Course 335

GSM 2.5G Migration:

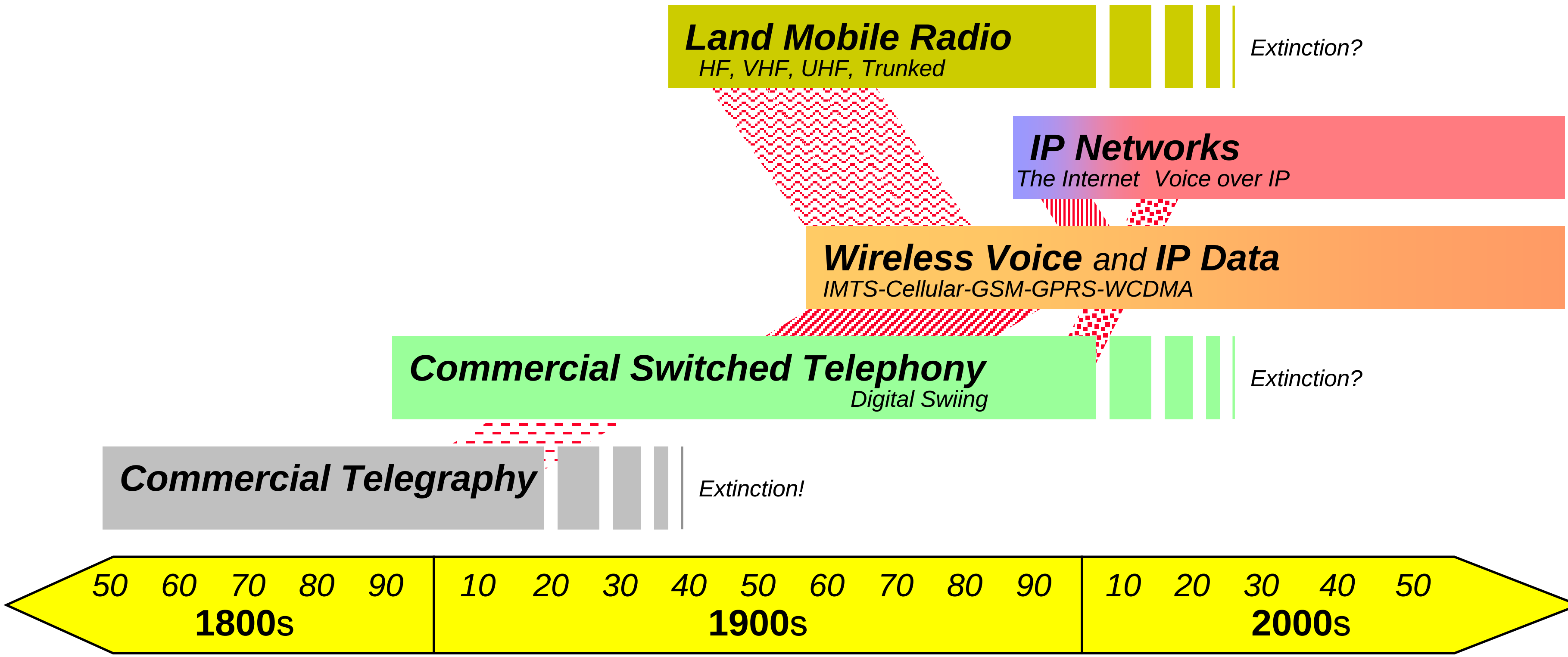
General Packet Radio Service GPRS

What's GPRS All About? How Does It Fit In?

- GSM: Global System for Mobile Communication
  - The world's most widely used wireless phone technology
    - Over 500,000,000 users worldwide!
    - TDMA-based radio interface, 200 kHz.-wide signals
  - But very limited data capability
    - 9,600 or 14,400 bps maximum in circuit-switched mode
- WCDMA / UMTS: The Long-Term 3G Data Solution
  - Uses spread-spectrum CDMA techniques, 4-MHz.-wide signals
  - Provides both voice and high speed packet data access
  - But not widely deployed and available until late 2004 or later
- GPRS: General Packet Radio Service
  - A packet-switched IP-capable way of using GSM radio infrastructure
  - Defined in 1996, wide deployment beginning in 2001
  - Provides both interim pre-WCDMA and long-term packet access

Communications Technology Family History
A Story of Births, Weddings and Funerals

- Commercial telegraphy gave birth to telephony, then died
- Telephony and Land Mobile Radio married, giving IMTS & Cellular
- IP networks developed, their usage and bandwidth are increasing
- The wedding of IP and Wireless is happening now in 3G!

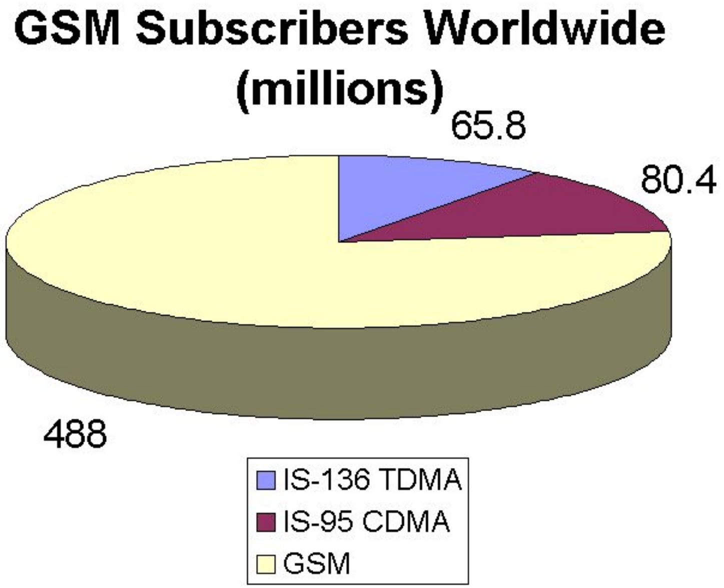


Background: GSM Technology
The Foundation of GPRS

The Beginnings of GSM

- 1980's: Europe used variety of first generation analog cellular systems: TACS, ETACS, NMT450, NMT900, Netz, etc.
  - Operation was limited to various national boundaries
  - Poor roaming capabilities, poor economies of scale in mfg.
- In 1982, CEPT the Conference of European Posts and Telegraphs created a group to study and define a 2G Pan-European system
  - Group Spécial Mobile (GSM)
  - In 1989, administration of GSM was transferred to the European Telecommunications Standards Institute (ETSI)
  - In 1990, the GSM specification, Phase I, was published
- GSM has become very popular due to many positive factors
  - Non-proprietary: anyone can manufacture networks/handsets
  - Thorough/integrated standard: well-defined RF air interface, network architecture, call delivery and roaming features

GSM World ACeptance



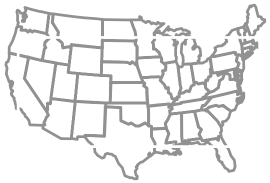
- GSM commercial deployment began in 1991
- By 1993, there were 36 GSM networks in 22 countries
- In 2000, there were over 200 GSM networks in over 110 countries around the world
  - Operation in 900 MHz., 1800 MHz., and 1900 MHz. bands
- The wide aCeptance of GSM has provided tremendous economies of scale in network, handset, and test equipment manufacturing and distribution
- Worldwide in 2001, GSM users have passed the 500 million mark
  - One in 12 human beings uses a GSM phone!
- The global dominance of GSM provides a large market for the 2.5G and 3G enhancements GPRS and UMTS WCDMA

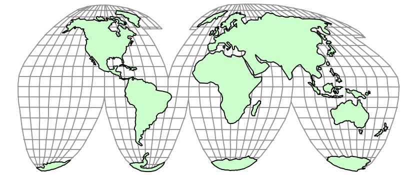
GSM vs. North American Standards

- Two different approaches to wireless technology development!
  - Americans: Invent cool new stuff driven by market forces, write standards if it works and the market aCepts it
  - Europeans: Study, Plan, build Standards, build Consensus, Plan, Review, build more Consensus, finally Deploy
- The differences are visible in the resulting standards
  - American: multiple interim standards necessary to define functionality
  - Europeans: single integrated standard covers all functionality

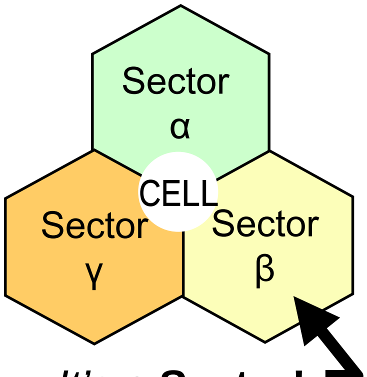
	North American CDMA	GSM
Other Features	**IS-637 SMS**, **IS-683 OTA**, **IS-707 Data**, **Etc.**	**The GSM Standard** One coordinated, uniformly structured family of documents
Intersystem Roaming, Call Delivery, Handoff	**IS-41C, D, P**	
Network Architecture	**IS-634 A-interface**	
Air Interface RF Architecture	**IS-95/J-Std 008 CDMA**	

GSM Terminology

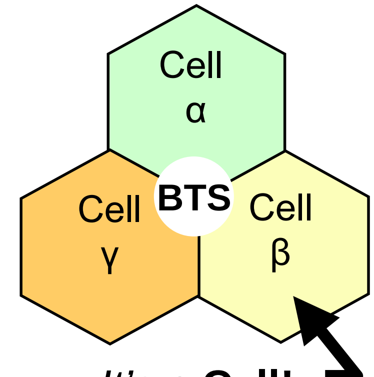




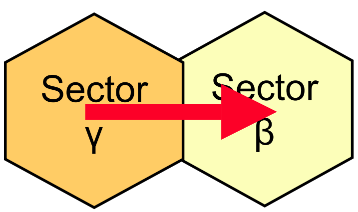
- Some terms have different meanings when used in GSM or North American practice!



It's a **Sector!**

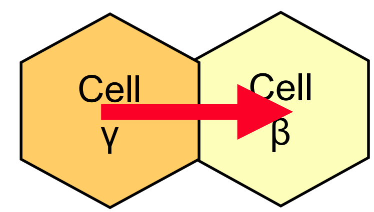


It's a **Cell!**



That was a **Handoff!**

The frequencies used by each sector are its **channel set***.*

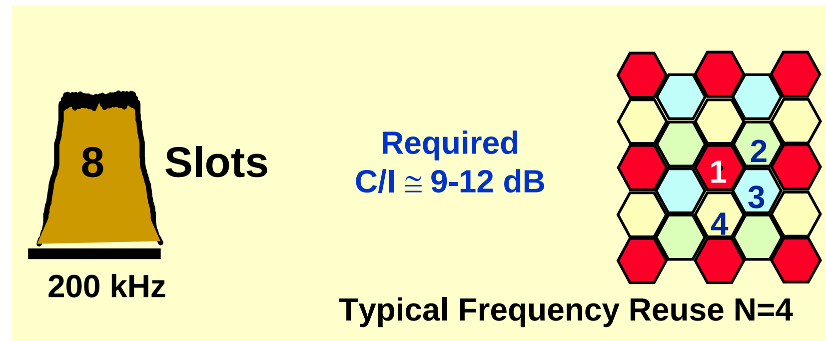


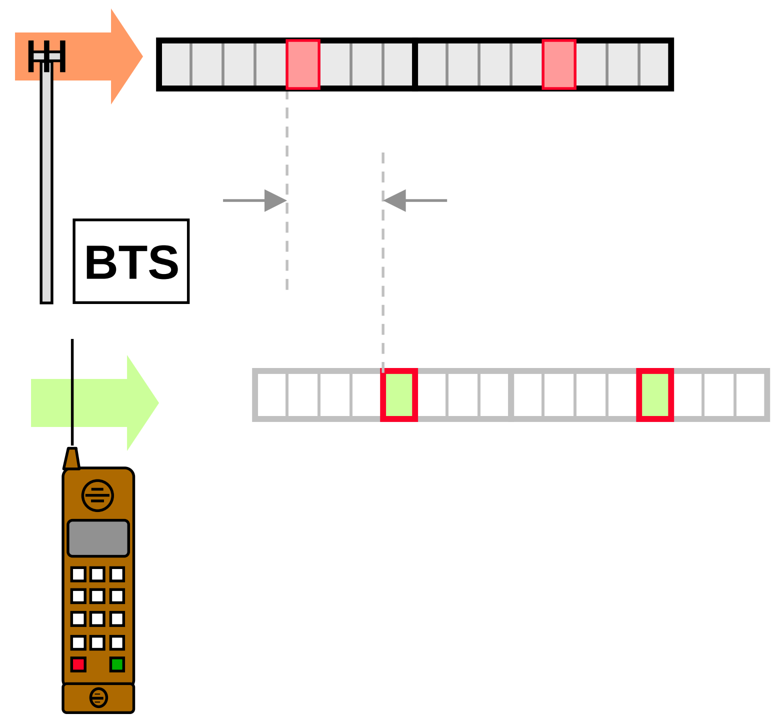
That was a **Handover!**

The frequencies used by each cell are its **allocation***.*

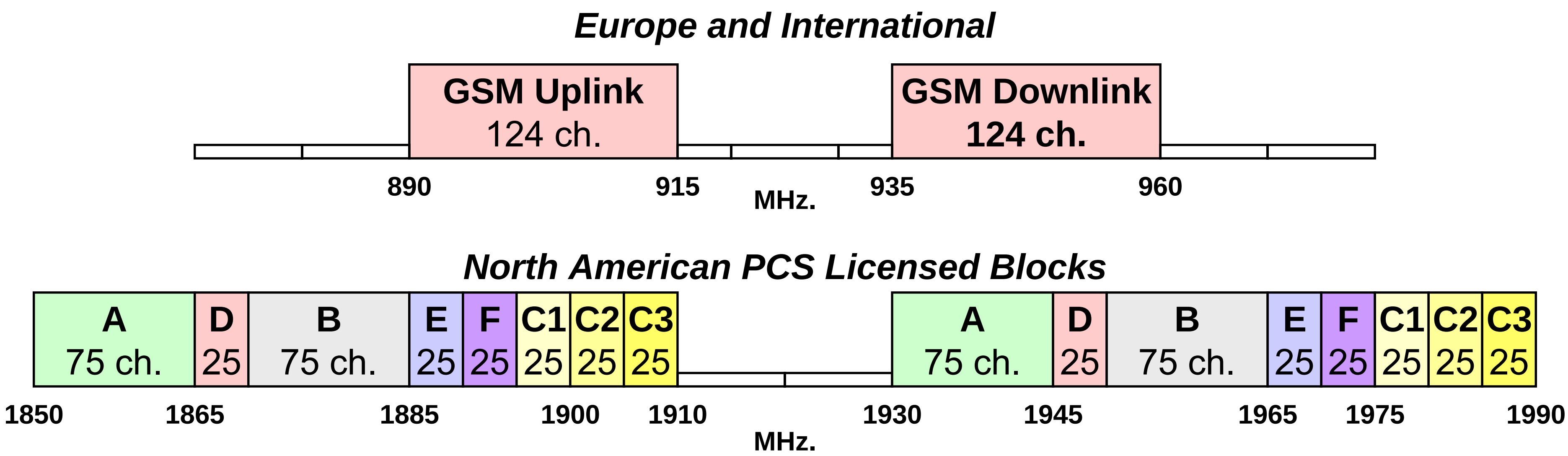
Structure of a GSM Signal

- GSM carriers are spaced 200 kHz. apart
- In the BTS downlink signal, different timeslots belong to different users - a mobile listens only to its recurring timeslots
  - During unused timeslots, a mobile can measure the signal strength of surrounding BTSs to guide the handover process
- The mobile on its uplink transmits only during its assigned timeslots
  - Mobiles transmit only during their own timeslots
  - Mobile transmit timeslots oCur three timeslots after the corresponding BTS transmit timeslot
    - This avoids simultaneous mobile TX/RX and the need for duplexer at the mobile



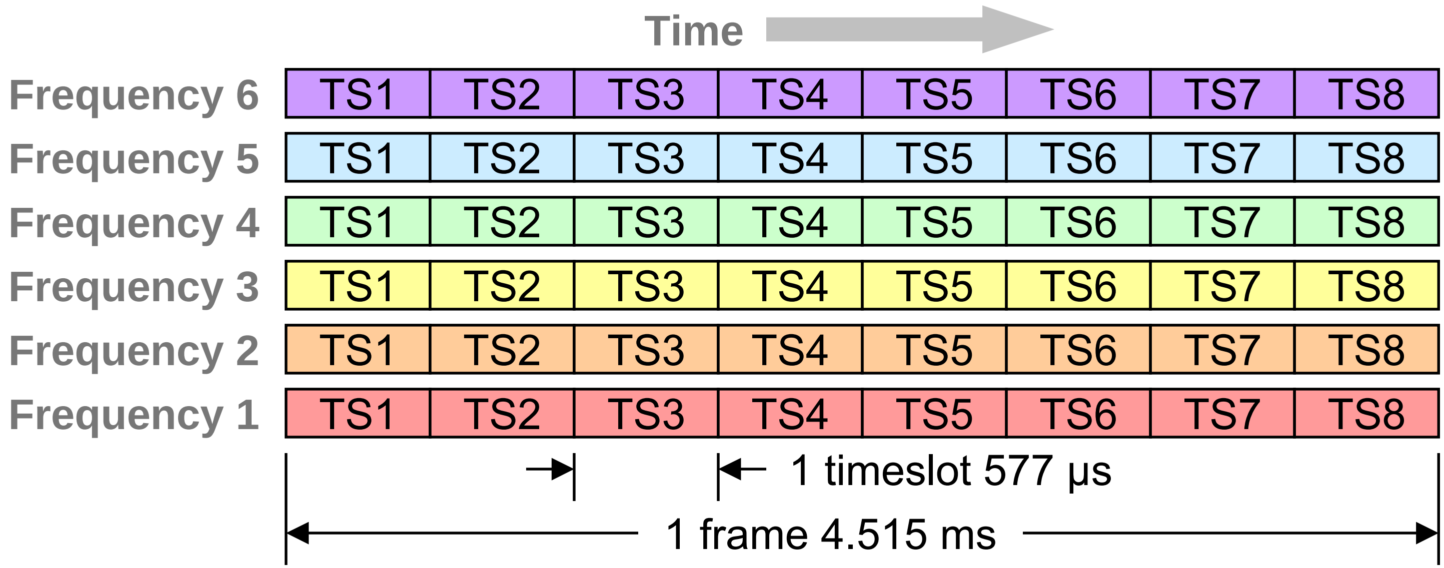


The Frequencies Used by GSM



- GSM operates in a variety of frequency bands worldwide
- GSM carrier frequencies are normally assigned in 200 KHz. Increments within the operator's licensed block of spectrum
- Spectrum is provided in "blocks"
  - Base stations transmit in the upper block
  - Mobiles transmit in the lower block
- Each cell uses a certain number of carriers, called its "allocation"

Multiple Carriers in a GSM Cell

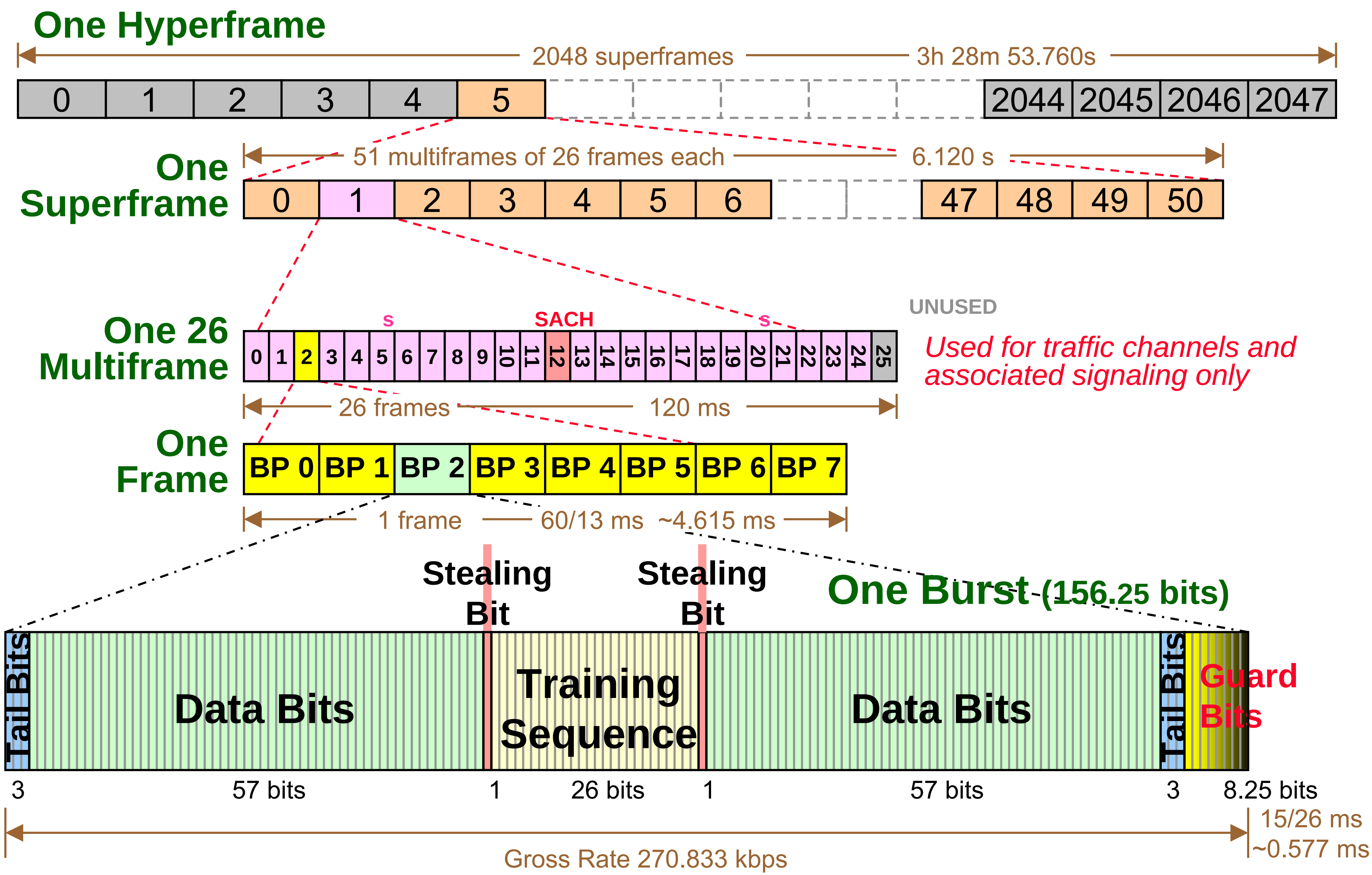


- A GSM base station transceiver makes a signal ~240 kHz. wide
- The signal is time-divided into a repeating pattern of frames
  - Each frame is 60/13 = 4.515 ms long, there are ~221.5 frames per second
- Each frame is further subdivided into 8 timeslots, each 15/26 ms = 577 µs long
  - A timeslot can hold the bits of a channel of information
    - One user’s voice signal, or a signaling/administrative channel
- One GSM base station can have several transceivers, each one producing a GSM signal on a different frequency - six carriers in the example above
  - Various repeating patterns of information can use the timeslots to carry channels of information

