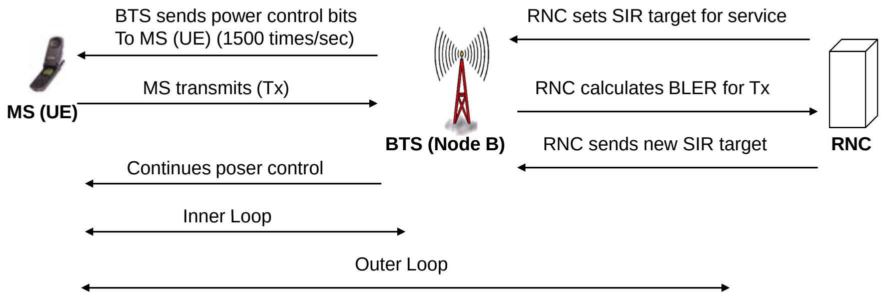
The initial power control is Open Loop. The MS (UE) estimates the power level based on the received level of the pilot from the BTS (Node B). If no response is received the MS waits a defined time and retransmits with a higher power level. The MS continues to do this until it receives a response.



Power Control

<u>Closed loop power control</u>

When communication is established, power is controlled by the Closed Loop Power Control.



Power Control

- The RNC sets the target BLER (Block Error Rate) level for the service.
  - RNC derives SIR (Signal to Interference Ratio) target from BLER, and sends it to the BTS.
- Uplink RNC performs frequent estimations of the received SIR and compares it to a target SIR.
  - If measured SIR is higher than the target SIR,
  - the base station will command the MS to lower the power:
  - If it is too low, it will command the mobile station to increase its power:
  - The measured-command-react cycle is executed a rate of 1500 times per second (1.5 KHz) for each mobile station (Inner Loop).
- The RNC calculates the SIR target once every 10 ms (or more depending on services) and adjusts the SIR target (Outer Loop).
- Downlink, same closed-loop power control technique is used but the motivation is different: it is desirable to provide a marginal amount of additional power to mobile stations at the cell edge, as they suffer increased adjacent cell interference.

QoS Classes/Services

Traffic class	Conversational	Streaming	Interactive	Background
Characteristics	Preserve time relation (variation) between information entities of the stream Conversational pattern (stringent and low delay)	Asymmetric applications More tolerant to jitter than conversational class. Use of buffer to smooth out jitter	Request response pattern Preserve data integrity	Destination is not expecting the data within a certain time Preserve data integrity
Application examples	Voice, video telephony, video games	Streaming multimedia	Web browsing, network games	Background download of e-mail, electronic postcard

Conversational Classes

Speech service

- Speech codec in UMTS employs a Adaptive Multi-rate (AMR) technique. The multi-rate speech coder is a single integrated speech codec with eight source rates: 12.2 (GSM-EFR), 10.2, 7.95, 7.40, 6.70, 5.90, 5.15, 4.75 kbps and 0 kbps.
- The AMR bit rates are controlled by the radio access network and not depend on the speech activity.
- For interoperability with existing cellular networks, some modes are the same as in existing cellular networks:

