



**Southern Methodist University**

**SMU EETS 8306, Fall 2004**

**Wireless, Cellular, & Personal Telecommunications**

**<http://www.engr.smu.edu/~ebird/>**

## **Lecture 11: Global System for Mobile Communications (GSM)**

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**Engineering and Beyond**



### **Outline**

- History of GSM
- Frequency bands of operation around the world
- Physical channels and framing structure
- Logical channels
- Sample call setup and Layer 3 messages
- Coding and modulation
- Crunching the numbers
- Radio network features

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*"GSM is now in more countries than  
McDonalds."*

Mike Short,  
Chairman, GSM MoU Association 1995-96



**What's in a Name?**

**GSM**

did stand for...

**G**roupe **S**péciale **M**obile

...but now stands for...

**G**lobal **S**ystem for **M**obile **C**ommunications



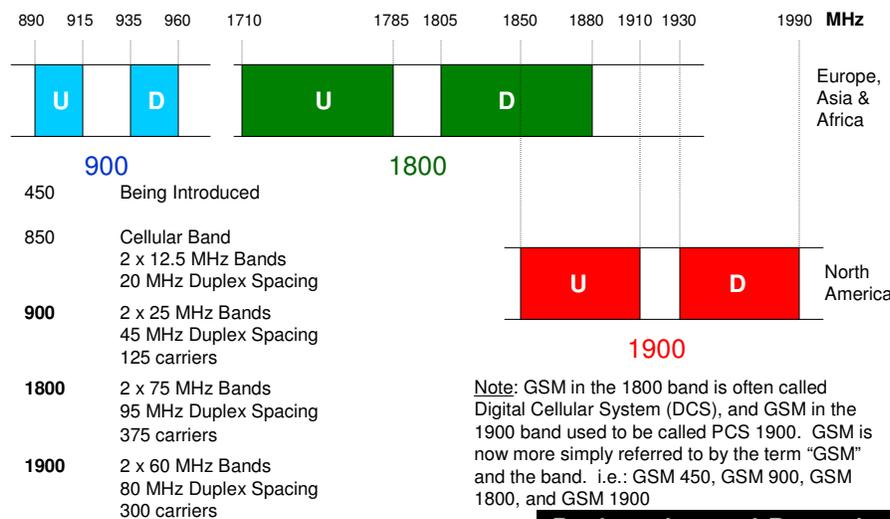
## GSM History

- 1982** CEPT establishes *Groupe Speciale Mobile* to develop standards for pan-European mobile network
- 1987** Memorandum of Understanding (MoU) signed by 12 countries
- 1989** Responsibility transferred to newly formed ETSI. GSM now stands for *Global System for Mobile Communications*
- 1990** Phase I specs. published & specs. ported to DCS 1800
- 1992** Official commercial launch of GSM in Europe
- 1995** GSM specifications ported to PCS 1900
- 2000** Responsibility for GSM Standard transferred to 3GPP  
AT&T lead TDMA operators in announcing shift to GSM
- 2001** 554 million subscribers in over 171 countries (end of June)

Source: GSM Association Website, July 2001

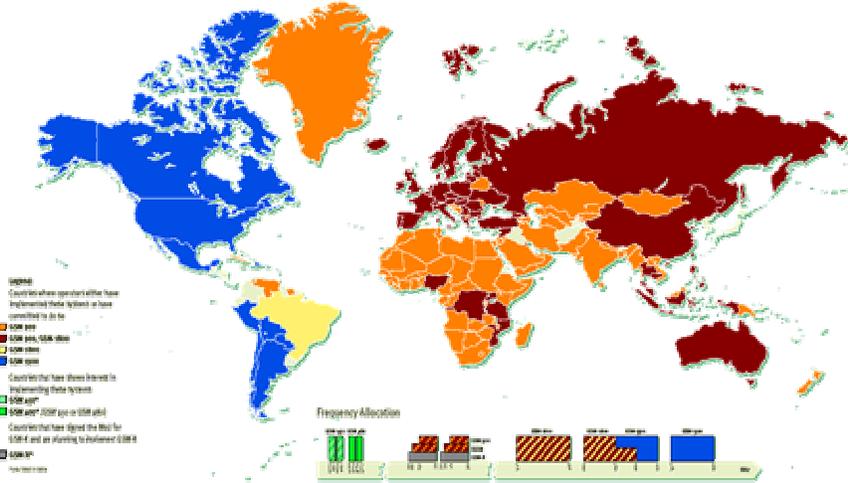


## GSM Bands Around the World





# GSM Around the World

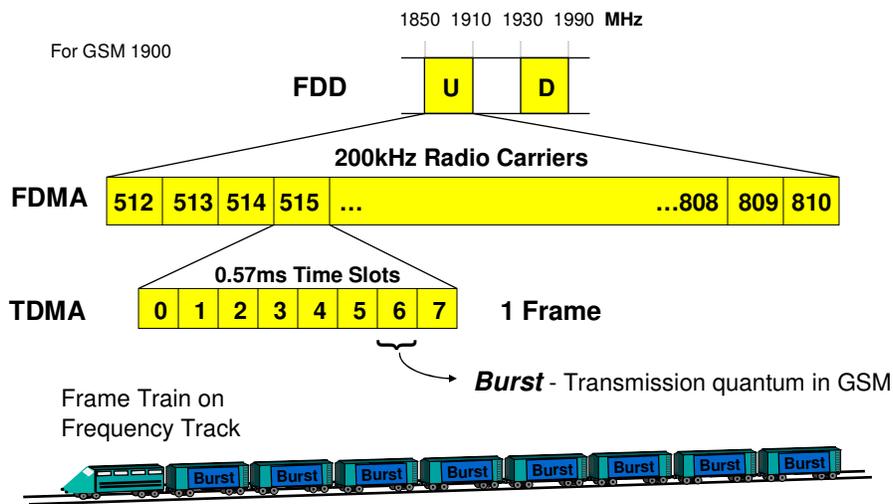


Source: Acterna web site

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# Duplex and Access Configuration