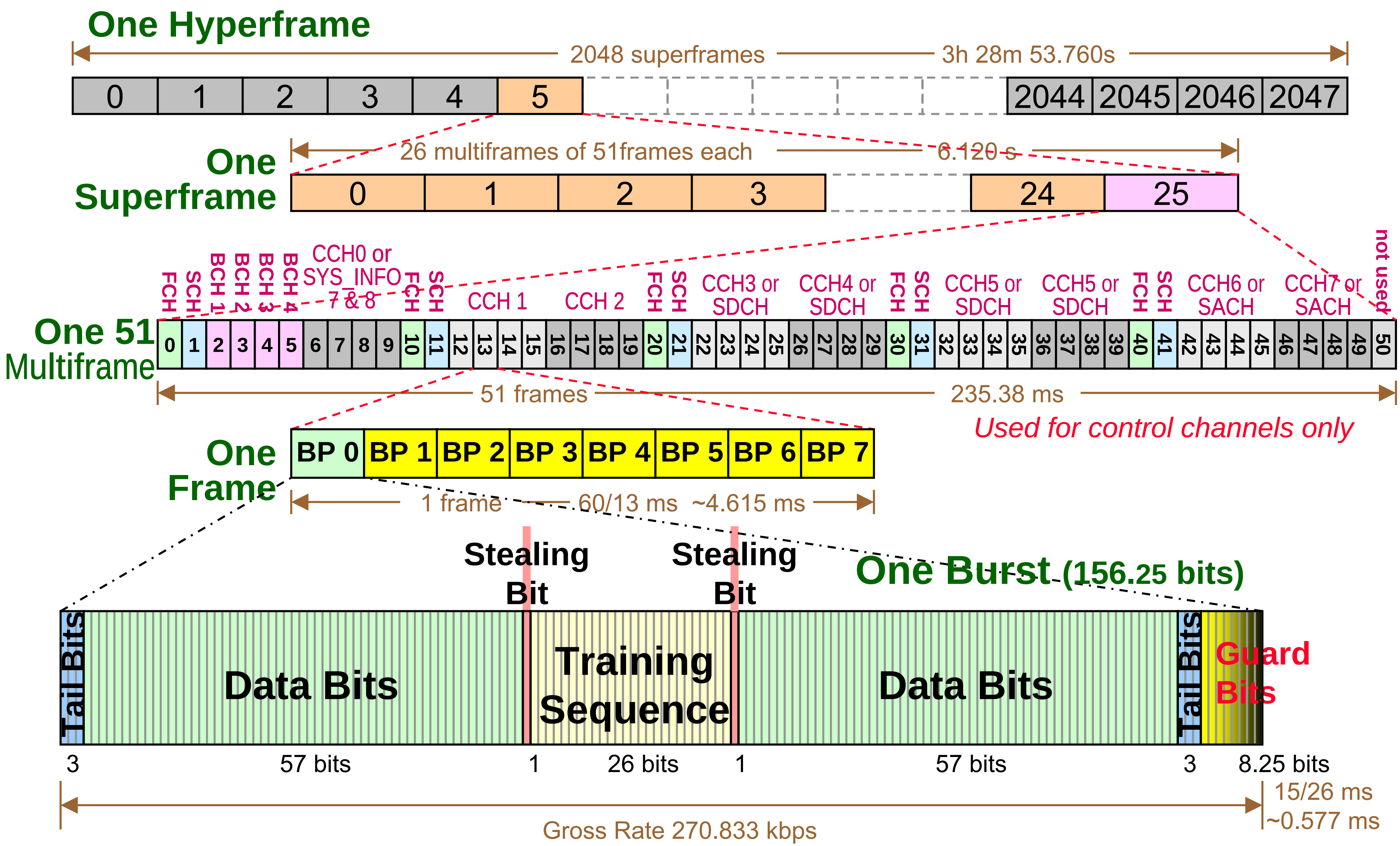
Channels in GSM: Repeating Patterns

- Channels of information in GSM oCupy physical timeslots of the GSM signal in repeating patterns
  - Similar to the way that classes and activities of a university oCupy the physical classrooms on a defined schedule
    - Some classes meet daily, some only three days a week
    - Some labs once or twice a week
    - Meals daily in the cafeteria, movies on Friday nights
    - Graduation ceremonies each semester
- Dedicated channels (carrying traffic or control information for individual users) oCur in a repeating 26-multiframe pattern 120 ms long
  - 24 frames are used for traffic, one for SACH, one is unused
  - Full-rate s oCur in each traffic frame
  - Half-rate s (if used) oCur in alternating traffic frames
  - 1/8 rate dedicated channels are defined for special purposes and are called SDCHs (Stand-Alone Dedicated Control Channels)

GSM *Traffic* Channels:
Hyperframes, Superframes, Multiframes, Frames, and Bursts



GSM *Control* Channels:
Hyperframes, Superframes, Multiframes, Frames, and Bursts



Typical Timeslot Allocation in Multiframe Patterns on One GSM RF Carrier

TIME →

Frame Number	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
TimeSlot 7	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	SACCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	IDLE
TimeSlot 6	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	SACCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	IDLE
TimeSlot 5	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	SACCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	IDLE
TimeSlot 4	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	SACCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	IDLE
TimeSlot 3	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	SACCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	IDLE
TimeSlot 2	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	SACCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	IDLE

26 Multiframe Pattern for Traffic Channels

Frame Number	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
TimeSlot 7	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	SACCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	IDLE
TimeSlot 6	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	SACCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	IDLE
TimeSlot 5	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	SACCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	IDLE
TimeSlot 4	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	SACCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	IDLE
TimeSlot 3	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	SACCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	IDLE
TimeSlot 2	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	SACCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	TCH	IDLE

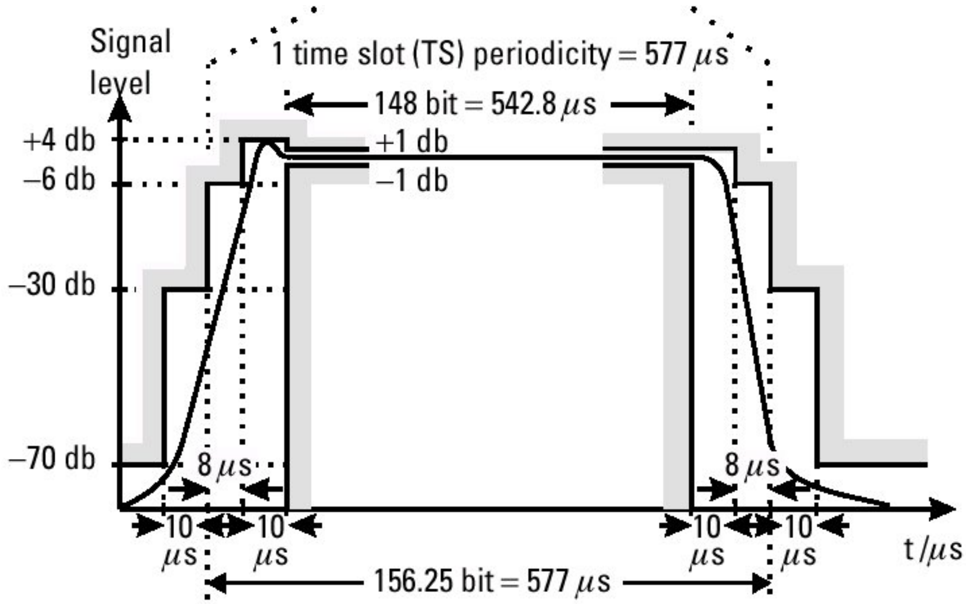
26 Multiframe Pattern for Traffic Channels

Frame Number	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
TimeSlot 1	SDCCH 0	SDCCH 0	SDCCH 0	SDCCH 0	SDCCH 1	SDCCH 1	SDCCH 1	SDCCH 1	SDCCH 2	SDCCH 2	SDCCH 2	SDCCH 2	SDCCH 3	SDCCH 3	SDCCH 3	SDCCH 3	SDCCH 4	SDCCH 4	SDCCH 4	SDCCH 4	SDCCH 5	SDCCH 5	SDCCH 5	SDCCH 5	SDCCH 6	SDCCH 6
TimeSlot 0	FCCH	SCH	BCCH 1	BCCH 2	BCCH 3	BCCH 4	AGCH/PCH	AGCH/PCH	AGCH/PCH	AGCH/PCH	FCCH	SCH	AGCH/PCH	AGCH/PCH	AGCH/PCH	AGCH/PCH	AGCH/PCH	AGCH/PCH	AGCH/PCH	AGCH/PCH	FCCH	SCH	SDCCH 0	SDCCH 0	SDCCH 0	SDCCH 0

Frame Number	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
TimeSlot 1	SDCCH 6	SDCCH 6	SDCCH 7	SDCCH 7	SDCCH 7	SDCCH 7	SACCH 0	SACCH 0	SACCH 0	SACCH 0	SACCH 1	SACCH 1	SACCH 1	SACCH 1	SACCH 2	SACCH 2	SACCH 2	SACCH 2	SACCH 3	SACCH 3	SACCH 3	SACCH 3	IDLE	IDLE	IDLE
TimeSlot 0	SDCCH 1	SDCCH 1	SDCCH 1	SDCCH 1	FCCH	SCH	CBCH	CBCH	CBCH	CBCH	SDCCH 3	SDCCH 3	SDCCH 3	SDCCH 3	FCCH	SCH	SACCH 0	SACCH 0	SACCH 0	SACCH 0	SACCH 1	SACCH 1	SACCH 1	SACCH 1	IDLE

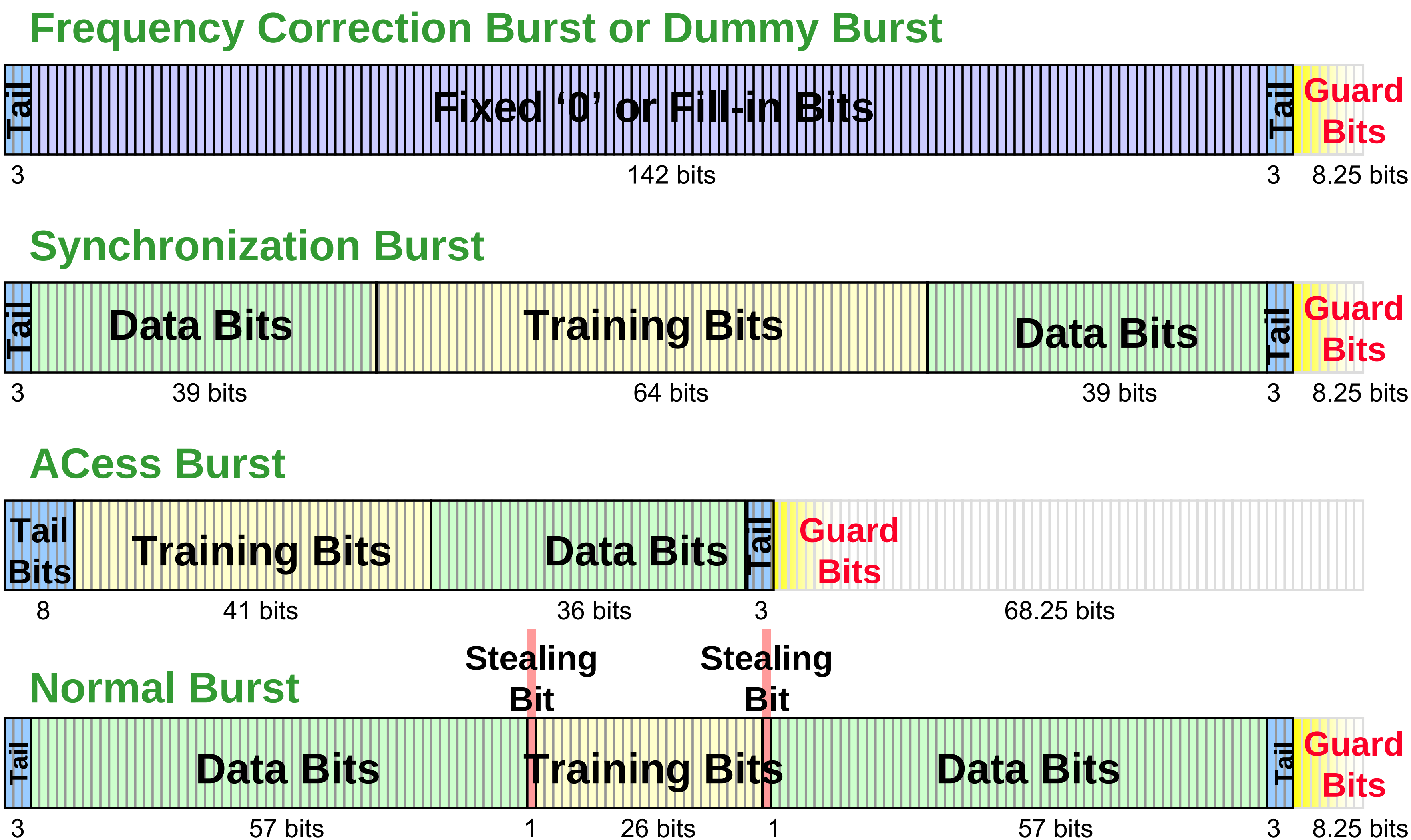
51 Multiframe Pattern for Control Channels

A GSM Uplink Normal Burst

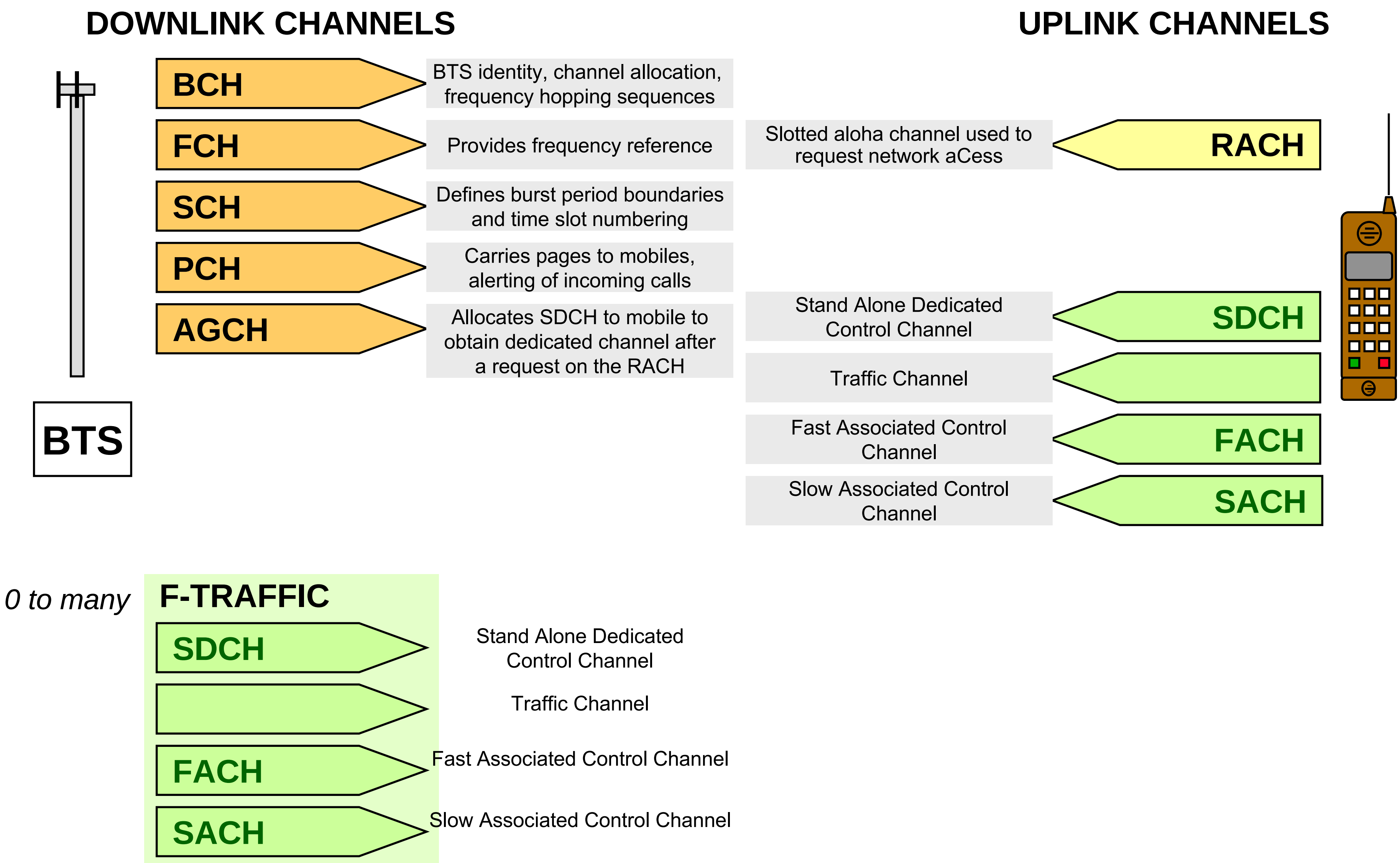


- GSM is a TDMA system and a mobile's transmission bursts are carefully constructed not to overlap with bursts from other mobiles
- Different propagation delays of mobiles near and far mobiles the BTS are compensated by automatically advancing mobile transmit timing
- Special training sequences are included in each uplink burst and downlink timeslot to facilitate demodulation
- During unused timeslots, a mobile measures the strength of surrounding base stations to guide the handover process (this is called MAHO, Mobile Assisted Hand Over)

GSM Bursts on the Uplink: 4 Types

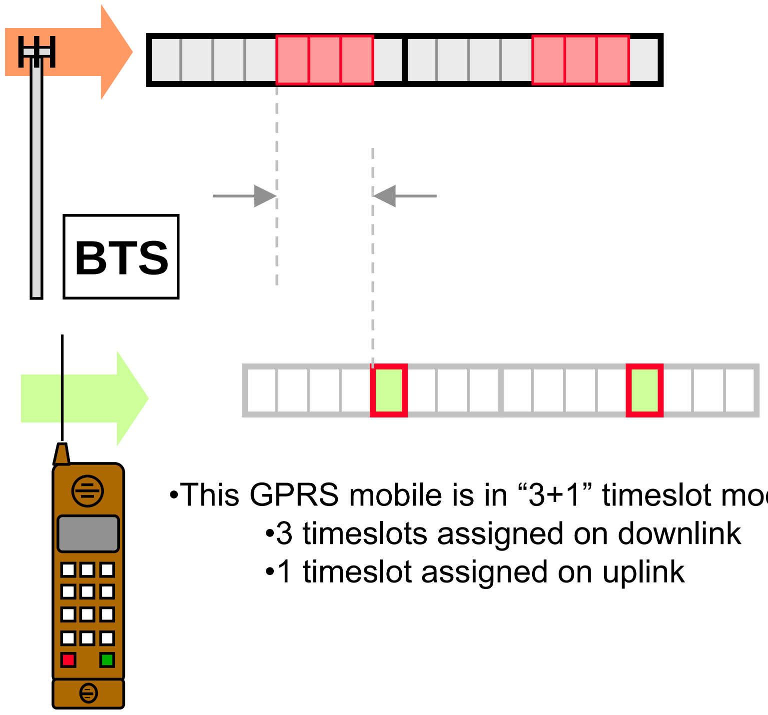


GSM Channels



The GPRS Timeslot Allocation

- In conventional GSM, a channel is permanently allocated for a particular user during the entire call period (whether speaking or silent, whether transmitting data or not)
  - In GPRS, the channels are only allocated when data packets are transmitted or received, and they are released after the transmission
  - For bursty traffic this results in much more efficient use of the scarce radio resources
  - Multiple users can share one channel
- GPRS allows a single mobile to transmit and/or receive on multiple timeslots of the same frame (this is called multislot operation)
  - This provides "bandwidth on demand" in a very flexible scheme
  - One to eight timeslots per frame can be allocated to a mobile
  - Uplink and downlink allocations can be allocated separately, which efficiently supports asymmetric data traffic (suitable for web browsing, for example)



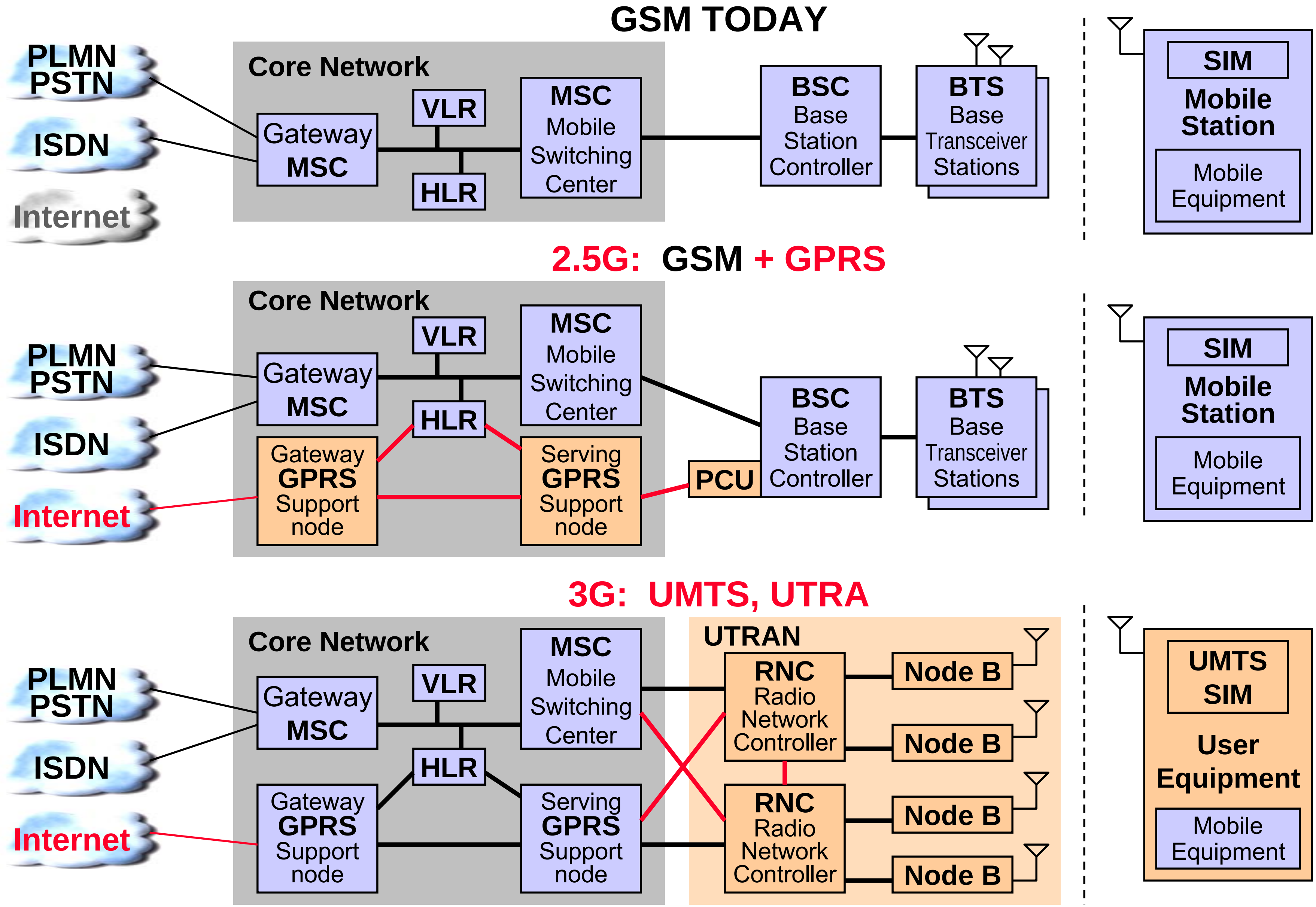
•This GPRS mobile is in "3+1" timeslot mode
•3 timeslots assigned on downlink
•1 timeslot assigned on uplink

Allocation of GPRS Channels

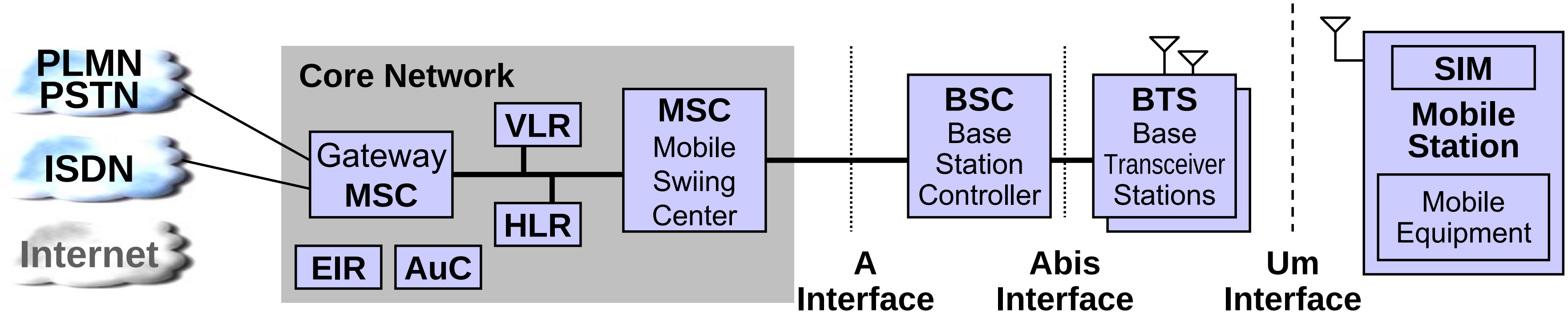
- A cell supporting GPRS may allocate physical channels for GPRS traffic
- Such a physical channel is denoted a Packet Data Channel (PDCH)
  - The PDCHs are taken from the common pool of all channels available in the cell
  - The radio resources of a cell are shared by all GPRS and all non-GPRS mobiles in the cell
  - The mapping of physical channels to either GPRS or GSM usage can be performed dynamically, based on:
    - Capacity on demand principle
    - Depending on the current traffic load, priority of service, and the multislot class
- A load supervision procedure monitors the PDCHs in the cell
- The number of channels allocated to GPRS can be changed aCording to current demand
  - Physical channels not currently in use by conventional GSM can be allocated as PDCHs to increase the GPRS quality of service
  - When there is a resource demand for services with higher priority, PDCHs can be de-allocated

GSM, GPRS, WCDMA
Coordinated Network Architecture

3 Steps to 3G: The GSM Transition



Architecture of a Phase-1 GSM Network

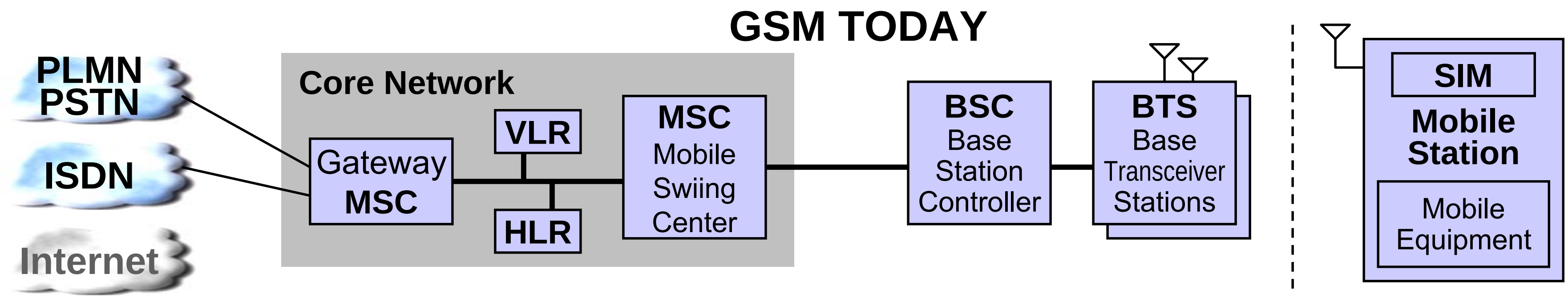


GSM Functional Entities and Network Elements

PLMN - Public Land Mobile Network	HLR - Home Location Register
PSTN - Public Swied Telephone Network	VLR - Visitor Location Register
ISDN - Integrated Services Digital Network	BSC - Base Station Controller
GMSC - Gateway Mobile Swiing Center	BTS - Base Transceiver Station
MSC - Mobile Swiing Center	SIM - Subscriber Identity Module
EIR - Equipment Identity Register	ME - Mobile Equipment
AuC - Authentication Center	MS - Mobile Station