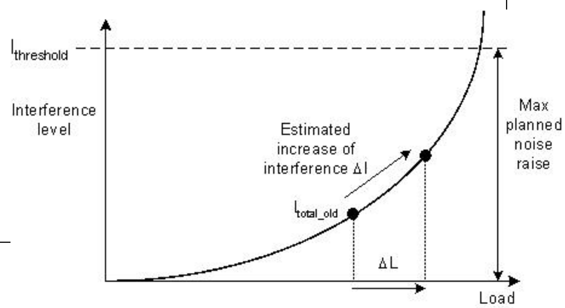
  12.2 kbps = GSM EFR codec

  7.4 kbps = North American TDMA speech codec

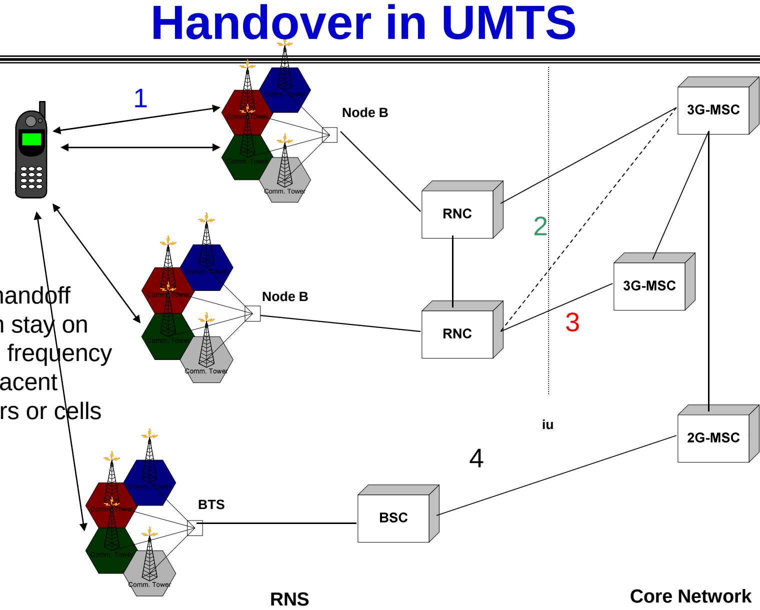
  6.7 kbps = Japanese PDC
- The AMR speech coder is capable of switching its rate every 20 ms speech frame upon command.

Admission Control

- Accepts or rejects requests to establish a radio access bearer
- Located at the RNC
- Estimates the load increase that the establishment of the radio access bearer would cause to the radio network
- Check is applied separately for uplink and downlink directions
- Radio access bearer will be accepted if admission control admits both uplink and downlink
- Example: Wideband power-based admission control



Handover in UMTS



Soft handoff
When stay on same frequency in adjacent sectors or cells

Types of UMTS Handoffs

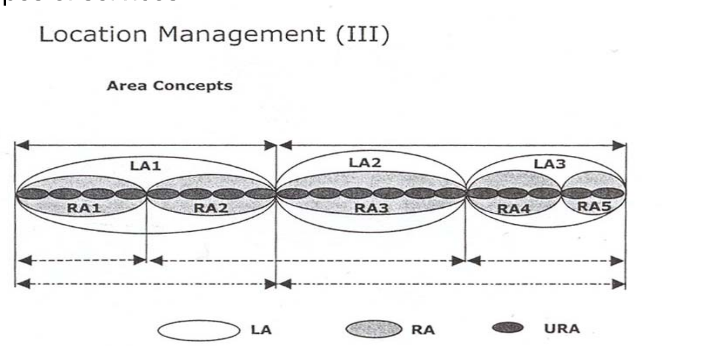
1. Intra RNC: between Node B's or sector of same Node B's attached to same RNC
2. Inter RNC: between Node B's attached to different RNC's, can be rerouted between RNC's locally if link , or rerouted by 3GMSC/SGSN, if RNC's in same service area
3. Inter 3GMSC/SGSN between Node B's attached to different
4. Inter System Handoff – between Node B and BTS along with a change of mode (WCDMA, GSM), (WCDMA, GPRS)

Note types 1,2, and 3 can be a Soft/Softer or Hard handoff, whereas, type 4 is always a Hard handoff

Location Management

Three types of location updating

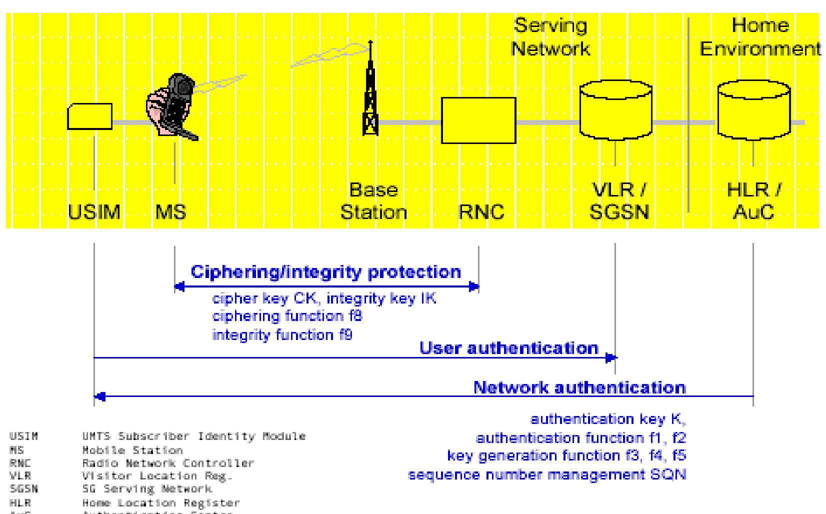
1. Location Area (LA)- zone registration as in GSM, plus can require periodic registration of users
2. Routing Areas (RA) – zone registration as in GPRS for packet based services
3. UTRAN Registration Areas (URA) – zone registration for certain types of services