- The network elements and interfaces of GSM are standardized
- This provides for inter-vendor participation in operators’ networks
  - Competition improves quality, provides economies of scale

GSM Network Evolution and History

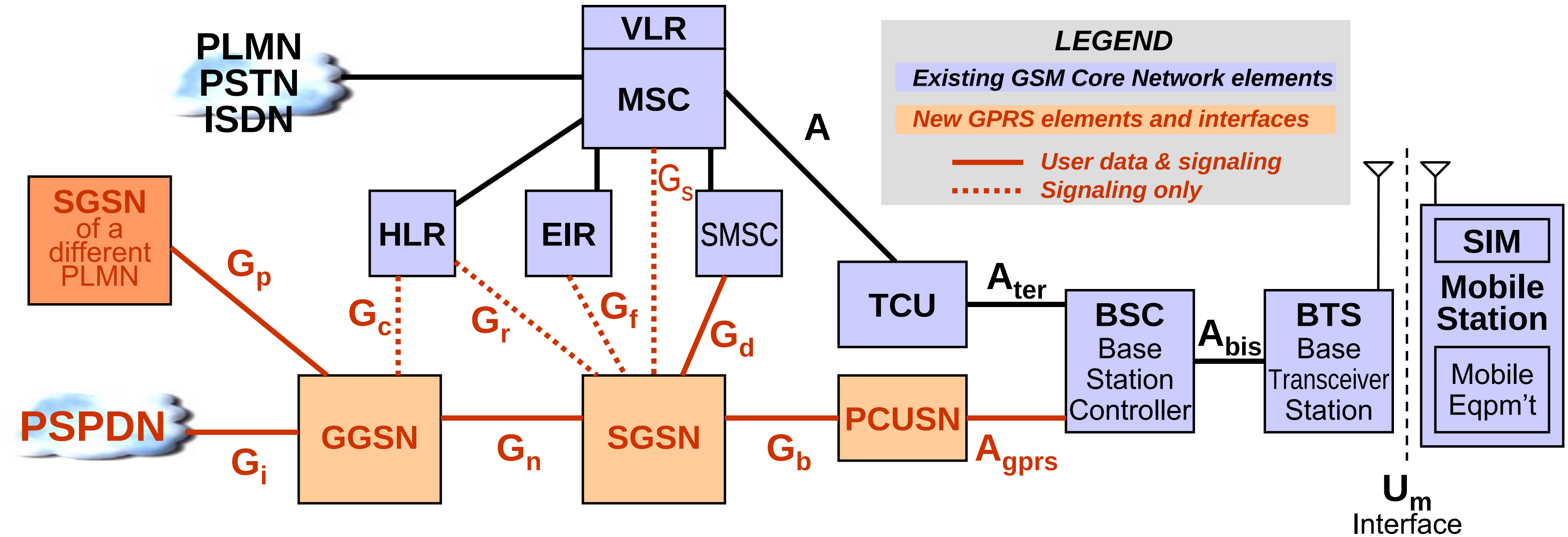


- The present GSM network architecture emerged from work of the ETSI in the late 1980s
- The GSM network can be divided into three main domains
  - The Network Swiing Subsystem (GMSC, VLR, HLR, MSC)
  - The Operations and Support Subsystem (not shown, includes OMC-R)
  - The Base Station Subsystem BSS (includes BSCs, BTSs)

GSM Evolution: General Packet Radio Service

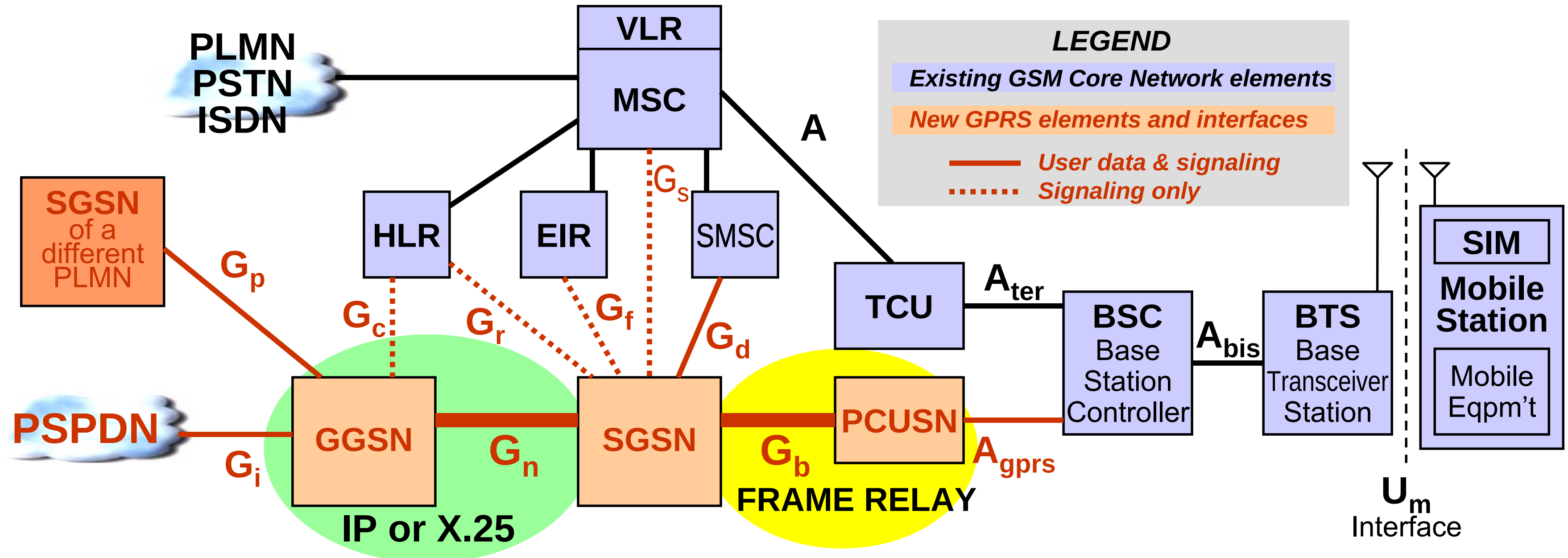
- Around 1994, the GSM phase 2 standards were enhanced to include a number of new and improved services. These enhancements became known as GSM Phase 2 Plus.
- One of the new features proposed in 1994 was a new bearer service, true packet radio service known as GPRS
- GPRS allows a user with suitable mobile station to oCupy multiple time slots on a TRX, culminating in the possible oCupancy of all 8 timeslots if they are available
  - Data rates supported per timeslot are 9.06, 13.4, 15.6, and 21.4 kb/s
  - When all 8 timeslots are available, throughput can reach 8 x 21.4 kb/s = 171.2 kb/s, although realistic expectations are around 115 kb/s due to BCH and other requirements
- GPRS applications are expected to include internet aCess/web browsing, video and Road Traffic and Transport Informatics (RTTI), and e-commerce and point-of-sale aCounting

GPRS Network Architecture



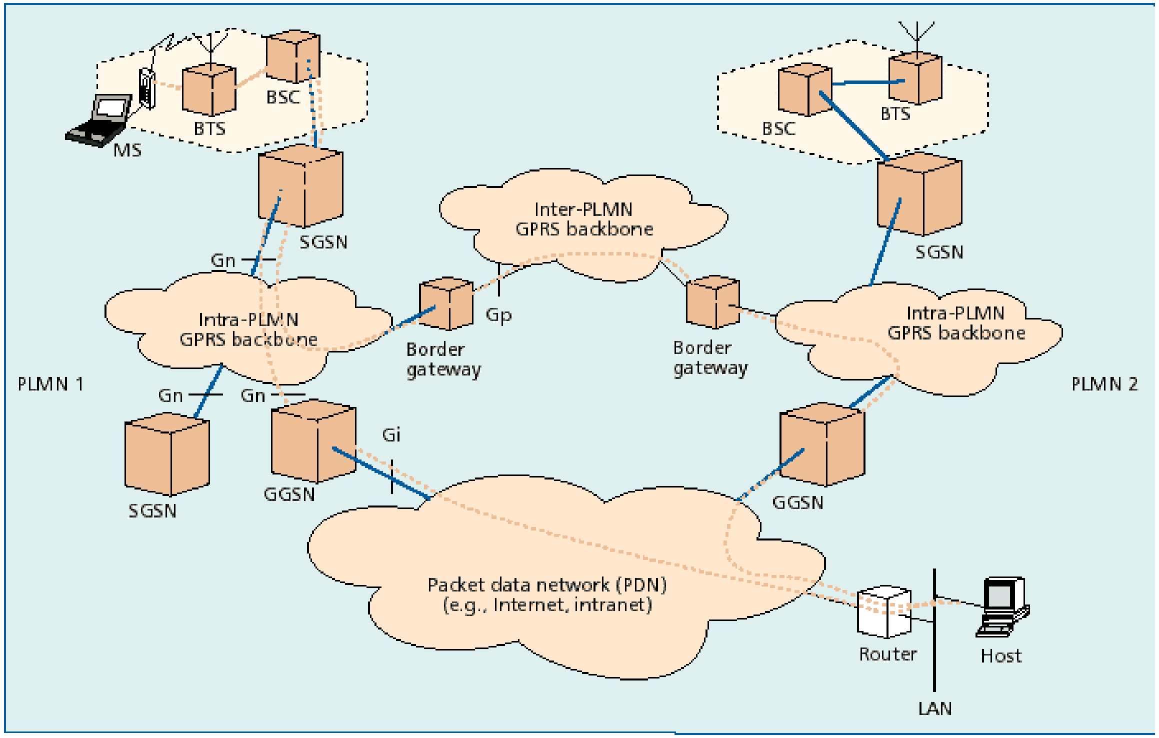
- The GSM network architecture was modified to add packet services, through the addition of the new network elements GGSN and SGSN
  - GGSN Gateway GPRS Support Node
    - Responsible for routing data packets entering and leaving the radio network; also as a router for packets within the network
  - SGSN Serving GPRS Support Node
    - responsible for packet delivery to mobiles in its area
    - a type of packet swi with capability to interrogate the GSM databases HLR and VLR for location and service profiles of mobiles
- Data is “tunneled” from the GGSN to the SGSN using GTP, GPRS Tunneling Protocol, encapsulating packets de-encapsulating on delivery

Understanding the Backbone Networks



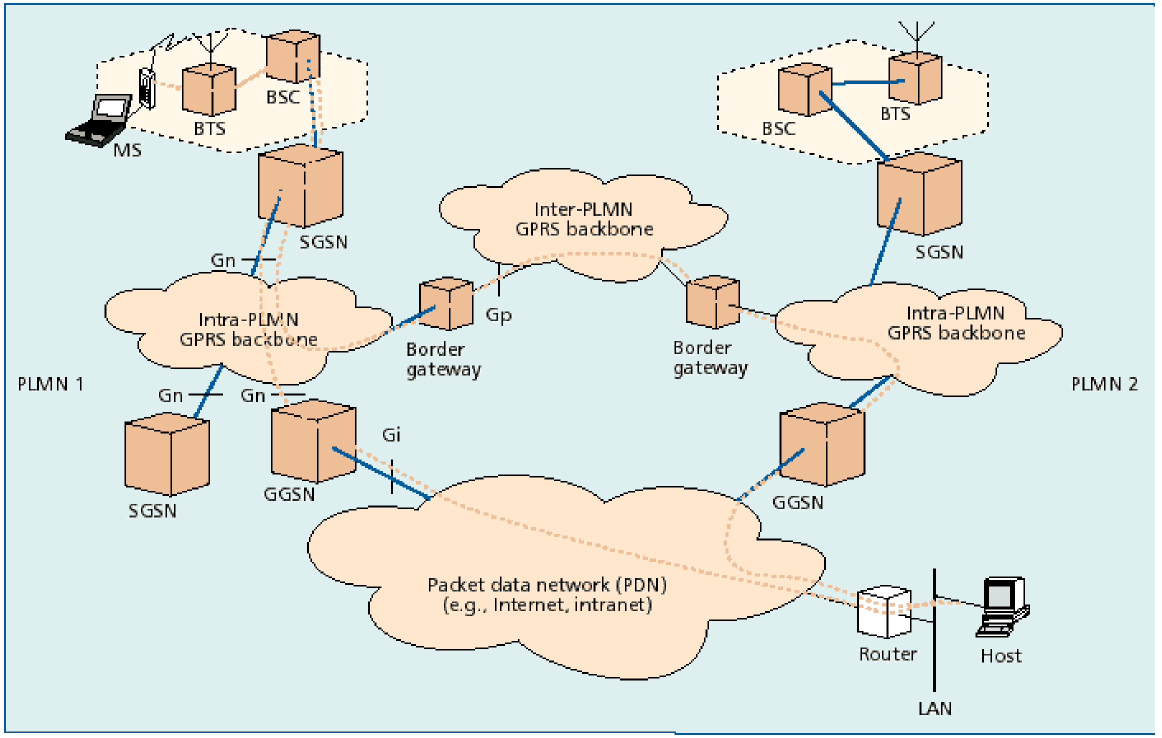
- Gb between SGSN-PCUSN uses Frame Relay protocols
- Gn between SGSN-GGSN uses IP routing, GPRS Tunnel Protocol
- Gr between SGSN-HLR is an extension of MAP
- Gi between GGSN and PDNs uses IP and X.25
- Gd between SGSN-SMSC delivers SMS messages using MAP
- Gc between GGSN-HLR is optional, uses MAP
- Gs between SGSN-MSC/VLR is optional, uses BSSMAP

GPRS Backbone Networks



- Two kinds of GPRS backbones:
  - Intra-PLMN among GSNs of same PLMN (private, IP-based)
  - Inter-PLMN among GSNs of different PLMNs (roaming agreements)
- Gateways between the PLMNs and the external inter-PLMN backbone are called Border Gateways
  - Border Gateways perform security functions to prevent unauthorized aCess and attacks
- The G_n and G_P interfaces are also defined between two SGSNs
  - This allows exchange of user profiles as mobiles move around
- The G_f interface allows a SGSN to query the IMEI of a registering mobile
- The G_i interface connects the PLMN to external public or private PDNs
  - Interfaces to IPv4, IPv6, and X.25 networks are supported
- The G_r interface allows an SGSN to communicate with an HLR

GPRS-GSM Coordination



- The MSC/VLR may be extended with functions and register entries for efficient coordination between GPRS packet swied and GSM circuit-swi services
  - Combined GPRS and non-GPRS location updates
- Paging requests for circuit-swied GSM calls can be performed via the SGSN
  - The Gs interface connects the databases of SGSN and MSC/VLR
- The Gd interface allows short message exchanges via GPRS
  - Gd interconnects the SMS gateway MSC (SMS-GMSC) with the SGSN

GPRS Services

- GPRS bearer services provide end-to-end packet-swied data transfer. There are two kinds:
- PTP Point-to-Point Service, available now, has two modes:
  - PTP Connectionless Network Service (PTP-CLNS) for IP
  - PTP Connection-oriented network Service (PTP-CONS) for X.25
- PTM Point-to-Multipoint Service (available in future releases)
  - PTM-M Multicast Services broadcasts packets in certain geographical areas; a group identified indicates whether the packets are intended for all users or for a group
  - PTM-G Group Call Service addresses packets to a group of users (PTM group) and are sent out in geographical areas where the group members are currently located
- SMS Short Message Services
- Supplemental Call Services:
  - CFU Call Forwarding Unconditional, CFNRc Call Forwarding Subscriber Not Reachable, CUG Closed User group
- Non-Standard Services may be offered at GPRS service providers
  - Database aCess, messaging, e-transactions, monitoring, telemetry

The Stages of the GPRS Specifications

- The GPRS specification is built in three stages
- Stage 1 describes the basic service capabilities
- Stage 2 describes the specific system and network architectures and the radio interface description
- Stage 3 provides details of the link control layer entities, specifications of the mobile stations, and details of the internal network element interfaces and their protocols

Stage 1

02.60	GPRS Service Description (overview)

Stage 2

03.60	GPRS Service Description (System and Architecture)
03.64	Radio Interface Description

Stage 3

04.60	MS-BSS: RLC/MAC layer descriptions
04.64	MS-SGSN: Logical Link Control
04.65	MS-SGSN: SNDCP
07.60	GPRS Mobile Stations
08.14	G_b (BSS-SGSN) layer 1
08.16	G_b (BSS-SGSN) network service
08.18	G_b (BSS-SGSN) BSSGP
09.16	G_s (MSC/VLR-SGSN) layer 2
09.18	G_s (MSC/VLR-SGSN) layer 3
09.60	G_n and G_p GPRS Tunneling Protocol

GPRS Initial Release Features

- All network manufacturers are expected to support IP and interworking with both internet and intranet in their first product release
  - To support this functionality, some form of server functionality must be provided
    - Domain Name Server (DNS) is required to translate between domain names and IP addresses
    - Dynamic Host Configuration Protocol (DHCP) is required to allow automatic reassignment of addresses for mobile hosts
- In early networks, a single SGSN will probably be sufficient due to the gradual growth of users and traffic as mobiles become available
- The connection between the GGSN and the MSC/VLR, HLR, and SMSC will require a gateway using SS7/IP or SIG to link the IP backbone with the interfaces to these network elements

A Closer View of the GPRS Internal Interfaces and Elements

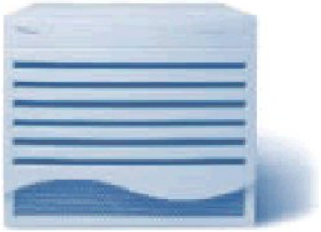
Serving GPRS Support Node (SGSN) Functions

- The Serving GPRS Support Node (SGSN) is responsible for the following to and from the mobile stations in its service area:
  - Packet Routing and Transfer
  - Mobility management (attach/detach and location management)
  - Logical Link management
  - Authentication and charging functions, encryption
  - Compression (optional)
  - Location register of SGSN stores location (cell, vlr) and user profiles
- A typical PLMN network will start with only one SGSN
- Each BSC has a Packet Communications Unit, PCU
  - Similar hardware provides the PCUSN function

Several models of the Nortel Passport Swi for SGSN and PCUSN service

Gateway GPRS Support Node (GGSN) Functions

- The Gateway GPRS Support Node (GGSN) is the interface between external packet data networks and GSM backbone network
  - Converts GPRS packets from the SGSN into packet data protocol format (IP, X.25) for the external networks
  - Converts PDP addresses of incoming data packets to GSM address of destination user, and forwards to responsible SGSN
  - GGSN stores the current SGSN address of the user and the user's profile in its location register
  - GGSN performs authentication and charging functions
  - Performs tunneling

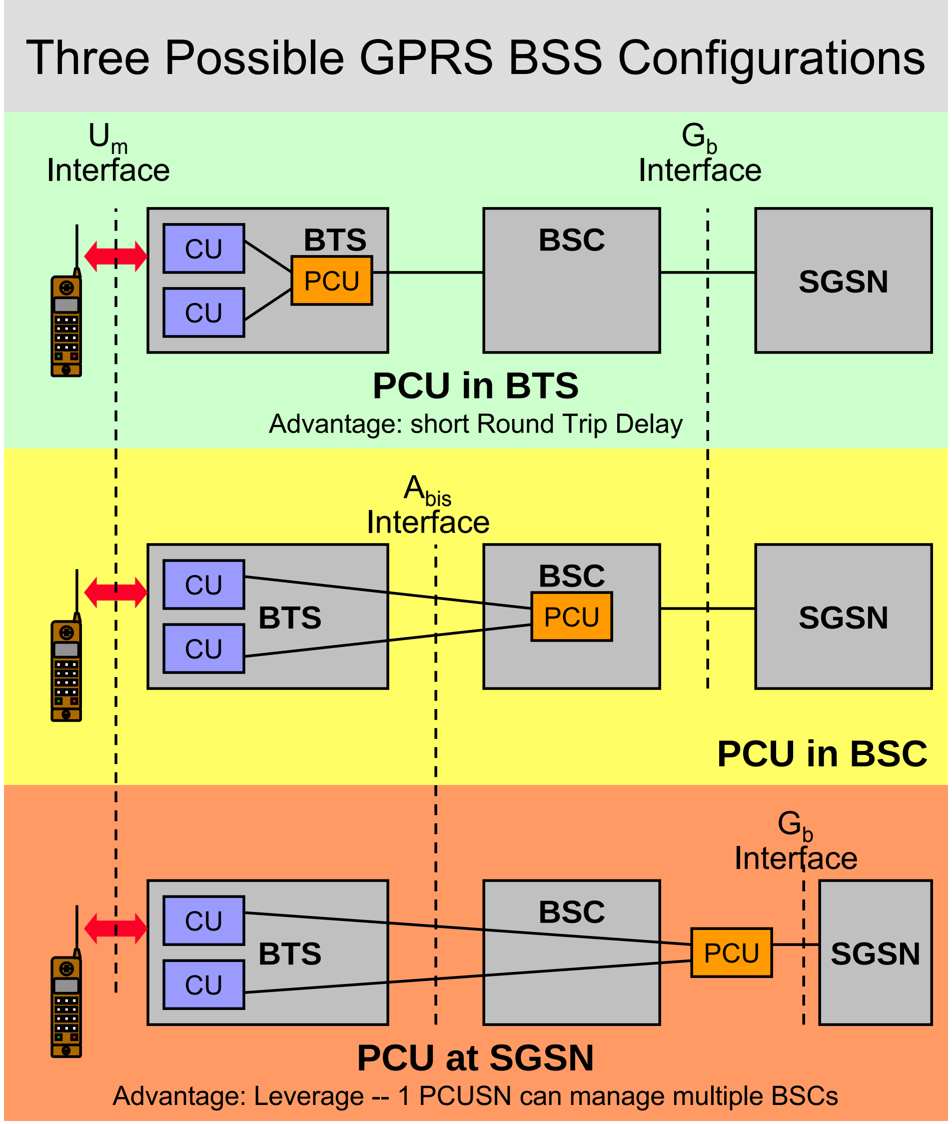


Nortel's GGSN:
Bay Contivity Extranet Swi
CES-4500

- Initial GPRS traffic in a PLMN network will be low, and a single GGSN will suffice for first service and an appreciable time thereafter

GSM BTS Changes Required to Support GPRS

- Since GPRS uses new coding schemes, a Channel Codec Unit (CU) is required
  - The CU can normally be implemented within BTS software
- Timeslot allocation for GPRS is handled by a new Packet Controller Unit (PCU) which also implements frame relay connection with the GPRS network
  - The PCU function can be physically implemented in the BTS, BSC, or at the SGSN, but is conceptually part of the BSS



Channel Coding Implemented at the BTS

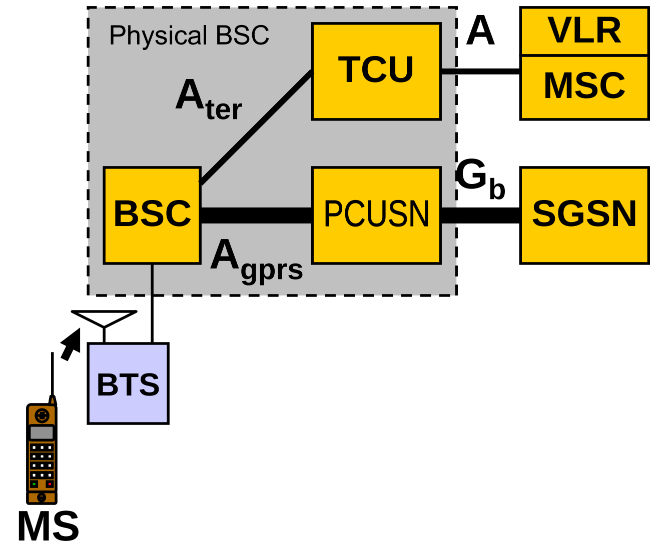
GPRS Coding Schemes

Coding Scheme	Pre-Cod. USF	Infobits Without USF	Parity Bits BC	Tail Bits	Output Conv. encoder	Punctured Bits	Code Rate	Data Rate Kbit/s
CS-1	3	181	40	4	456	0	1/2	9.05
CS-2	6	268	16	4	588	132	~2/3	13.4
CS-3	6	312	16	4	676	220	~3/4	15.6
CS-4	12	428	16		456		1	21.4

- Channel coding is used to protect the transmitted GPRS data packets against errors
  - The channel coding in GPRS is very similar to that of GSM
    - An outer block coding, an inner block coding, and an interleaving scheme are used
- Four different coding schemes are defined in the table above
- As of mid-2001, network manufacturers were only implementing CS-1 and CS-2

The MS-SGSN Interface

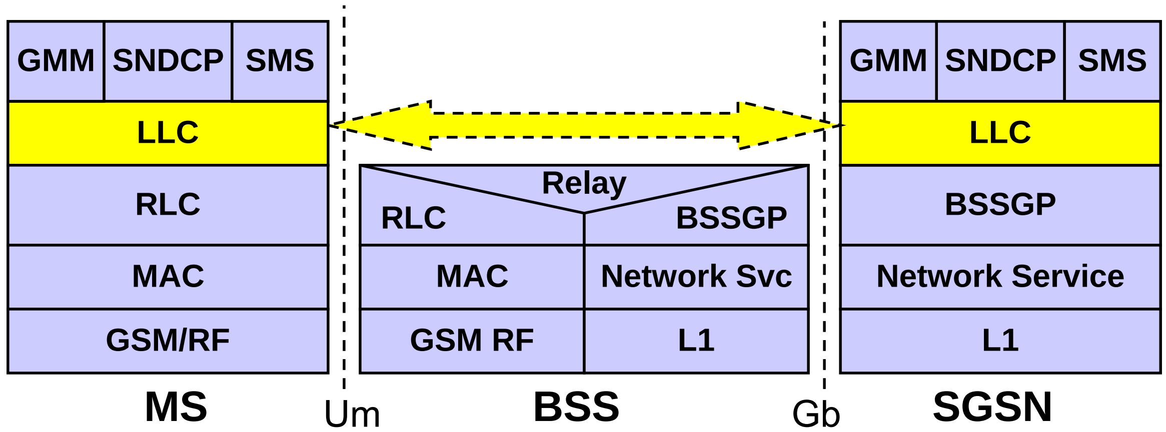
- Packet Controller functions are provided by the PCU, which is implemented in a physical PCUSN in the BSS
  - The PCUSN handles the GPRS-specific packet processing using frame relay protocols
  - The PCUSN connects to the BSC with network manufacturers' proprietary A_{gprs} interfaces
  - The PCUSN connects to the SGSN via the standard-defined G_b interface
- Although a PCUSN can optionally serve more than one BSC, all channels from one BSC must pass through the same PCUSN
- TRAU frames from the mobile pass through the BTS to the BSC and on into the PCUSN



PCUSN and PCU Distinction

•A PCUSN (Packet Controller Unit Serving Node) is the hardware unit which implements the PCU (Packet Controller Unit) function

MS-SGSN Logical Link Control (LLC)



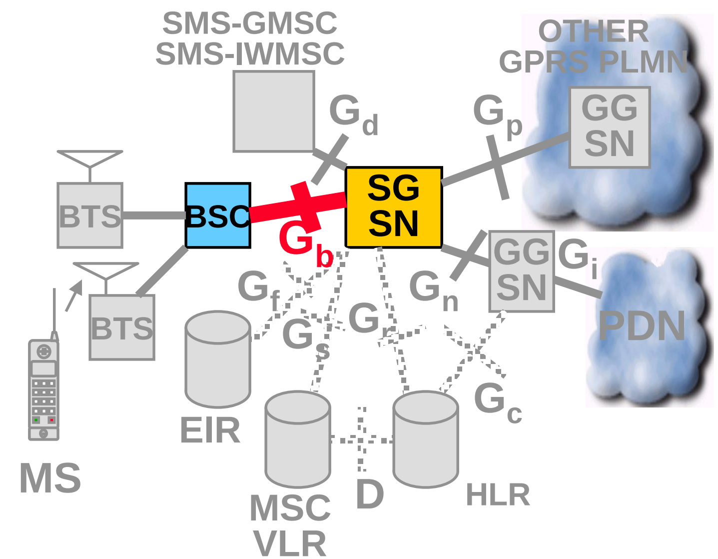
- LLC provides the reliable link between MS and SGSN
- LLC supports these layer-3 Protocols:
  - SNDCP Sub-Network Dependent Convergence Protocol
  - GMM/SM GPRS Mobility & Session Management
  - SMS Short Message Service
- Protocols supported by the LLC provide:
  - Data ciphering for security
  - Flow control; sequential order of delivery; error detection/recovery
  - Acknowledged and Unacknowledged data transfer modes
- The LLC provides transparency - the lower level radio link protocols are not involved and do not affect the GPRS applications running above

MS-SGN Service ACess Points (SAP) for LLC

- The LLC provides six service aCess points (SAP) to the upper layers
  - Each SAP has its own Service ACess Point Identity (SAPI)
- The SAPs include:
  - GMM/SM - Service for Signaling for Session/Mobility Management
  - SMS - Short Message Service
  - QoS1 Packet Transmission SNDCP aCess
  - QoS2 Packet Transmission SNDCP aCess
  - QoS3 Packet Transmission SNDCP aCess
  - QoS4 Packet Transmission SNDCP aCess
- Frames are assembled/disassembled using a multiplex procedure
  - A logical link management entity (LLME) manages resources

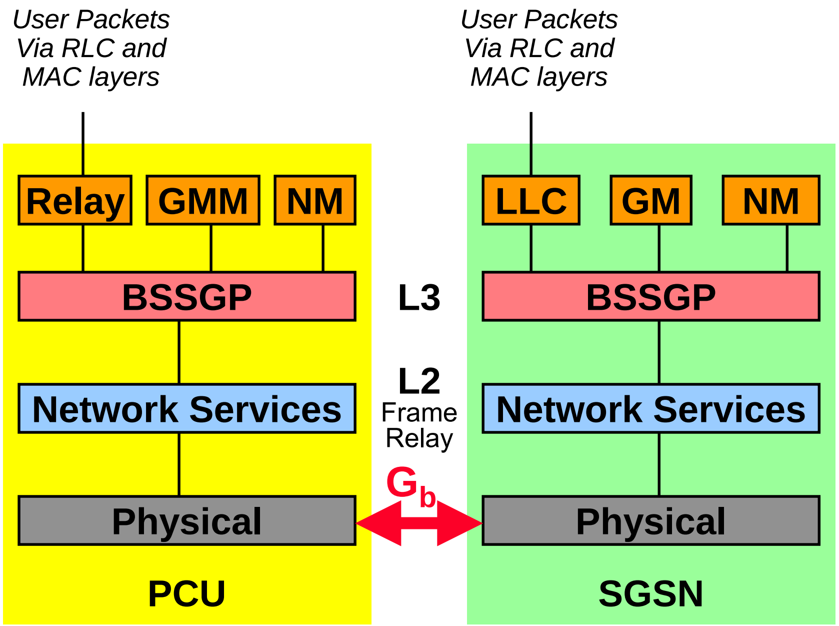
The G_b Interface: PCU-SGSN

- The SGSN and the PCUSNs of each BSC are linked by a backbone network using Frame Relay protocol over the G_b interface
  - Data rate can be up to 2 Mbps
  - Frame relay protocol implementation is actually simpler than X.25
- Layers at each node of the G_b :
  - Physical Layer
  - Network Service Layer (NS)
  - Base Station Subsystem GPRS Protocol (BSSGP)
  - Network Management (NM)
    - GPRS Mobility Management (GMM)
    - LLC/Relay



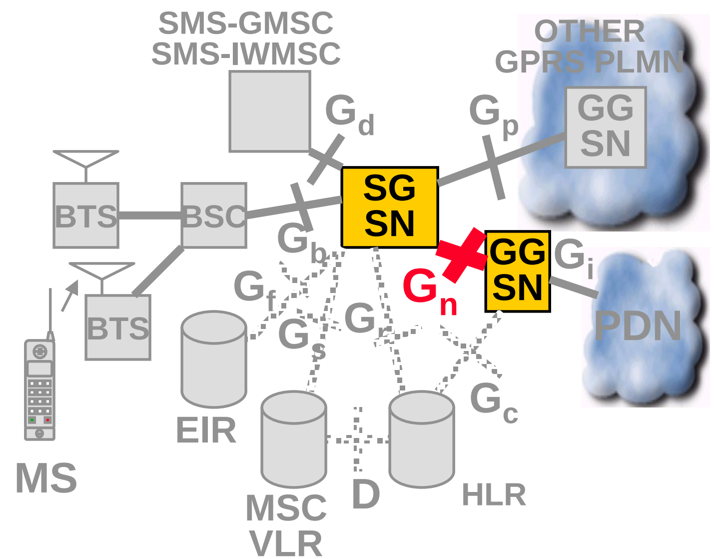
PCU and SGSN Operation over the G_b Interface

- BSSGP: Base Station Subsystem GPRS Protocol
  - Provides flow control, manages buffers, provides services for the higher layers
- GMM - GPRS Mobility Management
  - Manages mobility features for users, such as location updating and paging
- NM - Network Management
  - Manages flow control, buffers, virtual pathways between PCU/SGSN
- Network Services
  - Implements the communications protocol for the G_b interface (Frame Relay)
- Physical Layer
  - Hardware and physical nature of the interface



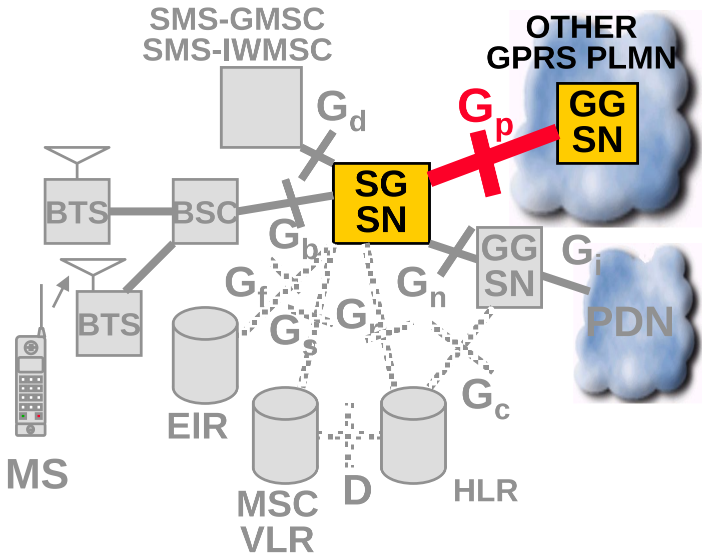
The G_n Interface: SGSN-GGSN

- The SGSN and GGSN are linked by a GPRS backbone using IP routing
- The G_n interface creates and operates through secure tunnels, using the GPRS Tunneling Protocol (GTP)
- The GTP packet headers include
  - Tunnel endpoint and group identity
  - PDU type
  - QoS parameters
  - Routing protocol identification
    - Static, RIP2, OSPF
- Beneath IP, any transport architecture can be used
  - Ethernet, Token-Ring, FDDI, ISDN, ATM



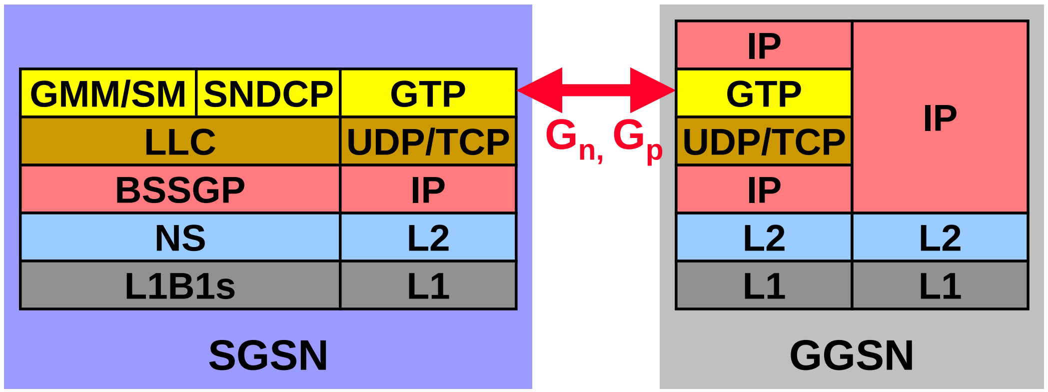
The G_p Interface: SGSN - Other PLMN GGSN

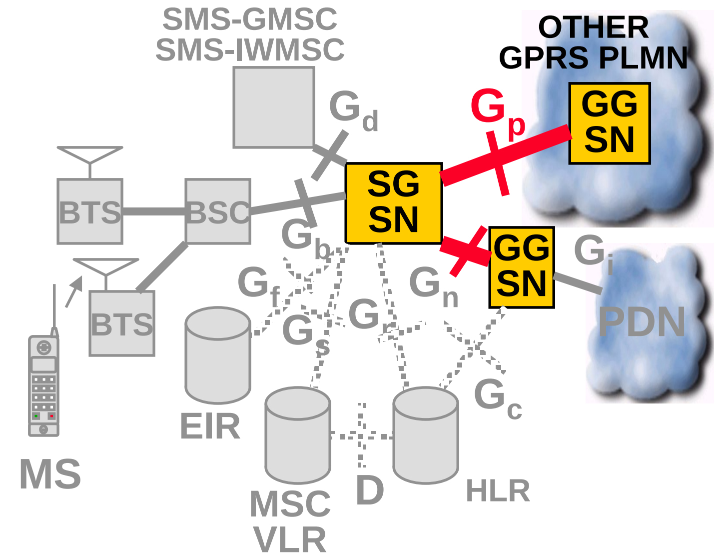
- The G_p interface connects an SGSN of one PLMN with a GGSN of another PLMN
- This interface forms an inter-PLMN backbone providing mobile IP capability for roaming mobiles
- Specific configuration of this link depends on the features intended by the two PLMN operators, as well as dimensioning issues



More About GPRS Tunneling on G_n and G_p

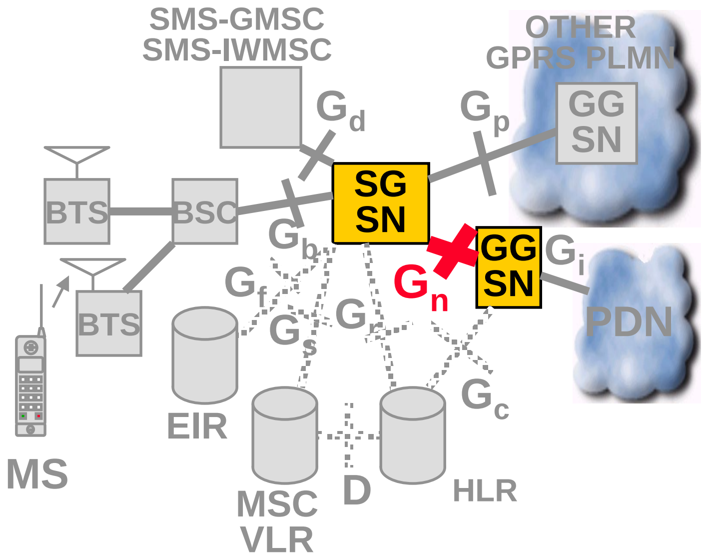
GPRS TUNNELING PROTOCOL (GTP) PROTOCOL STACK





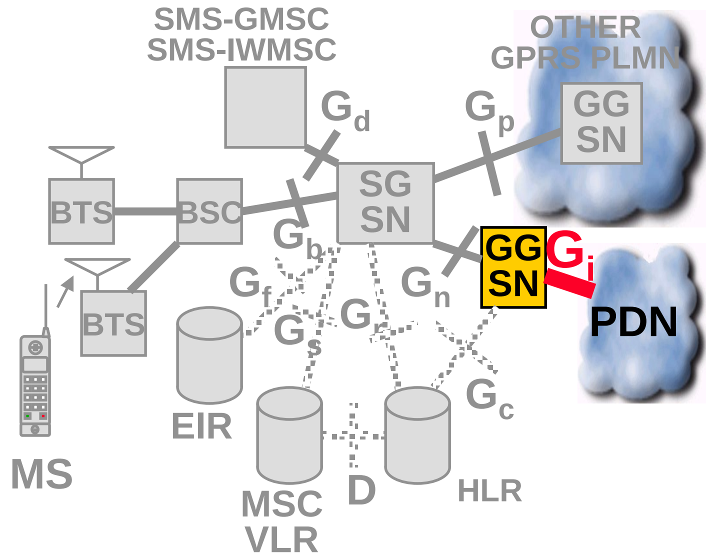
- GPRS Tunneling Protocol (GTP) is used to carry user packets between nodes
  - GTP allows various protocols and is adaptable to both inter- and intra-PLMN GGSN interfaces
    - UDP/IP if reliable link is not required, TCP/IP if required

The G_n Interface: SGSN-GGSN



- The SGSN and GGSN are linked by a GPRS backbone using IP routing
- The G_n interface creates and operates through secure tunnels, using the GPRS Tunneling Protocol (GTP)
- The GTP packet headers include
  - Tunnel endpoint and group identity
  - PDU type
  - QoS parameters
  - Routing protocol identification
    - Static, RIP2, OSPF
- Beneath IP, any transport architecture can be used
  - Ethernet, Token-Ring, FDDI, ISDN, ATM

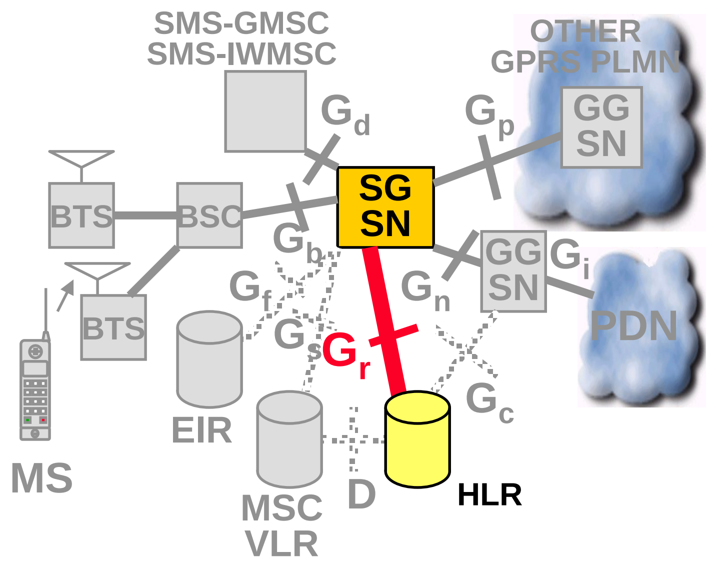
The G_i Interface: GGSN-PDN



- If the G_i interface is implemented via a public network, IP Security Protocol (IPSEC) can be used to provide link authentication and encryption
  - This allows use of public networks such as the internet while maintaining confidentiality of data
- The GGSN creates VPN tunnels using security protocols like IPSEC if needed
- Four tunneling protocols are available:
  - PPTP (client-initiated)
  - L2F, L2TP (implemented on ISP side)
  - IPSec (layer-3 secure protocol)
- Transparent and Non-Transparent modes are available

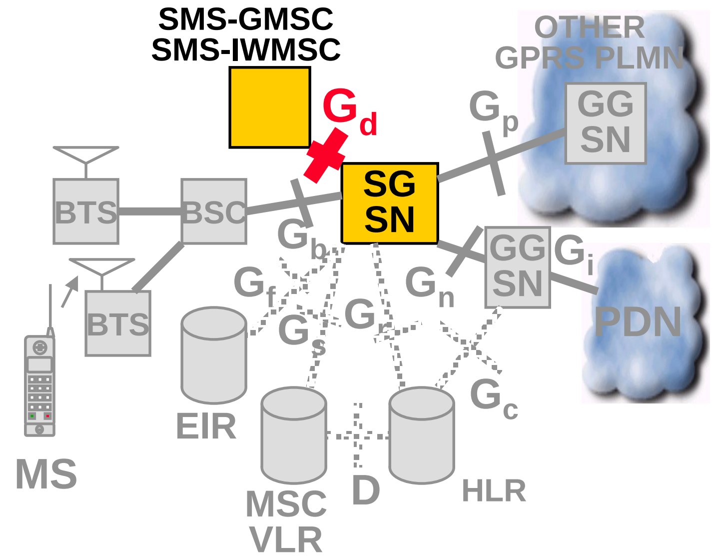
The G_r Interface: SGSN-HLR

- The G_r interface is an extension of the GSM-MAP (mobile application part)
- Most network manufacturers use an SS7 gateway element to provide interworking between the GPRS network and the SS7-based voice network
  - This relieves the SGSN from having to do SS7 processing
  - The SS7 gateway can be a conventional server, usually with redundancy features on both the SGSN (IP) and SS7 sides



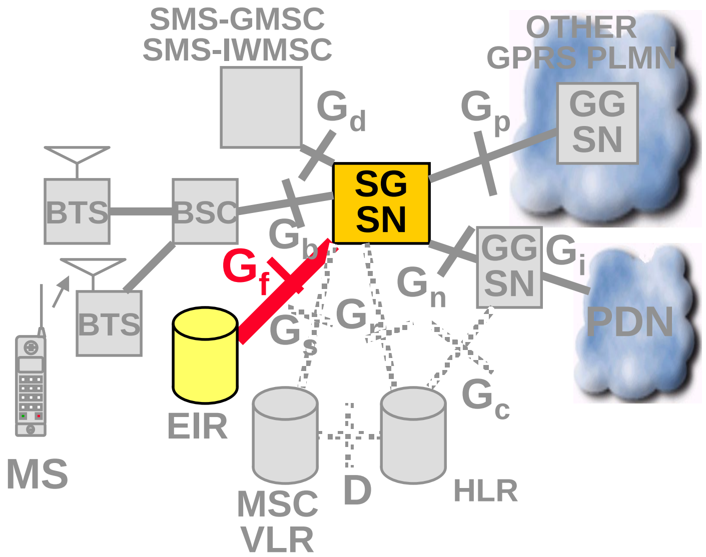
The G_d Interface: SGSN-SMCS GMSC/IWMSC

- The G_d interface delivers SMS messages via GPRS in the same manner as the GSM-MAP



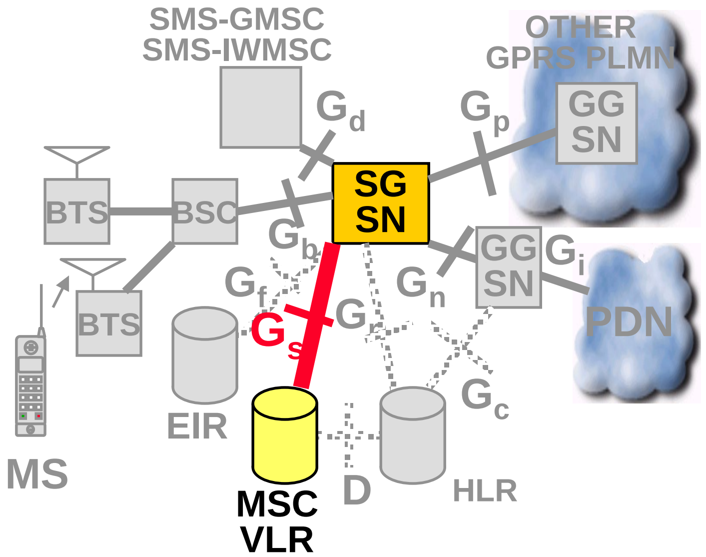
The G_f Interface: SGSN-EIR

- The G_f interface connects the SGSN and the Equipment Identity Register (EIR)



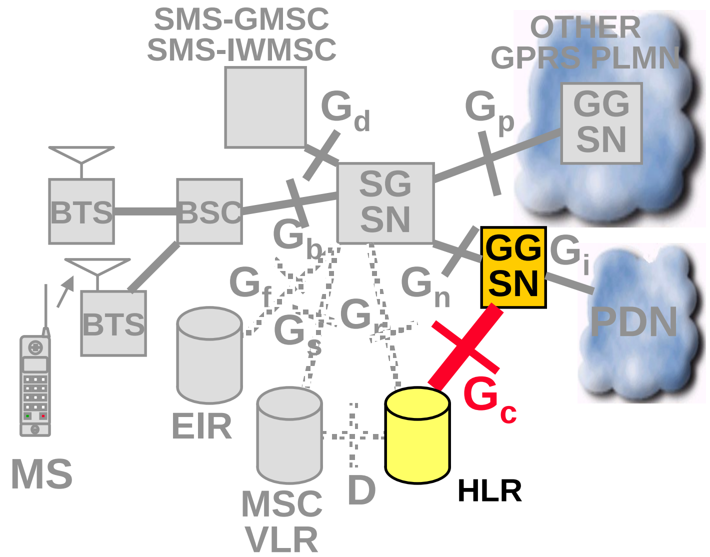
The G_s Interface: SGSN-MSC/VLR

- The G_s interface is optional
  - Provides simultaneous GPRS and GSM operation between SGSN and MSC/VLR (same as BSSMAP but optional)



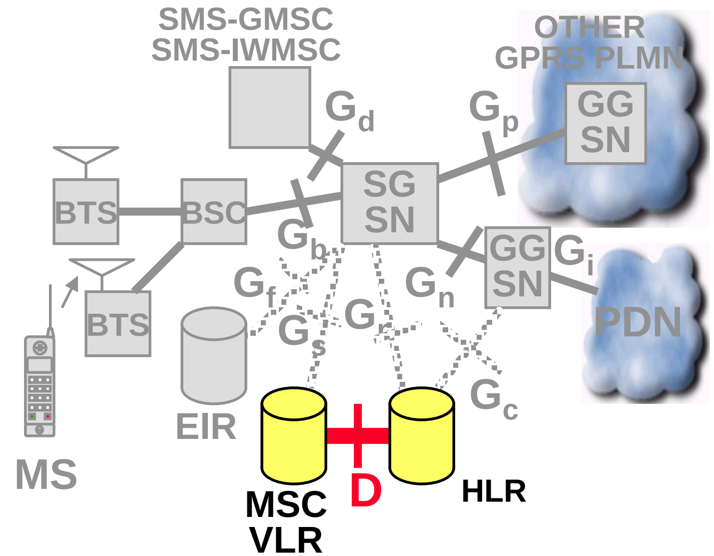
The G_c Interface: GGSN-HLR

- The G_c interface is optional
  - Provides the same functions as the MAP between GGSN and HLR