UMTS Security

- UMTS Security Functions
  - Main security elements from GSM
  - Authentication of subscribers using challenge/response
  - Subscriber identity confidentiality (TMSI)
  - SIM card (call USIM)
  - Authentication of user to USIM by use of a PIN
  - Radio interface encryption
- UMTS enhancements/new features
  - Mutual authentication to protect against false base stations
  - New encrpytion/key generation/authentication algorithms with greater security
  - Encryption extended farther back into wired network (prevents eavesdropping on microwave relays)

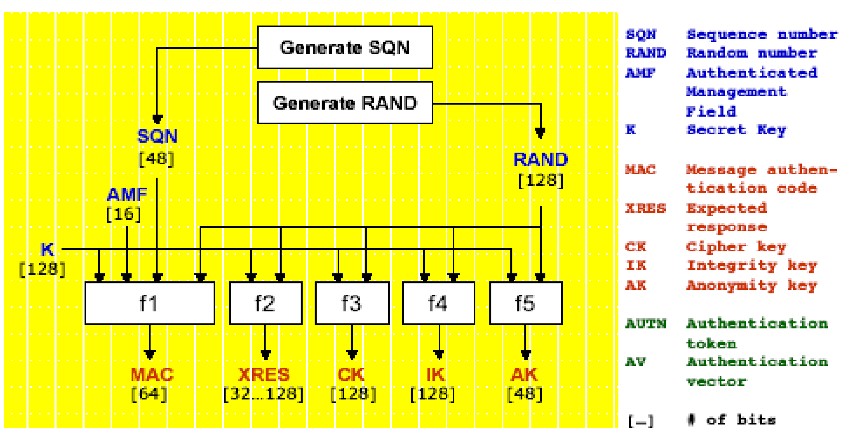
UMTS Security Architecture



UMTS Security

- UMTS authenticates and encrypts circuit switched and packet switched connections separately (even from same MS)
- AUC and USIM have 128 bit shared secret data
  - When authentication requested AUC generates a vector of 128 bit integrity keys (IK) using algorithm f4 with a 128 bit random number input RAND
- Authetication challenge is created using algorithm f9 with inputs:
  - Integrity Key
  - Direction of transmission (up or downlink)
  - 32 bit random number: FRESH
  - Hyperframe count (32 bits) – prevents replay attacks
  - Only RAND and FRESH and the correct response are transmitted over the air

UMTS Security



AUTN := SQN ⊕ AK || AMF || MAC

AV := RAND || XRES || CK || IK || AUTN

Security architecture at AUC

UMTS Security

• After authentication encryption provided using algorithm f8, with inputs

  • 128 bit cipher key CK, Hyperframe count (32 bits), direction, etc.

• CK is created by algorithm f3 using 128 bit random number RAND and 128 bit shared secret data of USIM/AUC

• The encryption algorithms allow for future improvement

• User specifies protocol version (algorithm used) in set up message along with times for length of using IKs

  • Currently Kasumi algorithm or Advanced Encryption Standard are used for f8 and f9

  • May eventually move to using IP level encryption and authentication

UMTS Versions

Release	Specs complete	First deployed	Major new features defined
98	1998		Last purely 2G GSM release
99	1Q 2000	2003	W-CDMA air interface
4	2Q 2001	2004	Softswitching IP in core network
5	1Q 2002	2006	HSDPA & IP Multimedia System (IMS)
6	4Q 2004	2007	HSUPA, MBMS, GAN, PoC & WLAN integration
7	4Q 2007	future	HSPA+, Better latency & QoS for VoIP
8	? 2009 ?	future	LTE, All-IP

W-CDMA – Wideband CDMA modulation
HSxPA – High Speed (Download/Upload) Packet Access
MBMS – Multimedia Broadcast Multicast Service
GAN – Generic Access Network
PoC – Push-to-talk over Cellular
LTE – Long Term Evolution, a new air interface based on OFDN modulation