The D Interface: MSC/VLR - HLR

- The MAP-D interface is used by both GSM and GPRS networks to communicate between the HLR and the VLR in the MSC
- This link is specified in the GSM-MAP and is not changed in GPRS



Quality of Service

Service Precedence
High
Medium
Low

Class	Reliability: Probability of Lost Packet	Reliability: Probability of Duplicated Packet	Reliability: Probability of Out-of Sequence Packets	Reliability: Probability of Corrupted Packets
1	10^9	10^9	10^9	10^9
2	10^4	10^5	10^5	10^6
3	10^2	10^5	10^5	10^2

- Mobile packet applications have a wide range of reliability expectations -- real-time multimedia, Web browsing, email transfer
- QoS Classes settable per session are a very important feature
  - Service Precedence
    - Priority of a service in relation to other services
  - Reliability
    - Required transmission characteristics (3 classes defined)
  - Delay
    - Maximum values for mean delay and 95-percentile delay
  - Throughput
    - Maximum-Peak bit rate and the mean bit rate

Quality of Service: the Delay Parameter

	Delay			
	128 byte packet		1024 byte packet	
Class	Mean Delay	95% Delay	Mean Delay	95% Delay
1	<0.5s	<1.5s	<2s	<7s
2	<5s	<25s	<15s	<75s
3	<50s	<250s	<75s	<375s
4	Best Effort	Best Effort	Best Effort	Best Effort

- Using these QoS Classes, QoS profiles can be negotiated between the user and the network for each session, depending on QoS demand and currently available resources.
  - Billing is based on data volume, type of service, and QoS profile

Mobile Classes and Simultaneous Usage

- In a GSM network, two classes of service can run concurrently:
  - Circuit-Swied Services (speech, data, and SMS)
  - Packet-Swied Services (GPRS)
- Three Classes of Mobile Stations are defined:
  - Class A mobiles
    - Support simultaneous operation of GPRS and conventional GSM services, but two separate radio chains are required
  - Class B mobiles
    - Able to register with the network for both GPRS and conventional GSM services simultaneously, but can only use one of the two services at a given moment - voice can pre-empt data
  - Class C mobiles
    - Able to attach for either conventional GSM or GPRS, manually swied
    - Simultaneous registration (and usage) is not possible, except for SMS messages which can be received and sent at any time

MultiSlot Classes of GPRS Terminals

- A mobile's multislot class is the sum of
  - Number of simultaneously supported slots in uplink
  - Number of simultaneously supported slots in downlink
- DL and UL number of slots can be different due to asymmetrical traffic
- Class 1 = 1 Rx and 1 Tx slot
- Class 29 = 8 Rx and 8 Tx slots
- As of mid-2001, Class-B mobiles with multislot class 4 (3 DL + 1 UL) were available

MultiSlot Class	Max # of Slots			Minimum # of Slots				Type
	RX	TX	Sum	Tta	Ttb	Tra	Trb	
1	1	1	2	3	2	4	2	1
2	2	1	3	3	2	3	1	1
3	2	2	3	3	2	3	1	1
4	3	1	4	3	1	3	1	1
5	2	2	4	3	1	3	1	1
6	3	2	4	3	1	3	1	1
7	3	3	4	3	1	3	1	1
8	4	1	5	3	1	2	1	1
9	3	2	5	3	1	2	1	1
10	4	2	5	3	1	2	1	1
11	4	3	5	3	1	2	1	1
12	4	4	6	2	1	2	1	1
13	3	3	n/a	n/a	a)	3	a)	2
14	4	4	n/a	n/a	a)	3	a)	2
15	5	5	n/a	n/a	a)	3	a)	2
16	6	6	n/a	n/a	a)	2	a)	2
17	7	7	n/a	n/a	a)	1	3	2
18	8	8	n/a	n/a	0	0	0	2
19	8	2	n/a	3	b)	2	c)	1
20	8	3	n/a	3	b)	2	c)	1
21	8	4	n/a	3	b)	2	c)	1
22	8	4	n/a	2	b)	2	c)	1
23	8	6	n/a	2	b)	2	c)	1
24	8	2	n/a	3	b)	2	c)	1
25	8	3	n/a	3	b)	2	c)	1
26	8	4	n/a	3	b)	2	c)	1
27	8	4	n/a	2	b)	2	c)	1
28	8	6	n/a	2	b)	2	c)	1
29	8	6	n/a	2	b)	2	c)	1

a) = 1 with frequency hopping
a) = 0 without frequency hopping
b) = 1 with frequency hopping or change from RX to TX
b) = 0 without frequency hopping and no change from RX to TX
c) = 1 with frequency hopping or change from RX to TX
c) = 0 without frequency hopping and no change from RX to TX

Type 1 mobiles never transmit and receive at the same time
Type 2 mobiles are capable of transmitting and receiving simultaneously

Session Management
Mobility Management
Routing

Attachment and Detachment Procedure

- Before a mobile station can use GPRS services, it must register with an SGSN of the GPRS network
  - The network checks to see if the user is authorized
  - copies the user profile from the HLR to the SGSN
  - assigns a packet temporary mobile subscriber identity (P-TMSI) to the user
  - This procedure is called GPRS attach
- For mobile stations with both circuit-swied and packet-swied services it is possible to perform combined GPRS/IMSI attach procedures
- Disconnection from the GPRS network is called GPRS detach
  - can be initiated by the mobile station
  - Can be initiated by the network (SGSN or HLR)

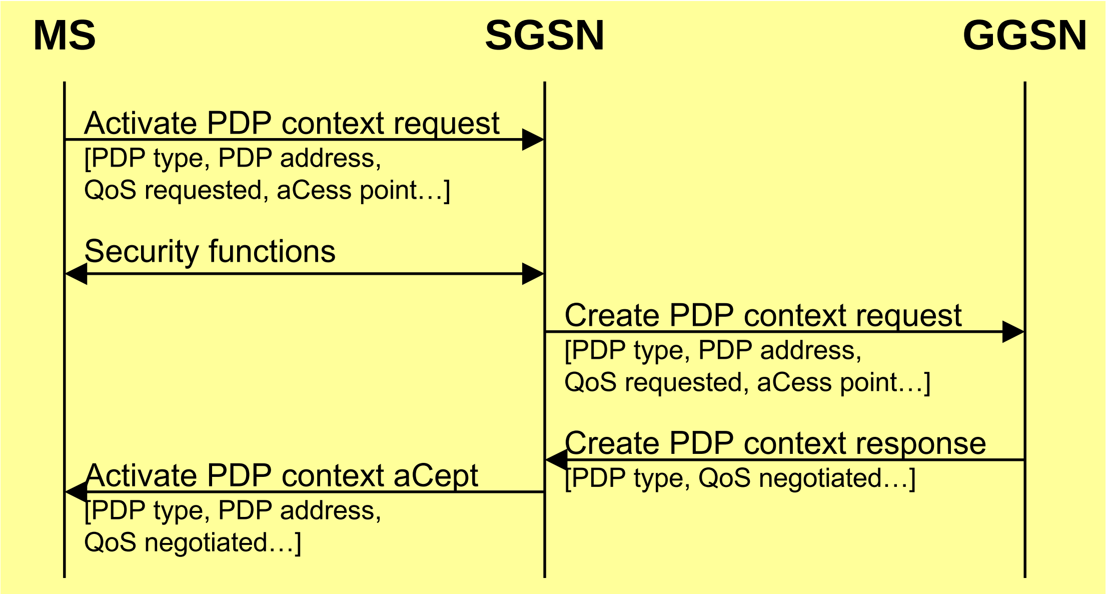
Session Management - PDP Context

- Suppose a mobile has suCessfully completed GPRS attach
- To exchange data packets with external PDNs, the mobile must apply for one or more addresses used in the PDN
  - An IP address in case the PDN is an IP network
  - This is called a Packet Data Protocol Address (PDP address)
- For each session, a PDP context is created describing its characteristics. It contains:
  - PDP type (IPv4, etc)
  - PDP address (129.187.222.10)
  - The requested QoS
  - The address of the GGSN that serves as the aCess point to the PDN
- The PDP context is stored in the MS, the SGSN, and the GGSN
- With an active PDP context, the mobile is “visible” to the external PDN and can send and receive packets
  - Mapping between the PDP and IMSI enables the GGSN to transfer data packets between the PDN and the MS
  - A user may have several simultaneous PDP contexts active at once

Allocation of PDP Addresses

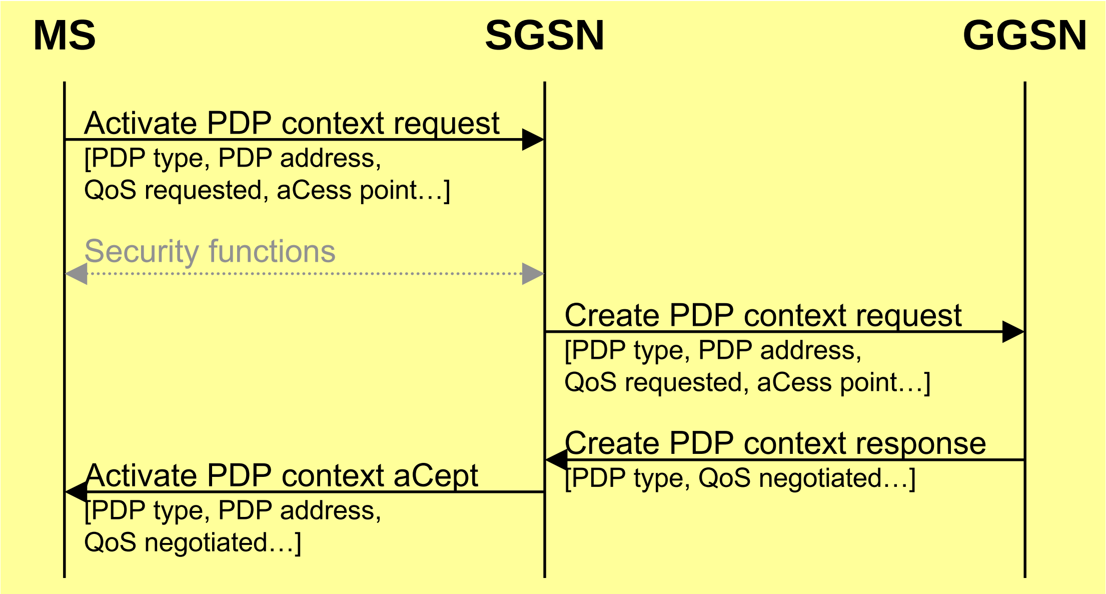
- PDP address allocations can be static or dynamic
  - Static: User's Home-PLMN network operator assigns a permanent PDP address to the user
  - Dynamic: A PDP address is assigned to the user upon activation of a PDP context
    - Can be assigned by the home PLMN (dynamic home-PLMN PDP address)
    - Can be assigned by the visited PLMN (dynamic visited-PLMN PDP address)
  - The home PLMN operator decides which alternative is used
  - In case of dynamic PDP addresses, the GGSN is responsible for the allocation and the activation/deactivitation of PDP addresses

PDP Context Activation Procedure



- The mobile station requests a PDP context from the SGSN
  - If dynamic PDP address assignment is requested, the parameter PDP address will be left empty
- Security functions (authentication) will be performed
- SGSN will ask for a PDP context from the GGSN
- The GGSN will create a new entry in its PDP context table
- GGSN sends confirmation to the SGSN including address if dynamic
- SGSN updates its PDP context table and confirms to the mobile

Anonymous PDP Context Activation

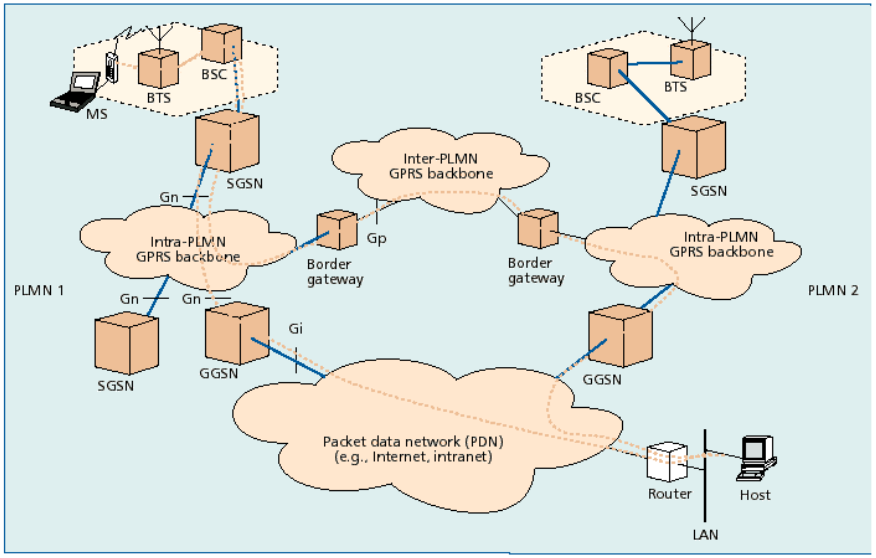


- GPRS also supports anonymous PDP context activation
  - In this case, security functions are skipped
  - The user (IMSI) using the PDP context is not known to the network
- Anonymous context activation can be used for prepaid services, where the user does not want to be identified
  - Only dynamic address allocation is possible in this case

Routing - An Example

Routing Example:

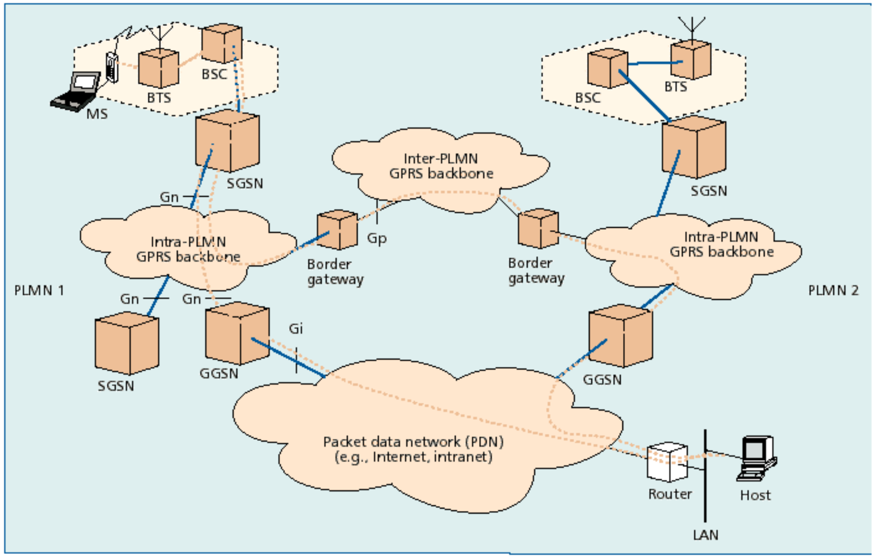
- A GPRS mobile in PLMN1 sends IP packets to a web server
- The mobile's SGSN encapsulates the IP packets, examines PDP context, and routes them through the intra-PLMN GPRS backbone to the appropriate GGSN



- The GGSN decapsulates the packets, sends them onto the IP network
  - IP routing mechanisms transfer the packets to the the aCess router of the destination network
  - The destination network aCess router delivers the packets to the host

Routing - Another Example

- Suppose the home-PLMN of the mobile station is PLMN2
- An IP address has been assigned to the mobile by the GGSN of PLMN2
  - Mobile's IP address has same network prefix as the IP address of the GGSN in PLMN2



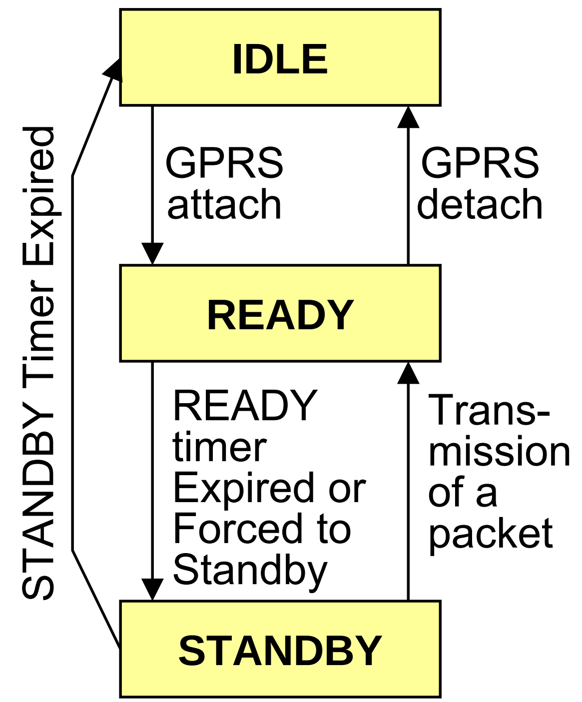
- The correspondent host is now sending IP packets to the MS
- Packets enter the IP network, are routed to the GGSN of PLMN2
  - This is the home-GGSN of the mobile
- The GGSN queries the HLR, finds the mobile currently in PLMN1
  - It encapsulates the incoming IP packets and tunnels them through the inter-PLMN GPRS backbone to the appropriate SGSN in PLMN1
- The SGSN decapsulates the packets and delivers them to the MS

Location Management

- The main task of location management is to keep track of the user's current location
  - This allows incoming packets to be routed to the MS
- The MS frequently sends location update messages to its SGSN
  - If the mobile sends updates infrequently, its location is not known and paging is necessary for each downlink packet (adding considerable delay)
  - If the mobile sends updates frequently, its location is well known and data packets can be delivered with no paging delay
  - Location updates consume battery power and uplink radio capacity, so a balance is required to optimize resource usage
- To optimize the location management function in GPRS, a state model has been created and applied

The GPRS Location Management State Model

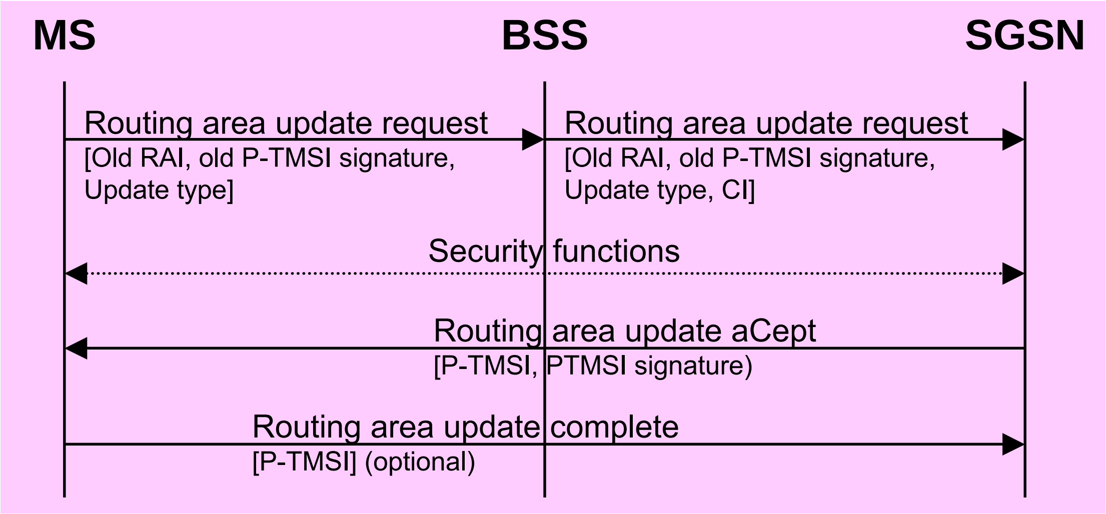
- A mobile can be in any of three states depending on its current traffic level
  - Location update frequency is dependent on the MS state
- In IDLE state, the mobile is not reachable
- Performing a GPRS attach, the mobile enters the READY state
- With a GPRS detach the mobile may disconnect from the network and fall back into the IDLE state
  - all PDP contexts will be deleted
- The STANDBY state is reached when a MS does not send any packets for a long period
  - The READY timer expires



Mobile Action based on GPRS Location State

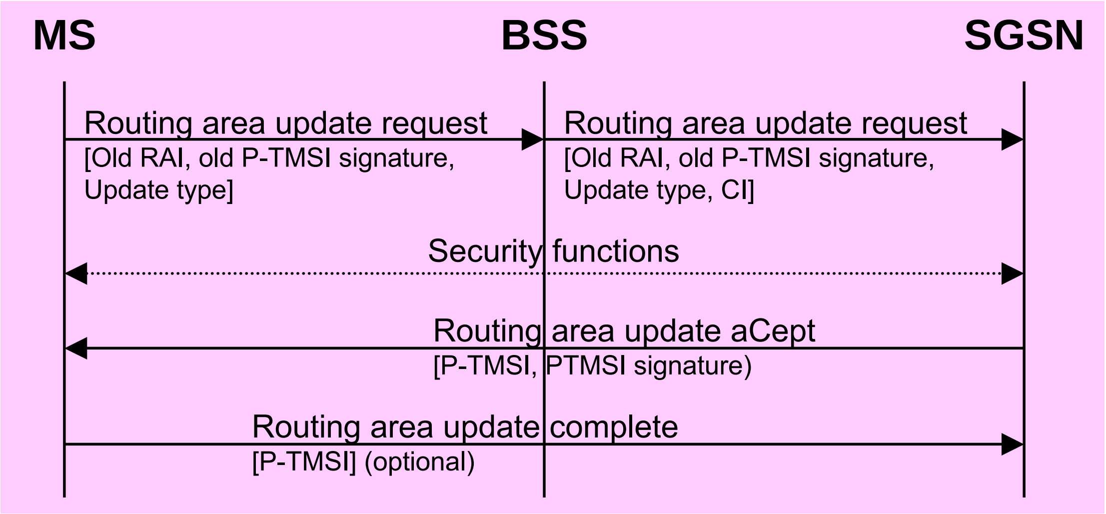
- In IDLE state, no location updating is performed
  - The current location of the mobile is unknown to the network
- An MS in READY state informs its SGSN of every movement to a new cell
- A GSM Location Area is divided into several Routing Areas (RAs)
  - An RA can consist of one or several cells
- A MS in STANDBY state will inform its SGSN only when it moves into a new RA
  - Cell changes are not disclosed
- To find out the current cell of a MS in STANDBY, the mobile is paged throughout the current RA
- For MS in READY state, no paging is necessary
- Whenever a mobile moves to a new RA, it sends a "routing area update request" to its assigned SGSN
  - Message contains the routing area identity (RAI) of its old RA
  - The BSS adds the cell identifier of the new cell, from which the SGSN can derive the new RAI

Intra-SGSN Routing Area Updates



- The mobile has moved into an RA that is assigned to the same SGSN as the old RA
  - The SGSN already has the necessary user profile
  - SGSN can assign a new packet temporary mobile subscriber identity (P-TMSI)
- Since the routing context does not change, there is no need to inform other network elements, such as the GGSN or the HLR

Inter-SGSN Routing Area Updates



- The new RA is administered by a different SGSN than the old RA
- The new SGSN realizes that the MS has changed to its area and requests the old SGSN to send the PDP contexts of the user
- The new SGSN informs the involved GGSNs of the users new routing context
- The HLR (and if needed, the MSC/VLR) are informed about the user's new SGSN

Combined RA/LA Updates

- It is also possible to have combined Routing Area/Location Area updates
  - These oCur when a mobile using GPRS as well as conventional GSM moves into a new LA
- The MS sends a "routing area update request" to the SGSN
  - The parameter "update type" is used to indicate that an LA update is needed
  - This message is forwarded to the VLR, which performs the LA update

SUMMING IT ALL UP:

MICRO vs MACRO MOBILITY MANAGEMENT

•**Micro mobility management** tracks the current routing area or cell of the mobile station.

•It's performed by the SGSN

•**Macro mobility management** keeps track of the mobile station's current SGSN and stores it in the HLR, VLR, and GGSN

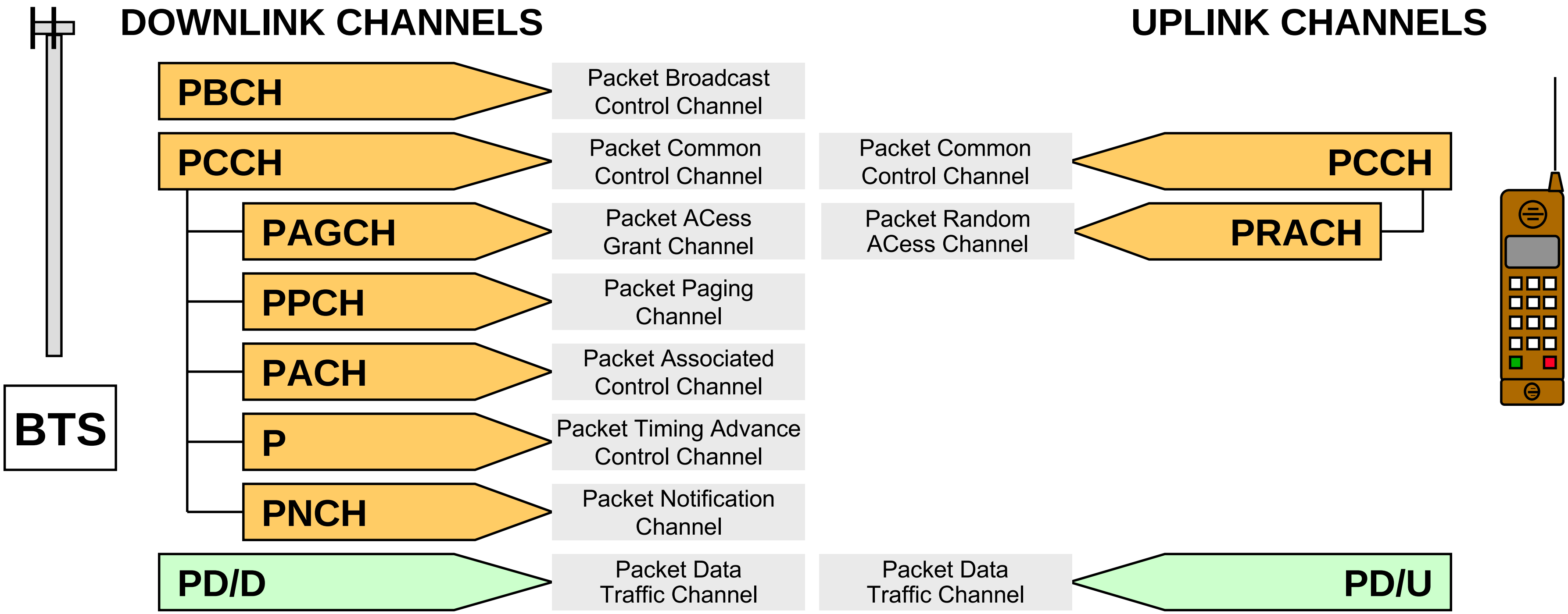
GPRS

Air Interface - Physical Layer

Logical Channels in GPRS

- A series of logical channels are defined on top of the physical channels for various purposes
  - Signaling
  - Broadcast of general system information
  - Synchronization
  - Channel assignment
  - Paging
  - Payload Transport
- These channels can be divided into two broad categories:
  - Traffic Channels
  - Signaling (control) Channels

GPRS Logical Channels



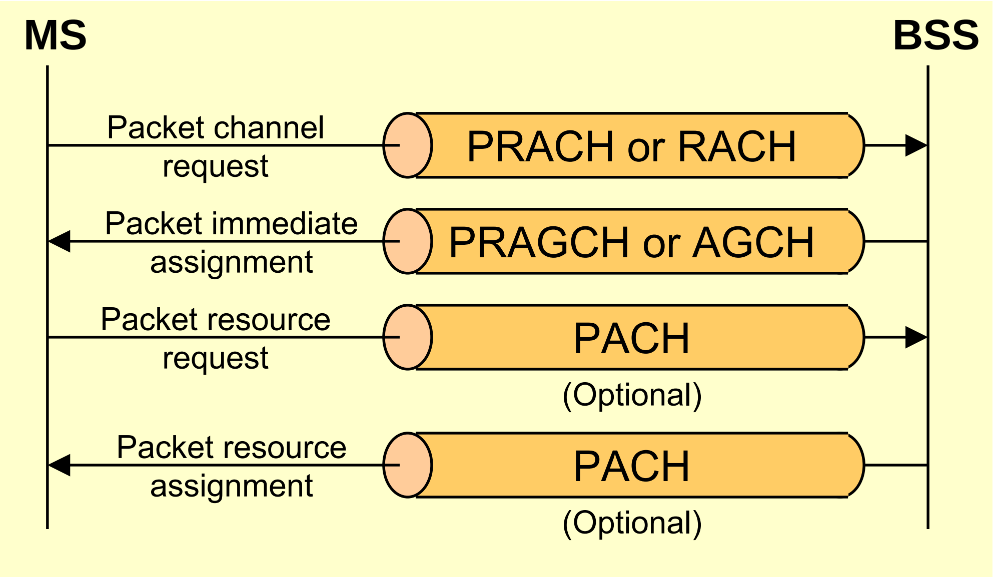
Functions of the Logical Channels

- The packet data traffic channel (PD) is used to transfer user data
  - Assigned to one mobile station (or multiple stations if a PTM)
  - One mobile can use several PDs simultaneously
- The packet broadcast control channel (PBCH) is a unidirectional point-to-multipoint signaling channel from the BSS to mobile stations
  - Used by the BSS to broadcast configuration data about the GPRS network to all GPRS mobile stations
  - The PBCH also broadcasts configuration data about the GSM cell so a GSM/GPRS mobile does not need to listen to the BCH
- The packet common control channel transports signaling information for network aCess management (allocation of radio resources & paging). It consists of four sub-channels:
  - The packet random aCess channel (PRACH) is used by the mobile to request one or more PD
  - The packet aCess grant channel (PAGCH) is used to allocate one or more PD to a mobile
  - The packet paging channel (PPCH) is used by the BSS to find out the location of a mobile (paging) prior to downlink packet transmission
  - The packet notification channel (PNCH) informs a mobile station of incoming PTM messages (multicast or group call)

More Logical Channel Detail

- The Dedicated Control Channel is a bidirectional point-to-point signaling channel. It contains:
  - The packet associated control channel (PACH)
    - Always allocated in combination with one or more PD assigned to one mobile
    - Transports power control information
  - The Packet timing advance control channel (P) is used for adaptive frame synchronization
- Coordination between circuit-swied and packet-swied channels is important
  - If the PCCH is not available in a cell, the mobile can use the CCH of conventional GSM to initiate a packet transfer
  - If the PBCH is not available, it will listen to the broadcast control channel (BCH) to get info on network configuration

Uplink Channel Allocation

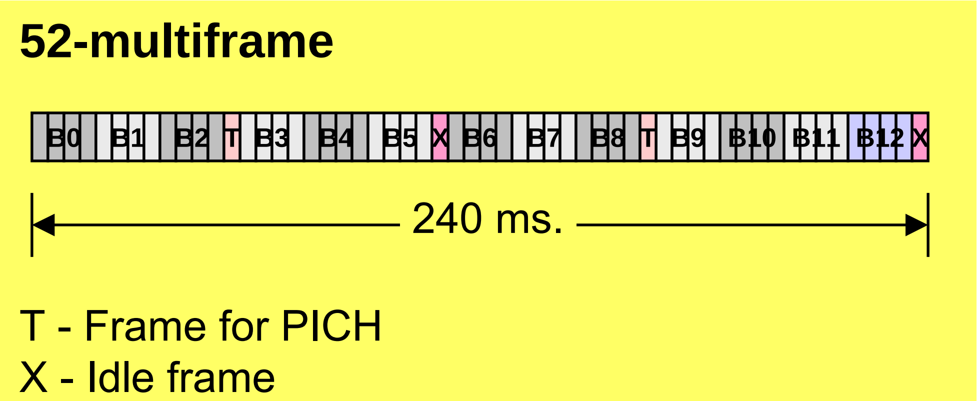


- Mobile requests radio resources for uplink transfer by sending a “packet channel request” on the PRACH or RACH
- The network answers on the PAGCH or AGCH, telling the mobile which PDCHs it may use
- An uplink state flag is transmitted on the downlink telling the mobile whether the uplink is free

Mapping of Packet Data Logical Channels onto Physical Channels

- The mapping of logical channels onto physical channels has two components:
  - Mapping in frequency based on the TDMA frame number and the frequencies allocated to the BTS and the mobile station
  - Mapping in time based on the definition of complex multiframe structures on top of the TDMA frames
- A multiframe structure for PDCHs consisting of 52 TDMA frames is shown in the next slide
  - Four consecutive TDMA frames form one block (12 blocks, B011), Two TDMA frames are reserved for transmission of the P, and the remaining two frames are idle frames
- The mapping of logical channels into blocks B0-B11 of the multiframe can vary from block to block and is controlled by parameters broadcast on the PBCH
- Besides the 52-multiframe, which can be used by all logical GPRS channels, a 51-multiframe structure is defined. It is used for PDCHs carrying only the logical channels PCCH and PBCH and no other logical channels

GPRS Physical Channel: 52-Multiframe



- The GPRS 52-multiframe is made up of two 26 control multiframes of voice mode GSM
  - Made up of 12 blocks, B0-B11 of four frames each, plus four additional frames
  - Length: 240 ms.
  - Packet mode control and data channels are mapped into different slots
- A multislot MS can be assigned up to eight slots in any frame of any of 12 blocks
- In a given cell up to four downlink/uplink pairs of 52-multiframes can be generated on four different pairs of frequencies

Channel Coding

Application of Channel Coding: Example

- Suppose that coding scheme CS-2 is being used
  - The coding steps are shown in functional block form above
- First, 271 information bits (including the 3-bit uplink state flag USF) are mapped to 287 bits using a systematic block encoder
  - In other words, 16 parity bits are added
  - The USF pre-encoding maps the first three bits of the information block (the USF) to six bits in a systematic way
  - Four zero tail bits are added at the end of the block
    - – The tail bits are needed for termination of the subsequent convolutional coding
  - For the convolutional coding, a non-systematic rate-1/2 encoder of constraint length 4 is used

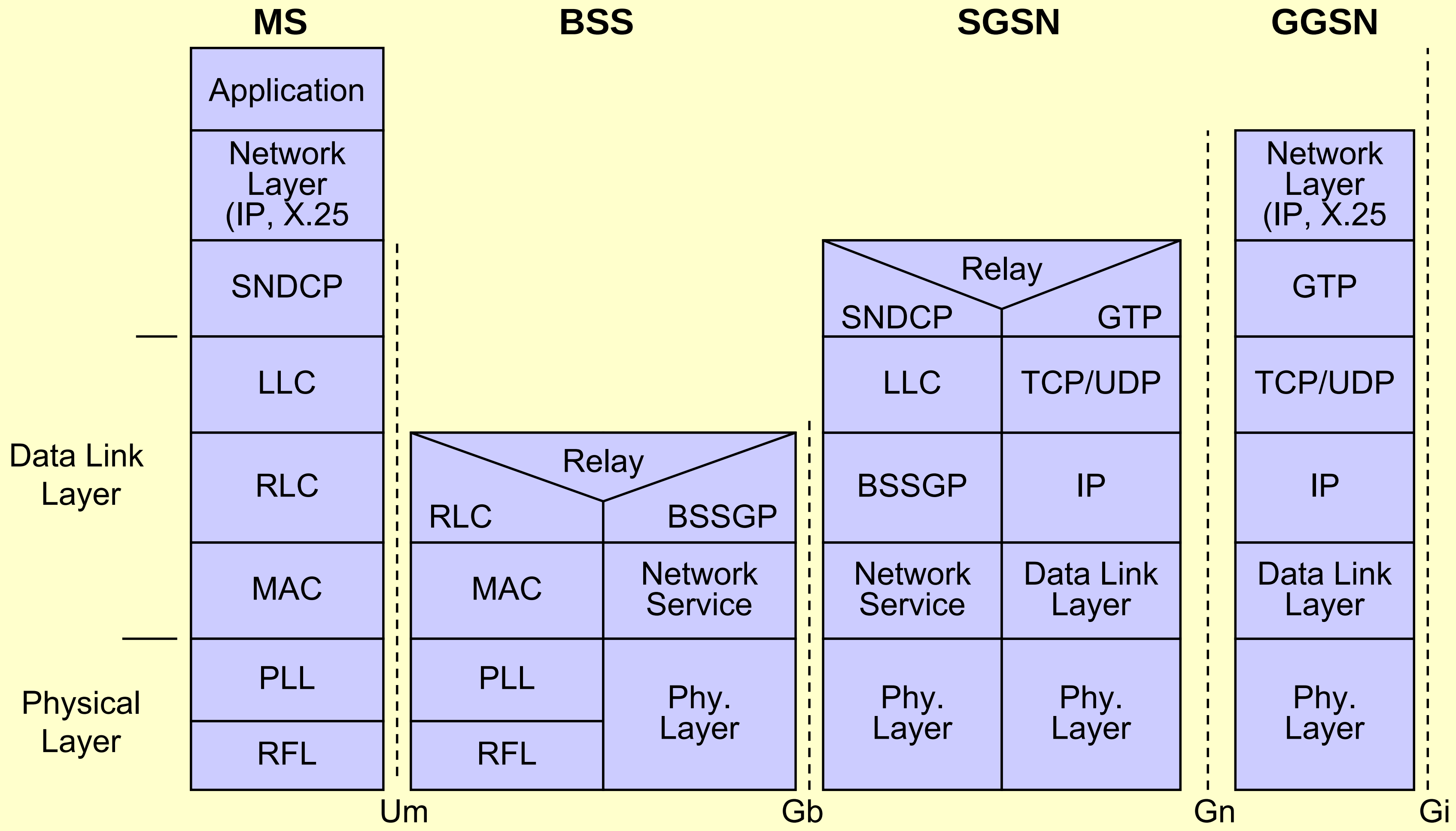
Coding of the PD Traffic Channel

- One of the four coding schemes is chosen for the PD, depending on the quality of the channel
  - Under bad conditions, use CS-1 and obtain a data rate of 9.05 kbit/s per GSM time slot, but with very reliable coding
  - Under good conditions, we may transmit without convolutional encoding and achieve a data rate of 21.4 kbit/s per time slot
  - With eight time slots we would obtain a data rate of 171.4 kbit/s
  - In practice, multiple users share the time slots, and a much lower rate is available to the individual user
    - About 40 kbit/s per user if three users share the slots and CS-3 is employed
- CS-1 is used for coding the signaling channels
- After encoding, the codewords are input to a block interleaver of depth 4
  - On the receiver side, the codewords are de-interleaved
  - The decoding is performed using the well-known Viterbi Algorithm

GPRS

Protocol Architecture

GPRS PROTOCOL ARCHITECTURE



SNDCP	Subnetwork dependent convergence protocol
LLC	Logical link control
RLC	Radio link control
MAC	Medium aCess control
PLL	Physical link layer
RFL	Physical RF layer

BSSGP	BSS GPRS application protocol
GTP	GPRS tunneling protocol
TCP	Transmission control protocol
UDP	User datagram protocol
IP	Internet Protocol

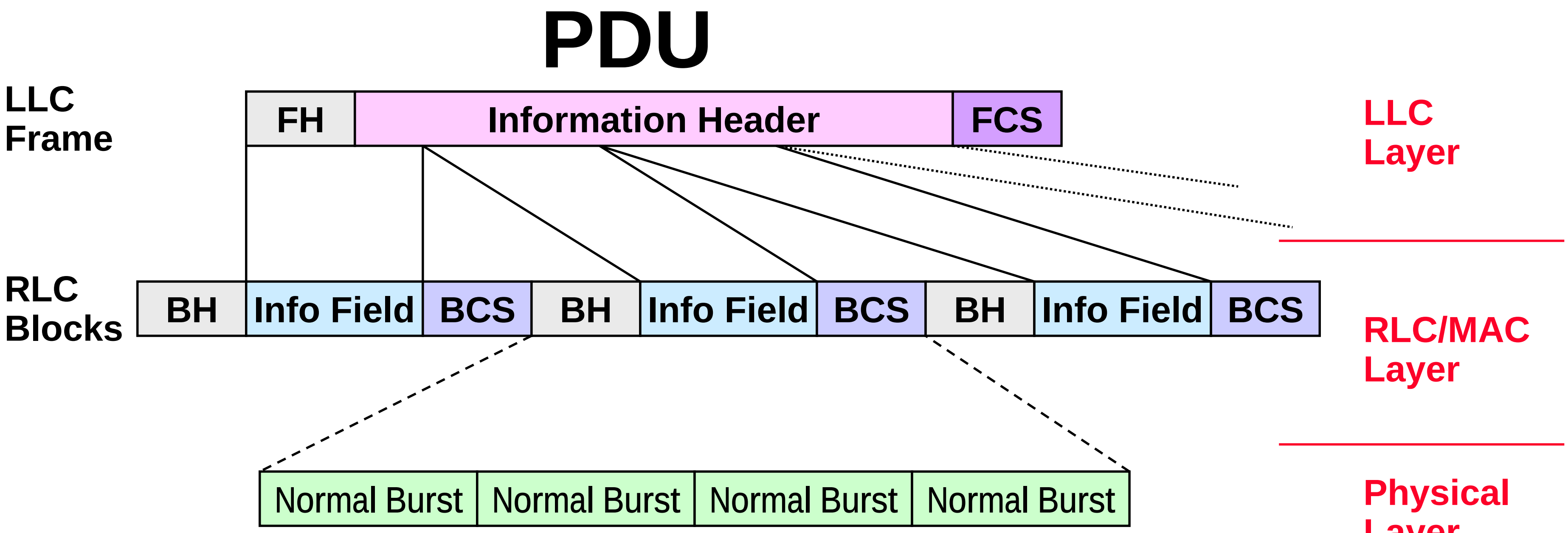
GPRS Backbone: SGSN GGSN

- User data packets are encapsulated within the GPRS backbone network
  - GPRS tunneling protocol tunnels user data packets and related signaling information between the GPRS support nodes (GSNs)
- The protocol is defined for two instances:
  - between GSNs of one PLMN (Gn interface)
  - Between GSNs of different PLMNs (Gp interface)
- In the transmission plane, GTP uses a tunnel mechanism to transfer user data packets
- In the signaling plane, GTP specifies a tunnel control and management protocol
  - The signaling is used to create, modify, and delete tunnels
- GTP packets carry the user's IP or X.25 packets
  - Below GTP, the standard protocols TCP or UDP are used to transport the GTP packets within the backbone network
  - X.25 expects a reliable data link, so TCP is used
  - UDP is used for aCess to IP-based packet data networks, which do not expect reliability in the network layer or below
  - IP is used in the network layer to route packets through the backbone
  - Ethernet, ISDN, or ATM-based protocols may be used below IP

Subnetwork Dependent Convergence Protocol

- The Subnetwork Dependent Convergence Protocol SNDCP is used to transfer data packets between the SGSN and MS. Its functionality includes:
- Multiplexing of several connections of the network layer onto one virtual logical connection of the underlying LLC layer
- Compression and decompression of user data and redundant header information

GPRS Downlink/Uplink Segmentation



FH: Frame Header
FCS: Frame Check Sequence
BH: Block Header
BCS: Block Check Sequence

GPRS Transmission/Reception Data Flow

- A temporary block flow (TBF) is a physical connection used by the two radio resource (RR) entities to support the unidirectional transfer of Logical Link Control (LLC) PDUs on packet data physical channels
- The TBF is allocated some radio resources on one or more PDCHs and comprises a number of RLC/MAC blocks carrying one or more LLC PDUs.
- A radio block consists of a 1 byte MAC header, followed by RLC data or an RLC/MAC control block and terminated by a 16-bit block check sequence (BCS)
    - It is carried by four normal bursts (I.e., it’s 57 bits long)
- A TBF is temporary and is maintained only for the duration of the data transfer
- Each TBF is assigned a temporary flow identity (TFI) by the network; the TFI is unique in both directions.

GPRS Slot Assignments and Throughput

- GPRS allows a maximum of eight slots per frame to be allocated to the PD on the downlink and uplink on all radio blocks B0-B11.
- On the downlink, an IP datagram of 1500 bytes to be transmitted as an LLC PDU must first be fragmented into 29 RLC blocks
  - These blocks can be transmitted using a total of 116 consecutive bursts
  - During one 52-multiframe with an 8 slots/frame dynamic allocation scheme, 3.3 such IP datagrams can be transmitted, yielding a maximum rate of 165.5 kb/s for the GPRS downlink
- On the uplink, an IP datagram of 1500 bytes to be transmitted as an LLC PDU, is fragmented into 31 RLC blocks which can be transmitted in 124 slots.
  - During one 52-multiframe with an 8 slots/frame dynamic allocation scheme, three such IP datagrams can be transmitted, yielding a maximum rate of 154 kb/s for the GPRS uplink

Air Interface: Data Link Layer - LLC

- The data link layer between the MS and the network is divided into two sublayers
  - LLC layer (between MS-SGSN)
  - RLC/MAC layer (between MS-BSS)
- The LLC layer provides a highly reliable logical link between an MS and its assigned SGSN
  - Uses HDLC protocol including sequence control, in-order delivery, flow control, error detection, and retransmission (ARQ), and ciphering for confidentiality
  - Variable frame lengths are possible
  - Both acknowledged and unacknowledged modes are supported
  - The protocol is mainly an adapted version of LAPDm of GSM

Air Interface - Data Link Layer RLC/MAC

- The RLC/MAC layer includes two functions:
  - Reliable link between the MS and BSS
    - Includes segmentation and reassembly of LLC frames into RLC data blocks and ARQ of uncorrectable codewords
  - Medium ACess Control MAC layer controls the aCess attempts of the MS on the radio channel shared by several MSs
    - Algorithms for contention resolution, multiuser multiplexing on a PD, scheduling and prioritization based on the negotiated QoS
    - Uses Slotted Aloha principle
    - Both acknowledged and unacknowledged modes are supported

Air Interface Physical Layer

- The physical layer is divided into two sublayers:
- The Physical Link Layer PLL
  - Provides a physical channel between the MS and the BSS
  - Tasks include:
    - Channel coding, detection of errors, forward error correction (FEC), indication of uncorrectable codewords, interleaving, and detection of physical link configuration
- The Physical RF Layer RFL
  - The RFL operates below the PLL
  - Its main roles are modulation and demodulation
- BSS SGSN Interface
  - The BSS GPRS Application Protocol (BSSGP) delivers routing and QoS information between BSS and SGSN
  - The underlying Network Service (NS) protocol is based on the Frame Relay protocol

Signaling Plane

- The protocol architecture of the signaling plane includes protocols for control and support of the functions of the transmission plane:
  - GPRS attach and detach
  - PDP context activation
  - Control of routing paths
  - Allocation of network resources
- Between MS and SGSN, the GPRS Mobility Management and Session Management (GMM/SM) is used
- Signaling architecture between SGSN and HLR, VLR, and EIR are the same as used in conventional GSM with a few additions

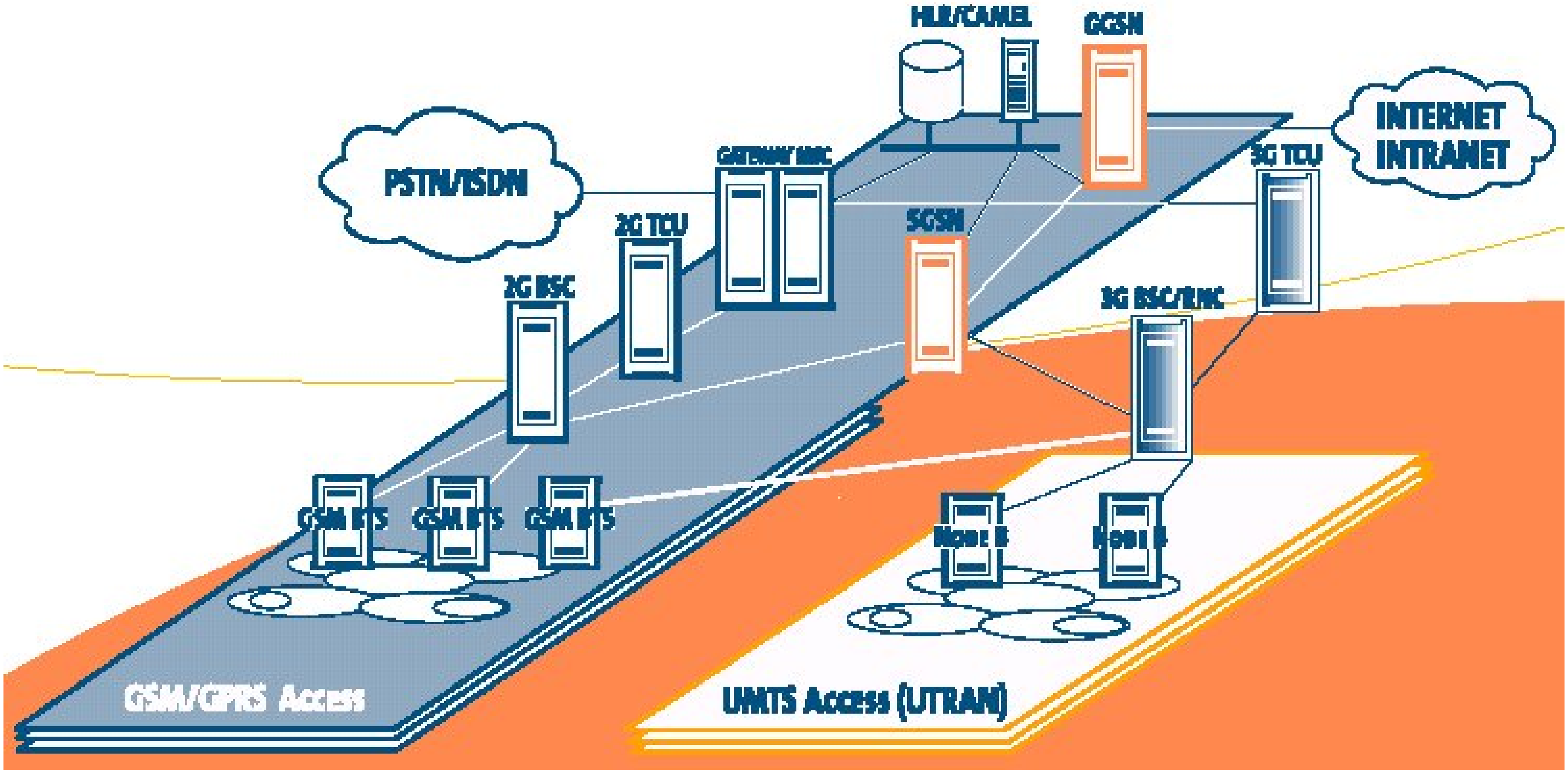
Interworking with IP Networks

- GPRS supports both IPv4 and IPv6
  - The Gi interface is the interworking point with IP networks
  - From outside, the GPRS network looks like any other IP subnetwork, and the GGSN looks alike a usual IP router
- Each registered user who wants to exchange data packets with the IP network gets an IP address
  - The IP address is taken from the address space of the GPRS operator
  - In order to support a large number of mobile users, it is essential to use dynamic IP address allocation (in IPv4)
    - DHCP server is installed; the address resolution between IP and GSM is performed by the GGSN using the appropriate PDP context
- To protect the PLMN from unauthorized aCess, a firewall is installed between the private GPRS network and the external IP network
- With this configuration, GPRS can be seen as a wireless extension of the Internet all the way to a mobile station or mobile computer. The mobile user has direct connection to the Internet!