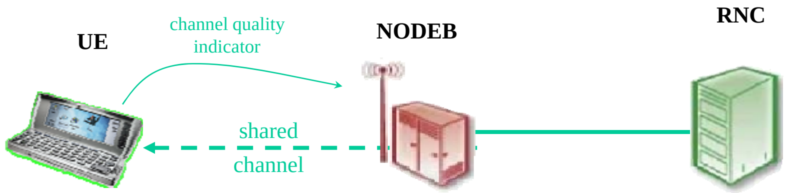
HIGH SPEED DOWLINK PACKET ACCESS (HSDPA)

- HSDPA ≈ 3.5G system upgrade of UMTS
- Standardised in *3GPP Release 5*
- Objective is to support *delay-tolerant* services in *low mobility* scenarios with with enhanced *resource efficiency* and *service quality*
  - support for background, interactive and (to some extent) streaming services
  - low mobility
  - enable *downlink* peak rates of 8-10 Mbits/s >> 3G requirements
  - lower resource consumption per transferred delay-tolerant bit

HIGH SPEED DOWLINK PACKET ACCESS

- HSDPA upgrade of UMTS similar to EDGE upgrade of GPRS
  - completely backwards compatible
  - no new spectrum needed
  - reuse existing infrastructure and 5MHz channels
    - primarily software and minor hardware upgrades
  - coexistence of HSDPA- and non-HSDPA-enabled terminals
  - coexistence of HSDPA- and non-HSDPA-enabled NODE-Bs
    - data flows on HS-DSCH moving from non-HSDPA-cell to HSDPA-cell
      are automatically switched to a supported transport channel, e.g. DCH
    - gradual hot-spot-based network upgrades possible
  - cost-effective

HSDPA Architecture

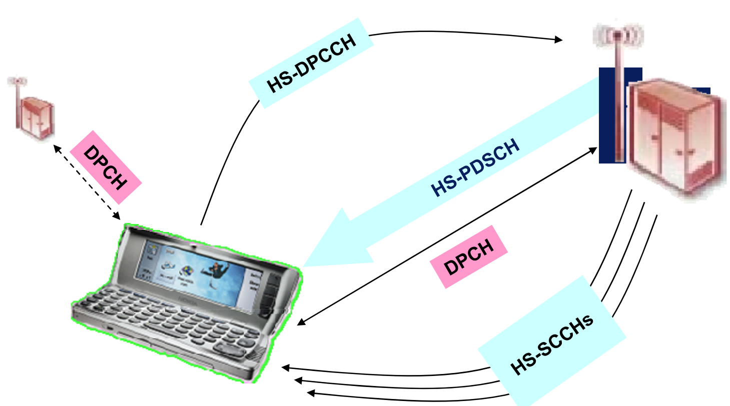


- Upgrade UMTS downlink channels to a *HS* version:
  - –*higher-order modulation:* QPSK and 16-QAM
  - –*fast link adaptation:* adaptive modulation and coding
  - –*fast channel-aware scheduling:* centered at the **Node B**
  - –*fast hybrid ARQ on downlink:* combines FEC and selective ARQ
  - –*reduced TTI of 2 ms:* to facilitate better tracking of channel variations
  - – HS channels typically transmits at relatively fixed power

NEW PHYSICAL CHANNELS

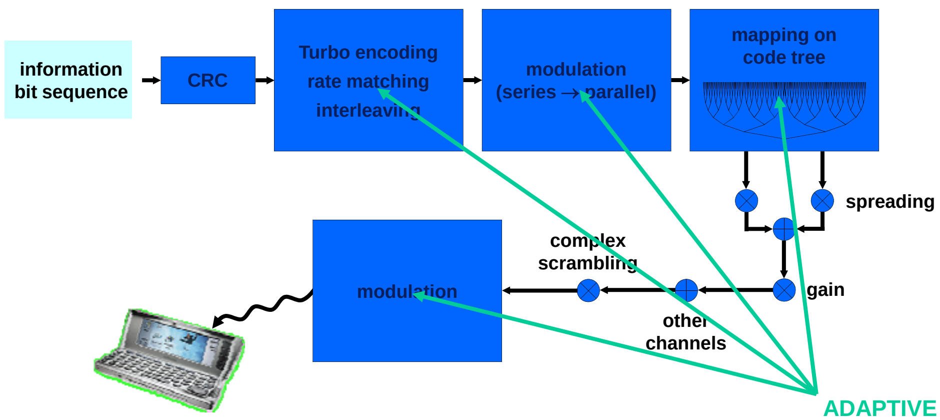
•PHYSICAL CHANNELS

–HS-PDSCH	downlink	SF 16	data only (up to 15 streams to a user)
–HS-SCCH(S)	downlink		MAC-hs signalling, H-ARQ,etc.
–HS-DPCCH	uplink	SF 256	CQI, (N)ACK