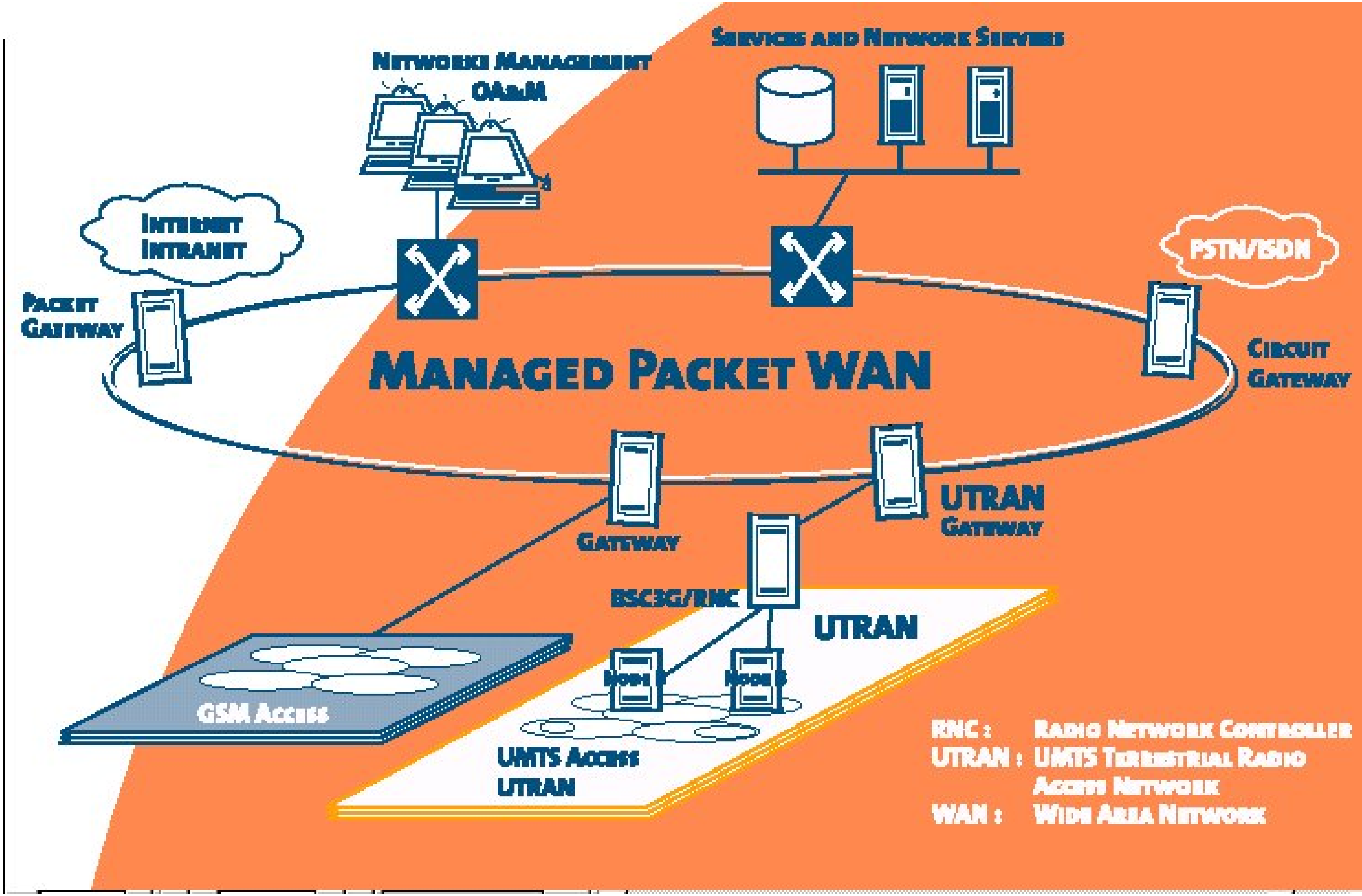
GPRS:

Nortel Implementation

Nortel GPRS-UMTS Integration



Nortel Managed Packet WAN



Feedback from GPRS Trials in UK

118 March 19, 2001 International

Credit RCR News, March 19, 2001 www.rcrnews.com

EUROPE UPDATE

Detractors concerned about GPRS speeds, interoperability

OXFORD, United Kingdom—While all the major European cellphone operators have either launched or announced target dates for GPRS services, a growing number of technology developers are voicing concerns.

One of the most recent to join the GPRS detractors is Ubinetics, which is involved in GPRS testing. The firm's Chief Executive Officer Ali Pourtaheri claimed interoperability among different vendors' equipment is becoming a real issue and has parallels with the early days of the WAP.

"Also, operators have to learn that packet-based networks are significantly different to existing circuit-switched voice infrastructure," Pourtaheri said.

The much-hyped speed of GPRS services at 115 kilobits per second (kbps) would seem, in practice, to be significantly less. BT Cellnet claimed that up to 30 kbps is achievable, and Orange said its services will launch with speeds of between 30 kbps and 40 kbps. However, a number of testing houses say that 12 kbps is a more realistic number for reliable data transmission, and at this speed, provides a more reasonable battery life for GPRS phones.

Belgium auction draws $419 million

BRUSSELS, Belgium—Belgium awarded three Universal Mobile Telecommunications System licenses to each of the country's three incumbent operators, bringing in about $419 million for the government. The prices raised from the auction were just at the minimum prices set by the government.

The auction ended after just one round, with only three bidders for four licenses. Mobistar and KPN Orange each paid $139.3 million, with the third license winner Proximus paying about $139 million.

Belgium originally had hoped to raise more than $1 billion from the sale. A Telefónica/Suez-Lyonnaise des Eaux consortium withdrew from the process earlier this year, leaving only three contenders.

GPRS Enhancements:

A Closer Look at EDGE

The Vision of EDGE

- Dead or not, Edge deserves a quick look in parting
- An Evolutionary path to 3G services for GSM and TDMA operators
- Builds on General Packet Radio Service (GPRS) air interface and networks
- Phase 1 (Release'99 & 2002 deployment) supports best effort packet data at speeds up to about 384 kbps - three times faster than GPRS
- Phase 2 (Release'2000 & 2003 deployment) will add Voice over IP capability

The EDGE Air Interface

- Extends GPRS packet data with adaptive modulation/coding
- 2x spectral efficiency of GPRS for best effort data
- 8-PSK/GMSK at 271 ksps in 200 KHz RF channels supports 8.2 to 59.2 kbps per time slot
- Supports peak rates over 384 kbps
- Requires linear amplifiers with < 3 dB peak to average power ratio using linearized GMSK pulses
- Initial deployment with less than 2x 1 MHz using 1/3 reuse with EDGE Compact as a complementary data service

Steps in the EDGE Evolution

- Best effort IP packet data on EDGE
- Voice over IP on EDGE circuit bearers
- Voice over IP with statistical radio resource multiplexing
- Network based intelligent resource assignment
- Smart antennas & adaptive antennas
- Downlink speeds at several Mbps based on wideband OFDM and/or multiple virtual channels

Edge Updates - April, 2001

6 April 9, 2001 News RCR Wireless News

EDGE debate roars on

BY SAM OMATSEYE

EDGE is dead. Long live EDGE.

Depending on where they stand on the EDGE debate, some operators want EDGE born alive. Others think it should be left as merely an idea.

Andrew Seybold of the Andrew Seybold Group is not amused by the optimism expressed about the technology and has declared it dead even before it is born.

"I don't believe that for a minute," he said of the notion that some carriers, including AT&T Wireless Services Inc. and Cingular Wireless, are committed to the technology because of its efficiency with data.

But the Universal Wireless Communications Consortium, which espouses all the virtues of TDMA and EDGE technologies, believes that skeptics have lost sight of both the technical and economic advantages of the protocol.

"EDGE will provide the ability to multiply the existing efficiency on data," remarked Frank Ubany, UWCC's chairman.

"EDGE will provide the ability to multiply the existing efficiency on data."

"GSM operators may decide to skip EDGE altogether as W-CDMA technology will be around the corner."

He said GPRS will combine with EDGE for data efficiency because of the small implementation cost, adding that it is a natural path for GSM to global 3G.

Chris Pearson, UWCC's executive vice president, chipped in the view that it can be deployed in existing spectrum, so EDGE can be complimentary to UMTS technology.

AT&T Wireless and Cingular Wireless have not retracted any commitments on their planned migration paths to 3G, a scenario some analysts believe is confirmed by their anticipated GSM overlay s for their current TDMA infrastructures.

One of the downsides associated with EDGE is that it is transitional and it could be plagued by a short life span. It may not take off because of the looming shadow of 3G technology on the GSM migration path: wideband CDMA. In a recent study, Strategis Group analyst Christine Stasikowski noted that "GSM operators may decide to skip EDGE altogether as W-CDMA technology will be around the corner."

In the study, she predicted that GSM operators in Europe will not adopt EDGE, but will gravitate to W-CDMA from GPRS. However, in the United States, operators may adopt EDGE since an upgrade to W-CDMA may not be necessary.

Stasikowski thinks that only operators who lose out in the bid for more spectrum will settle for EDGE, which promises the technology a lease on life since some bidders are doomed to emerge on the short end of the battle.

Seybold draws attention to the beauty of cdma2000 in the context of efficiency.

"Of the top five carriers in the United States, Sprint, Verizon and Nextel are for cdma2000 1x and 1x-EV," he pointed out, "because it is a much smarter migration path and easier upgrade for their networks." He also referred to the strides of KDDI in Japan on the CDMA 1x front as well as Korea Telecom in South Korea.

"A lot of claim is being made that it is efficient," he said, "but it's not going to happen."

But Urbany and Pearson believe that AT&T Wireless and Cingular Wireless are committed and also point out the advantages going EDGE's way because of the standing of TDMA in Latin America, the Middle East and Russia.

Pearson said Vimpelcom in Russia and Celcom in Israel have already adopted EDGE, noting that EDGE is always looking for cooperation models.

Since TDMA is the dominant technology in Latin America, EDGE continues to have a good chance for the future.

Seybold says that phone makers have been clever to make their phones EDGE-compatible, so as as not to lose out in case of a hiccup with the migration to W-CDMA.

The new phones by Siemens, Motorola Inc., Nokia Corp. and Ericsson Inc. have not discounted EDGE technology. For instance, the Siemens S47 phone will accommodate the GSM/GPRS/EDGE/W-CDMA path, but could skip EDGE to W-CDMA. RCR

Credit RCR News, April 9, 2001 www.rcrnews.com

Two EDGEs: Compact and Classic

- Fundamental difference is the frequency reuse and minimum startup spectrum: Compact (1/3 and 2x 600 kHz) and for Classic (4/12 and 2x 2.4 MHz)
- Classic is specified by ETSI SMG2
- Compact is specified by the PDFG of the UWC
- Compact achieves 4/12 reuse on control channels by combining 4/4 time reuse with 1/3 space reuse
- Compact achieves 2x spectral efficiency of Classic on traffic channels by combining 1/3 reuse with partial loading

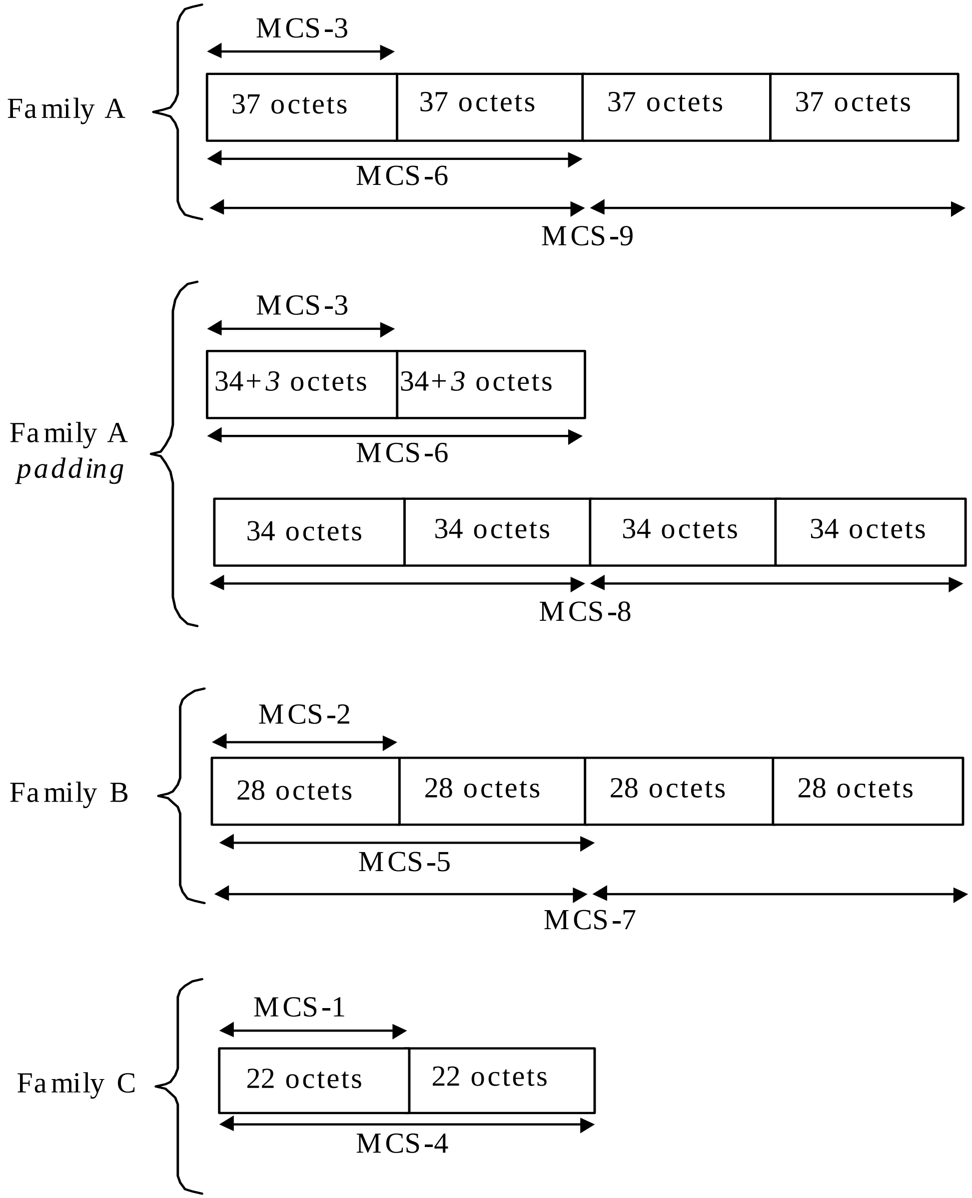
EDGE Modulations

Scheme	Modulation	Maximum rate [kb/s]	Code Rate	Family
MCS-9	8PSK	59.2	1.0	A
MCS-8		54.4	0.92	A
MCS-7		44.8	0.76	B
MCS-6		29.6 / 27.2	0.49	A
MCS-5		22.4	0.37	B
MCS-4	GMSK	17.6	1.0	C
MCS-3		14.8 / 13.6	0.80	A
MCS-2		11.2	0.66	B
MCS-1		8.8	0.53	C

The EDGE Multi-Mode Radio Link

Scheme	Modulation	Maximum rate [kb/s]	Code Rate	Header Code Rate	Blocks per 20 ms	Family
MCS-9	8PSK	59.2	1.0	0.36	2	A
MCS-8		54.4	0.92	0.36	2	A
MCS-7		44.8	0.76	0.36	2	B
MCS-6		29.6 / 27.2	0.49	1/3	1	A
MCS-5		22.4	0.37	1/3	1	B
MCS-4	GMSK	17.6	1.0	0.53	1	C
MCS-3		14.8 / 13.6	0.80	0.53	1	A
MCS-2		11.2	0.66	0.53	1	B
MCS-1		8.8	0.53	0.53	1	C

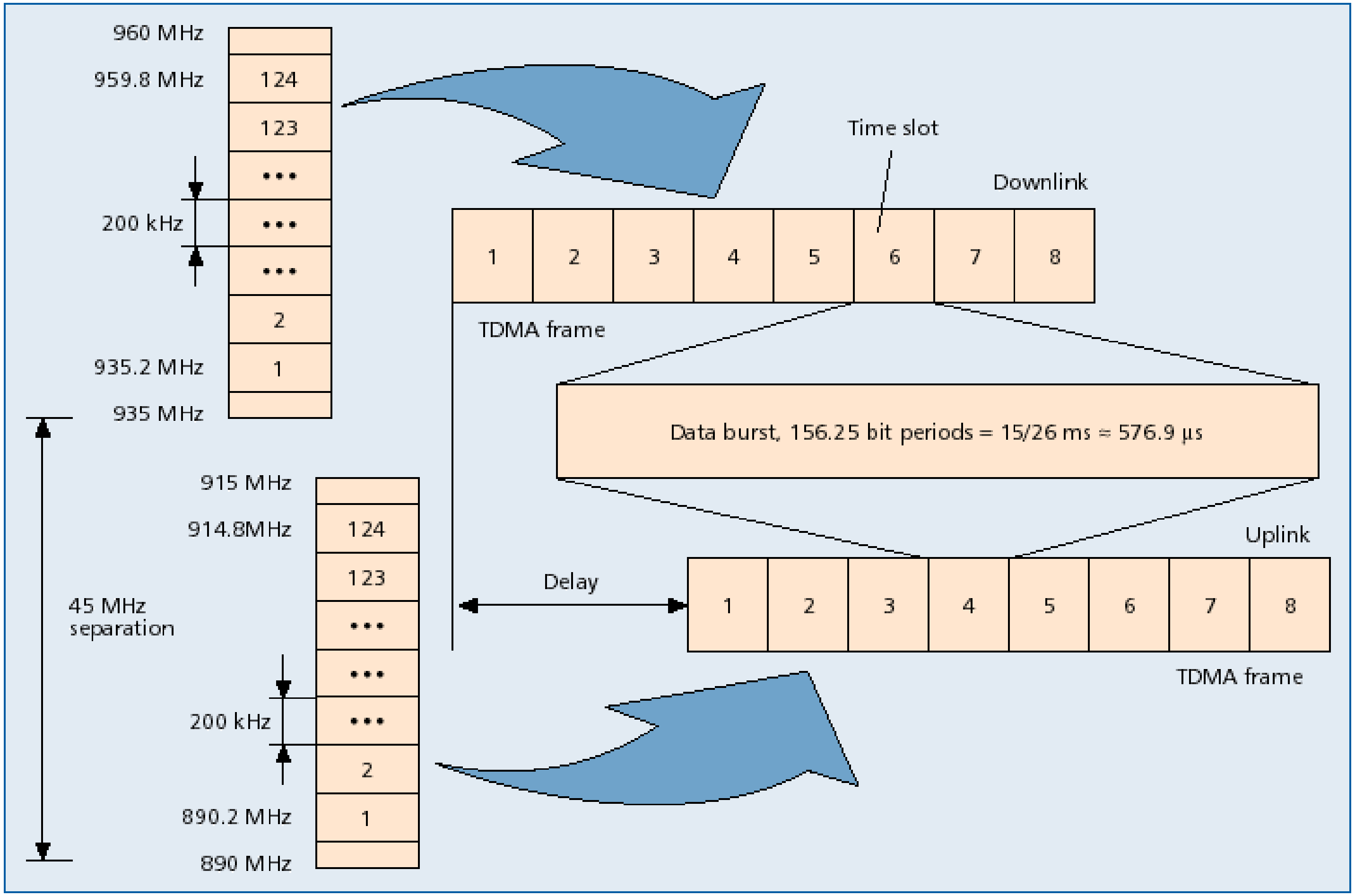
EDGE Payload Format



Carriers,Frames,Timeslots & Channels for Classic & Compact

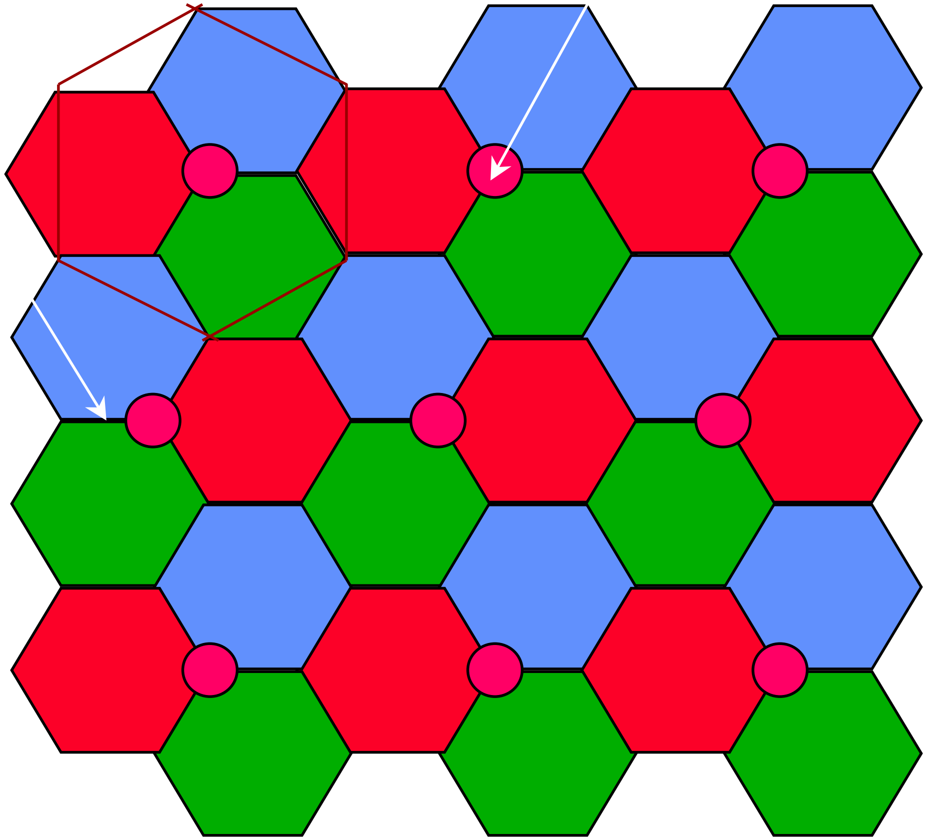
- A GSM carrier’s time is divided into frames
- A frame is divided into 8 timeslots and each is designated a timeslot number, TN0 …TN7
- All timeslots of a carrier’s timeslot number are considered a single physical channel
- Control/Traffic logical channels map to parts of the physical channels

GSM Carriers and TDMA Frames for EDGE Classic and Compact

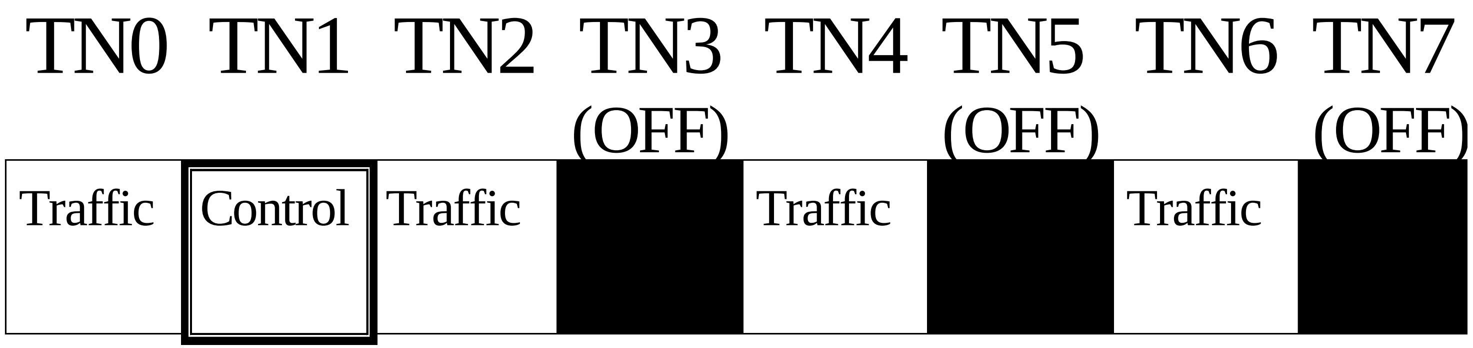


1/3 Frequency Re-use (EDGE Compact)

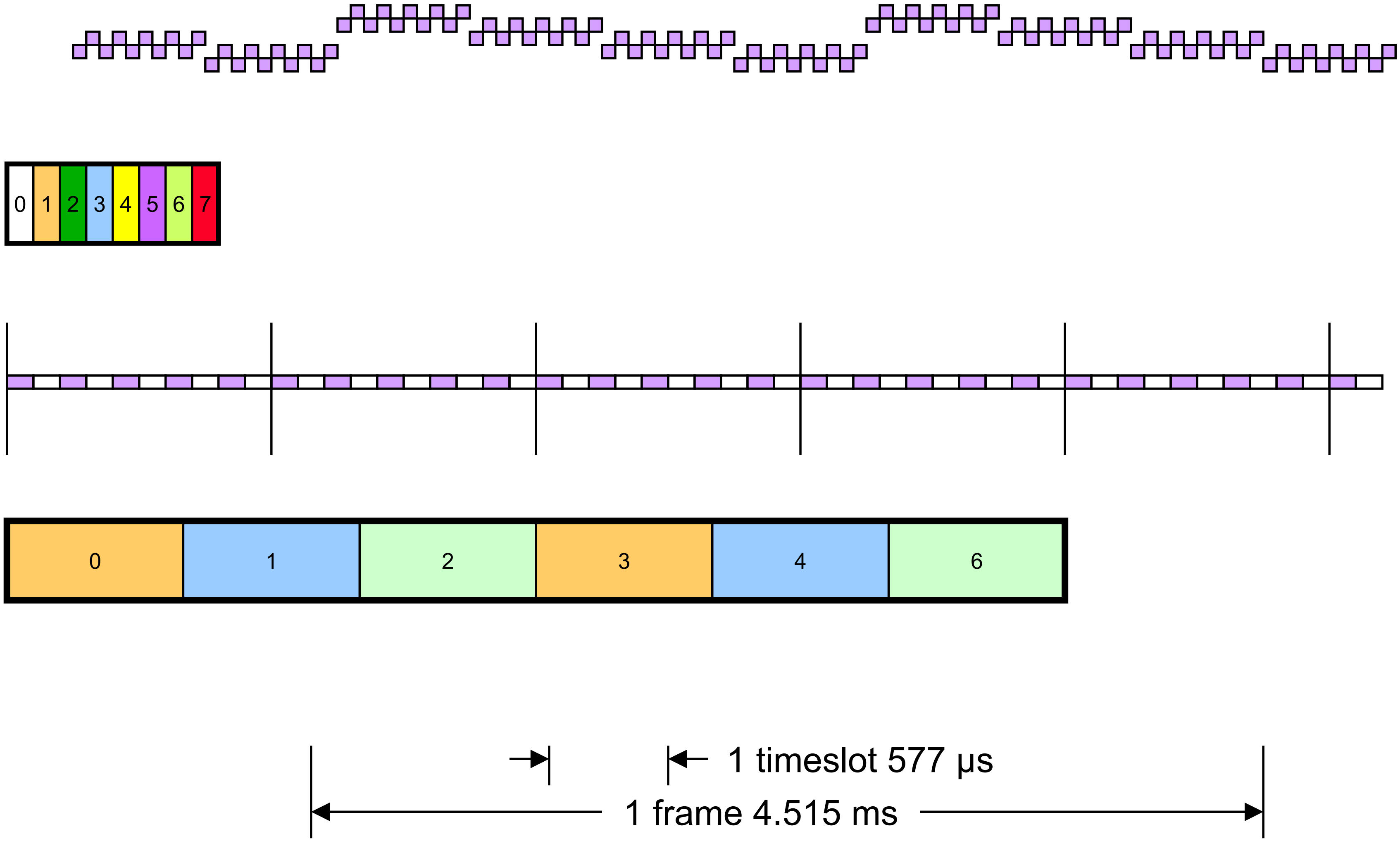
- 3 x 200 kHz carrier, reused in every site
- <1MHz x 2 initial deployment
- 3 sectors per site



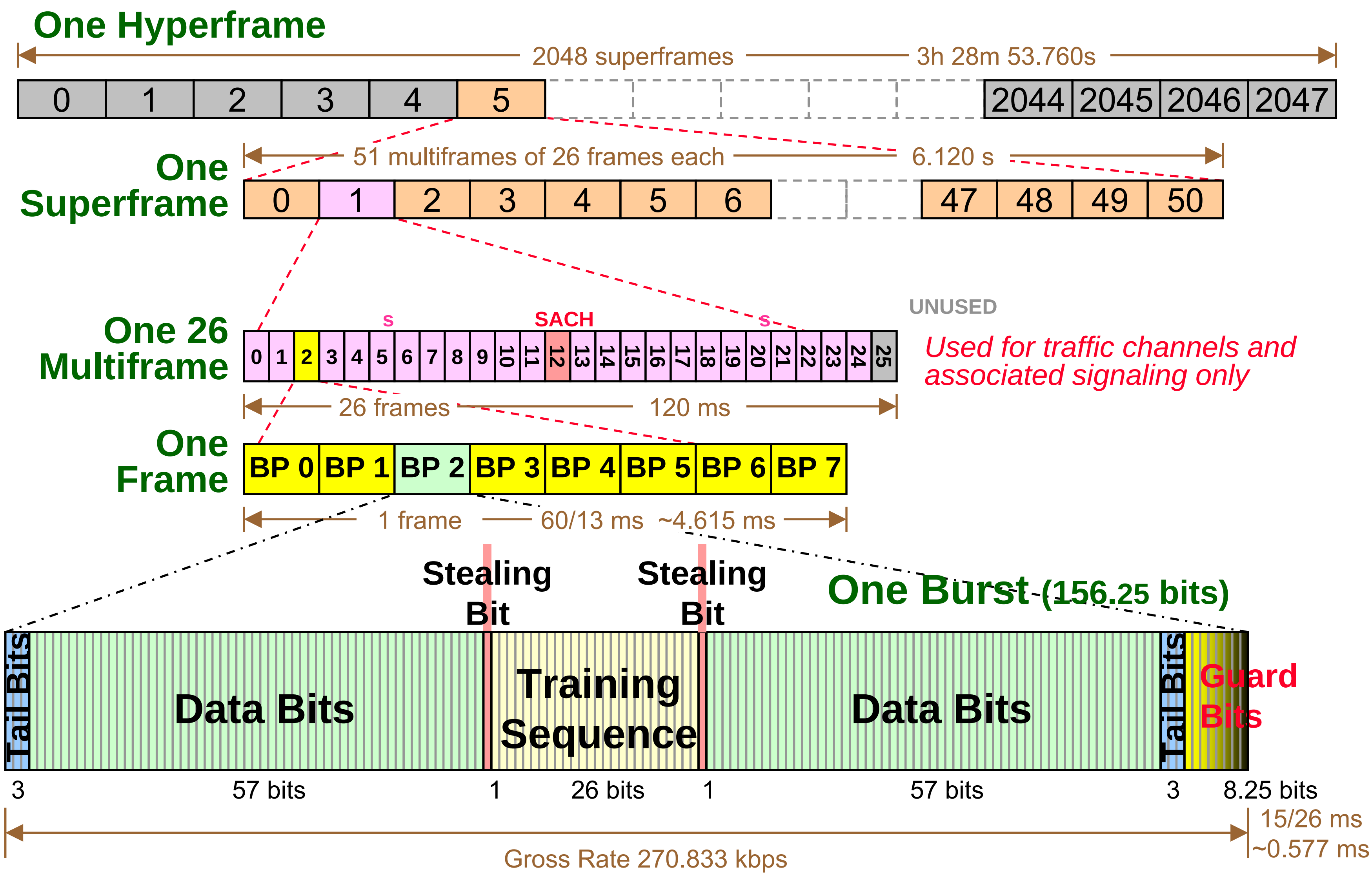
Reuse in Time for EDGE Compact



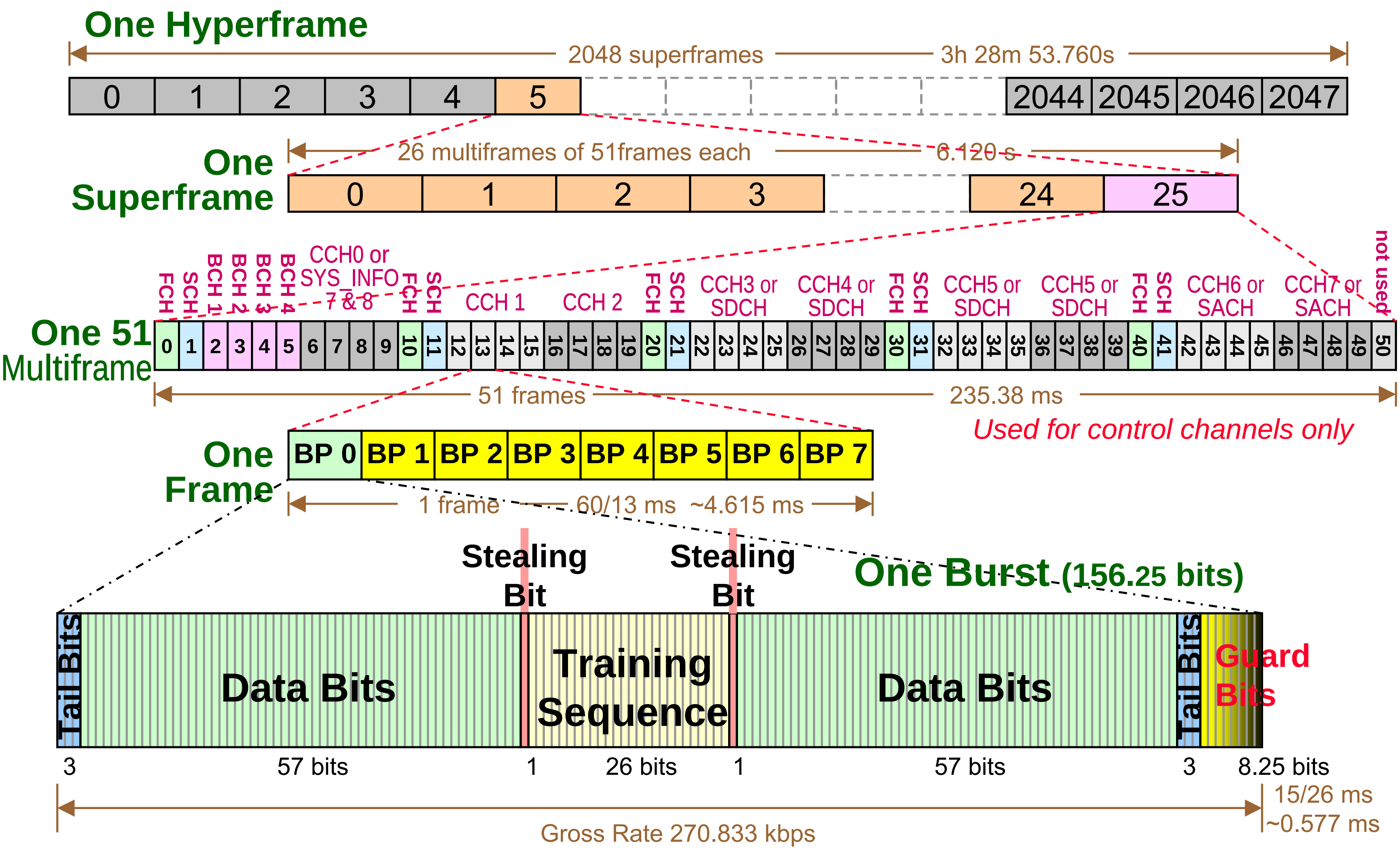
- Base Station Frame Synchronization - so that all base stations can be swied on/off synchronously to achieve reuse in time
- Modified air-interface protocols - to be able to handle the resulting discontinuous nature of transmissionsse is in space only
- Reuse for control and reuse for traffic channels are independent of each other
- The actual reuse employed - for traffic or control - is operator controlled and limited only by the available spectrum
- Typically, 4/12 is used for control and 1/3 for traffic. However, other combinations are also possible subject to performance requirements, environment and spectrum availability.


0
1
2
3
4
5
6
7
0
1
2
3
4
6
1 timeslot 577 µs
1 frame 4.515 ms

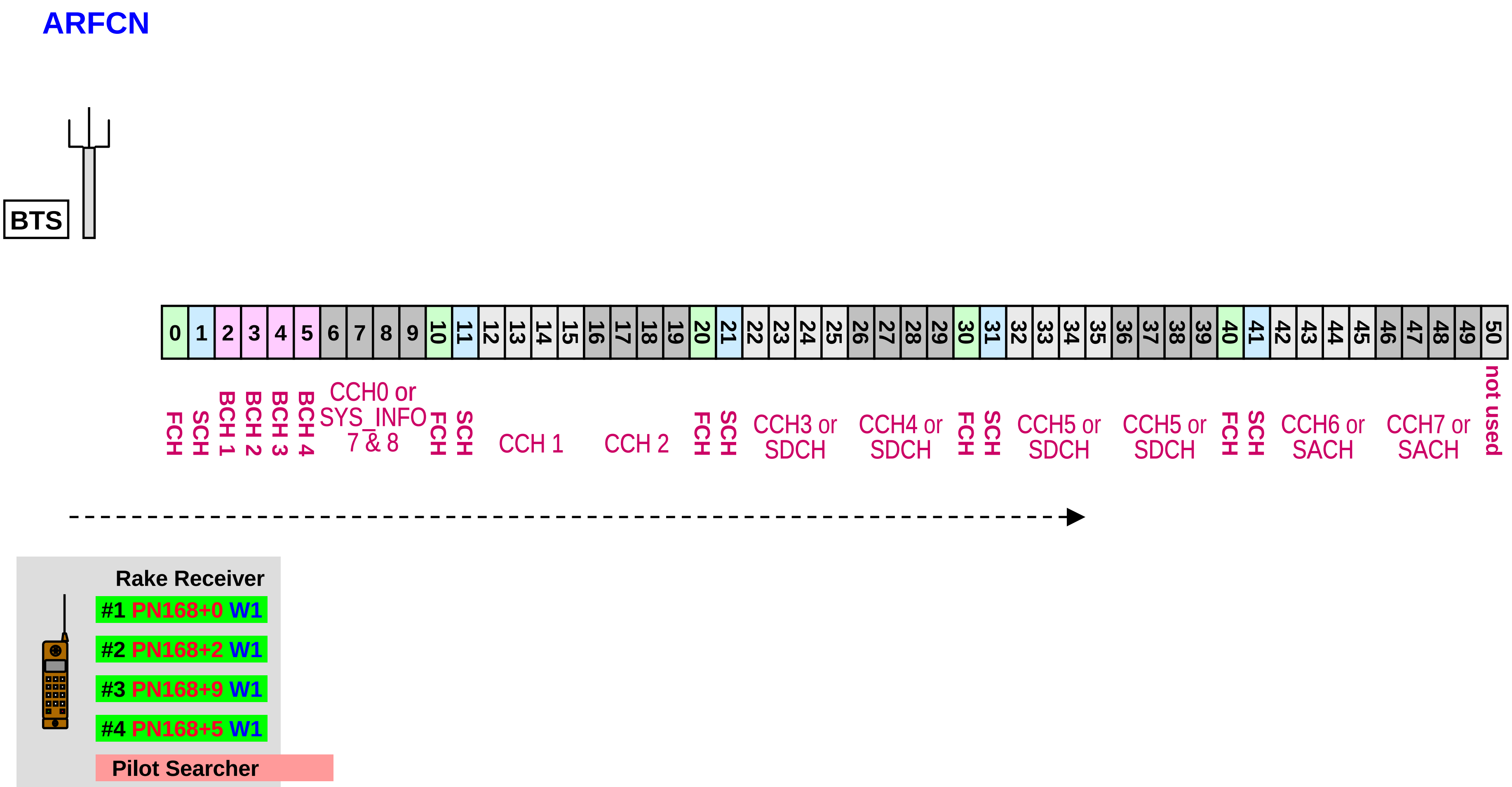
GSM *Traffic* Channels:
Hyperframes, Superframes, Multiframes, Frames, and Bursts



GSM *Control* Channels:
Hyperframes, Superframes, Multiframes, Frames, and Bursts

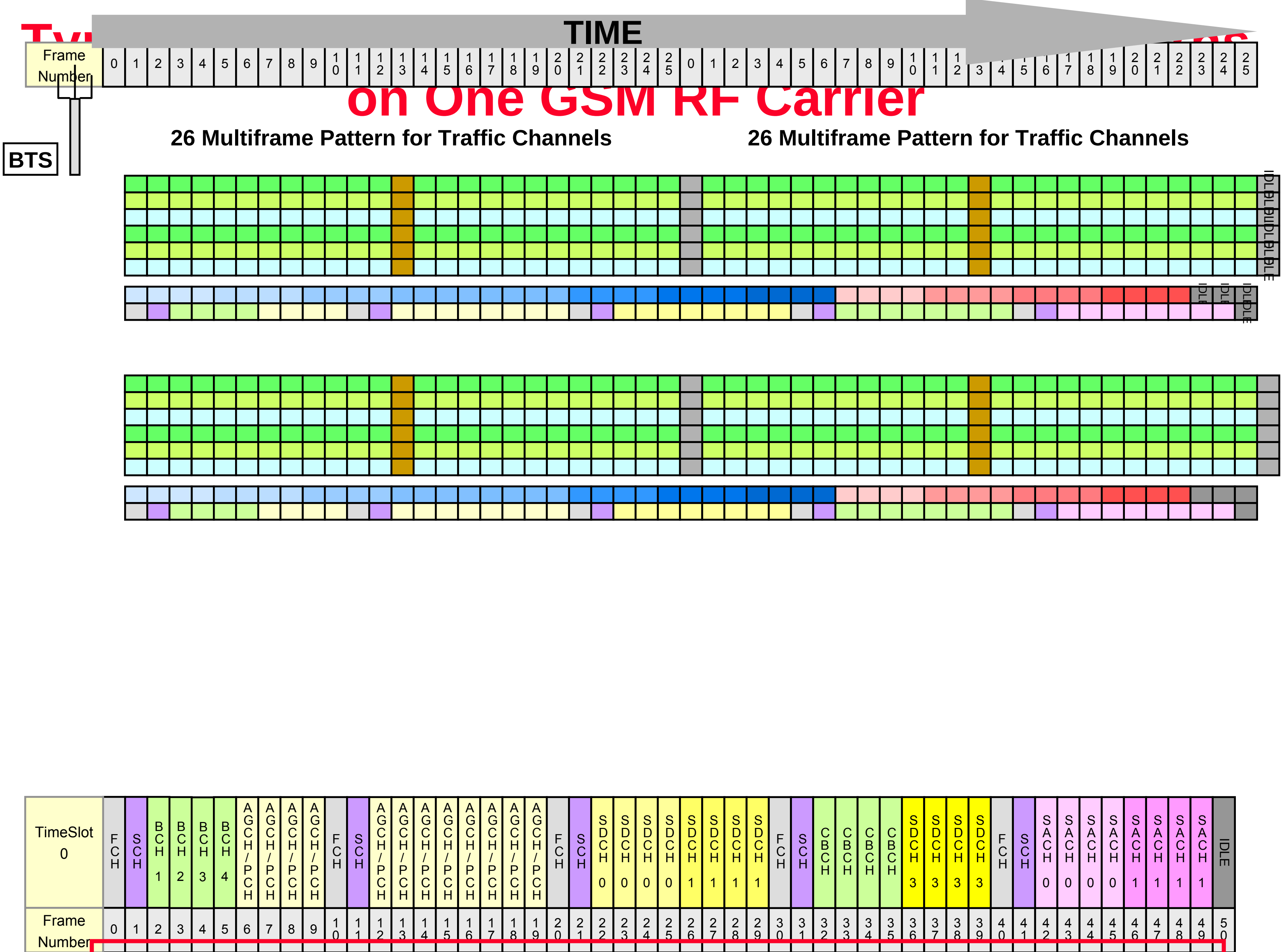


5. Collect the Configuration Messages!

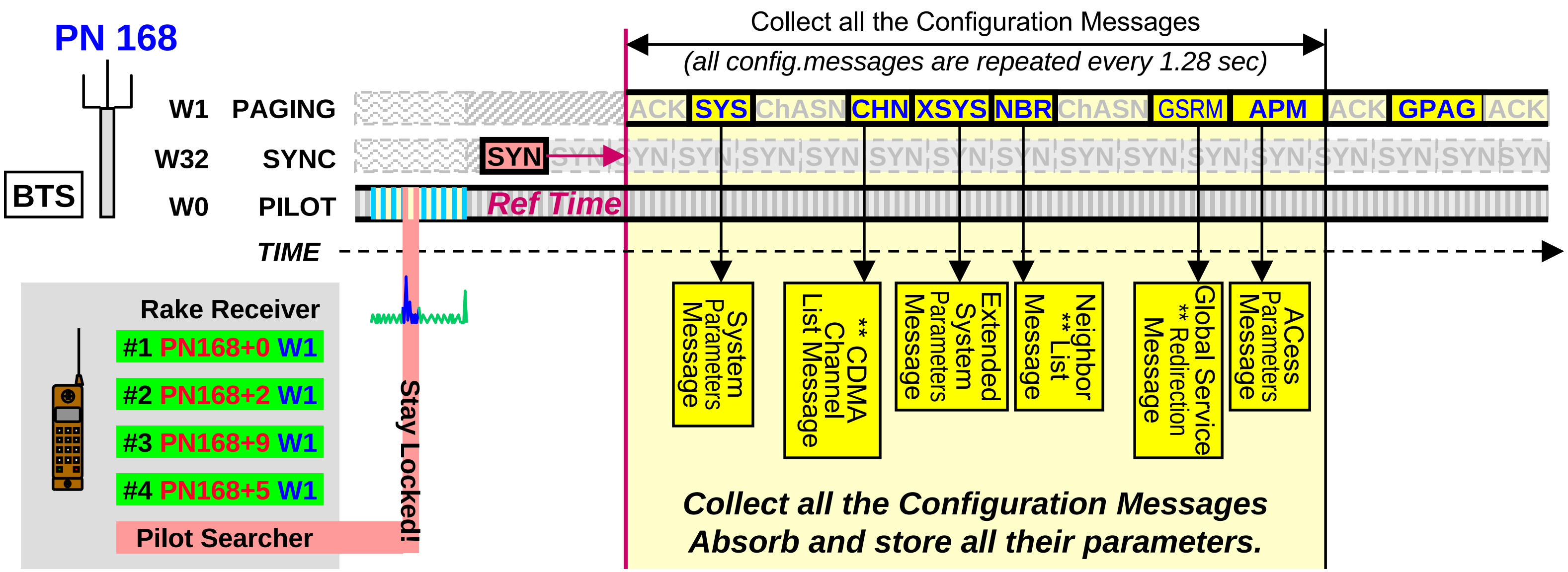


- x

on One GSM RF Carrier

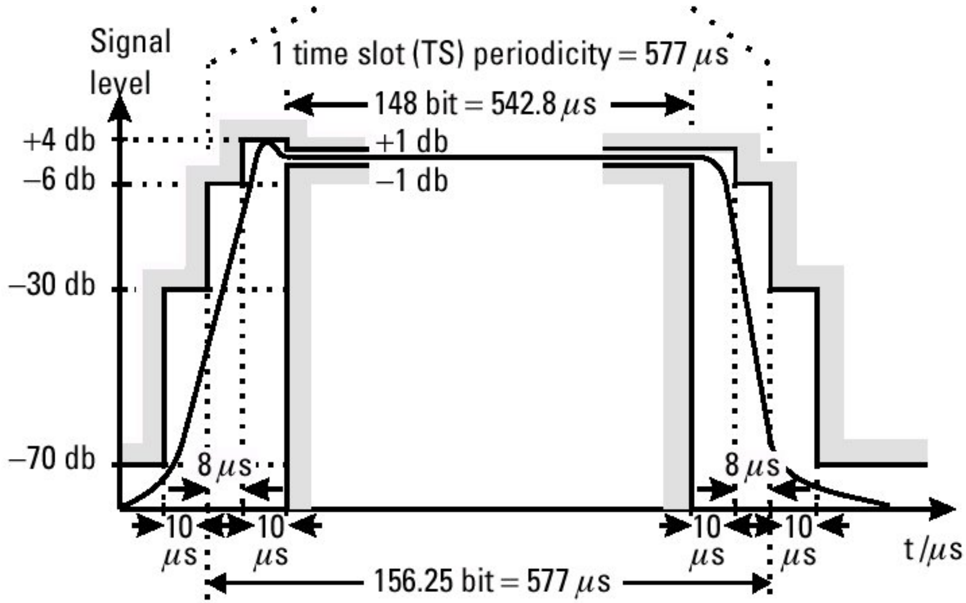


5. Collect the Configuration Messages!



- The Configuration Messages tell the mobile everything it needs to know to suCessfully operate on the system
  - ACess Parameters Message *(how to behave on the aCess channel)*
  - System Parameters Message *(registration, handoff, window settings)*
  - Extended System Parameters Message *(how to identify; packet details)*
  - Channel List Message *(list of all carrier frequencies on this sector)*
  - Neighbor List Message *(list of nearby sectors to wa out for)*
  - Global Service Redirection Message *("don't stay here - go over there")*

A GSM Uplink Normal Burst



- GSM is a TDMA system and a mobile's transmission bursts are carefully constructed not to overlap with bursts from other mobiles
- Different propagation delays of mobiles near and far mobiles the BTS are compensated by automatically advancing mobile transmit timing
- Special training sequences are included in each uplink burst and downlink timeslot to facilitate demodulation
- During unused timeslots, a mobile measures the strength of surrounding base stations to guide the handover process (this is called MAHO, Mobile Assisted Hand Over)