PHYSICAL LAYER PROCESSING

- **Physical Layer Processing**



ADAPTIVE MODULATION AND CODING

- LINK ADAPTATION: channel-dependent AMC
  - typically more efficient for services that tolerate short-term data rate variations
  - with only power-controlled channels, it is difficult to exploit all resoures
  - AMC can exploit resources better, at the cost of transfer rate jitter
  - Fixed spreading factor SF but variable number of streams and bits per channel symbol

MODULATION	SPREADING FACTOR	TURBO CODE RATE	BITS/ BLOCK/CODE	DATA RATE (15 CODES)
QPSK	16	1/4	240	1.8 Mbps
	16	1/2	470	3.6 Mbps
	16	3/4	711	5.3 Mbps
16-QAM	16	1/2	950	7.2 Mbps
	16	3/4	1440	10.8 Mbps

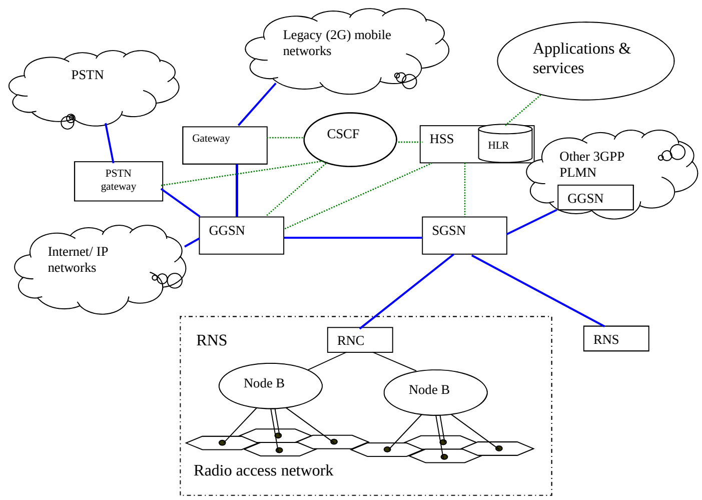
HSDPA Upgrades

- Infrastructure
  - NODE-B
    - a new MAC sublayer (MAC-hs) is standardised and needs to be implemented in the NODE-B
    - depending on the legacy NODE-B capabilities, this update may be done via remote software downloads or may possibly require hardware upgrades as well
  - RNC is largely maintains the UMTS Release ’99 functionality
    - a software-only upgrade is required, e.g. to enable assignment of data flows to the HS-DSCH (~ channel switching)
  - no substantial impact on the CORE network is expected
  - New Mobile Terminals
    - Support physical interface, higher data rates and H-ARQ
- HSDPA deployments began 2006 in Europe, Canada, etc. Over 100 deployments

HSUPA

- High Speed Uplink Packet Access
- Similar to HSDPA – advanced coding and modulation techniques with hybrid ARQ to improve data rate on uplink channel in UMTS
- Now called Enhanced Uplink (EUL) (3GPP)
- Data rates from .73Mbps – 5.76Mbps, 11.5Mbps being tested
- Uses new Enhanced versions of Signaling and physical channels
- Focus of UMTS now on IP in the backhaul

3GPP IP Reference Architecture



The 3GPP IP reference architecture – all traffic IP - with QoS Classes

UMTS

- UMTS is most popular 3G technology
  - Upgrade path from GPRS/EDGE – primarily in air interface to WCDMA standard
  - Now called 3GSM
  - WCDMA – variable power/spreading cdma
  - Provides standard benefits of cdma technology (frequency reuse factor 1, soft handoff, etc.)
  - Deployed throughout the world
  - Upgrade path to HSPDA and HSUPA and all IP in the core defined - over 62.5 million HSPA users