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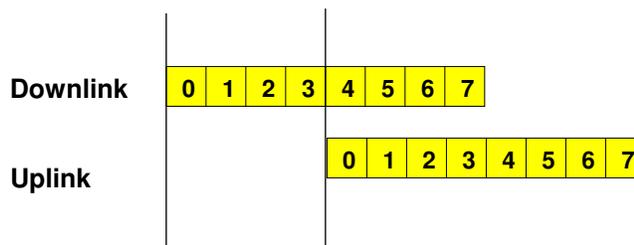


## Channel Numbering

- GSM 1900 (US Only)
  - Channel Number 512 – 810
  - Uplink Frequency (MHz) =  $1850.2 + 0.2 * (\text{Channel Number} - 512)$
  - Downlink Frequency (MHz) = Uplink Frequency + 80
- GSM 1800 (Global)
  - Channel Number 512 – 885
  - Uplink Frequency (MHz) =  $1710.2 + 0.2 * (\text{Channel Number} - 512)$
  - Downlink Frequency (MHz) = Uplink Frequency + 95
- GSM 900 (Global)
  - Channel Number 1-124
  - Uplink Frequency (MHz) =  $890 + 0.2 * \text{Channel Number}$
  - Downlink Frequency (MHz) = Uplink Frequency + 45



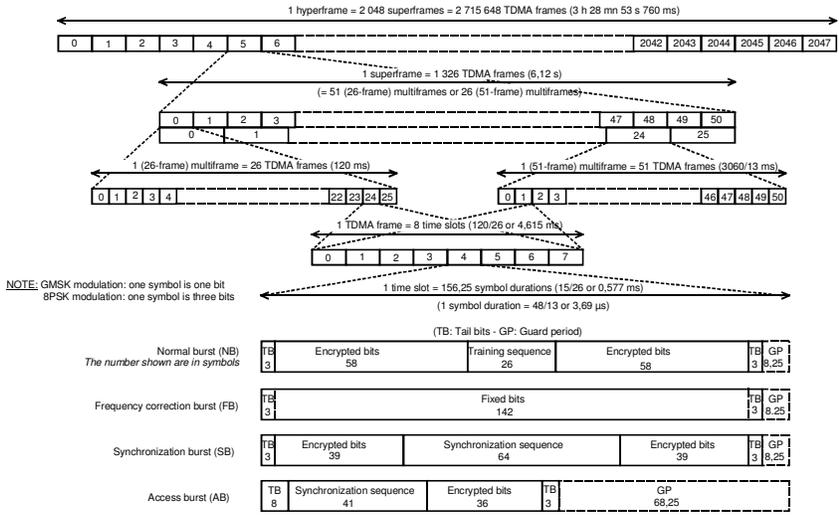
## Uplink Downlink separation



- Separation in time removes the requirement for a duplex filter in the mobile



# GSM Frame Reference

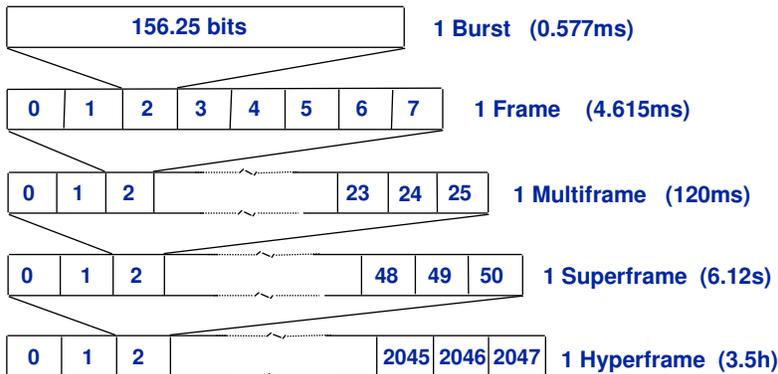


Source: 3GPP – GSM Spec 5.01



# Frame Structure

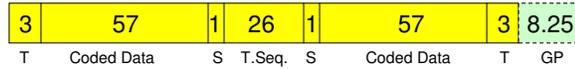
Bit-rate = 270,833bps => T = 3.69us



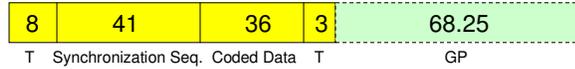


## 5 Burst Structures in GSM

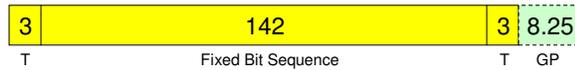
**Burst - The Transmission Quantum:**



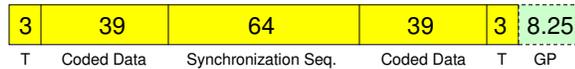
**Normal Burst**



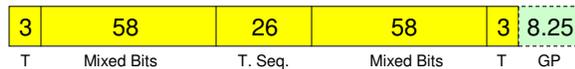
**Random Access Burst**



**Frequency Correction Burst**



**Synchronization Burst**



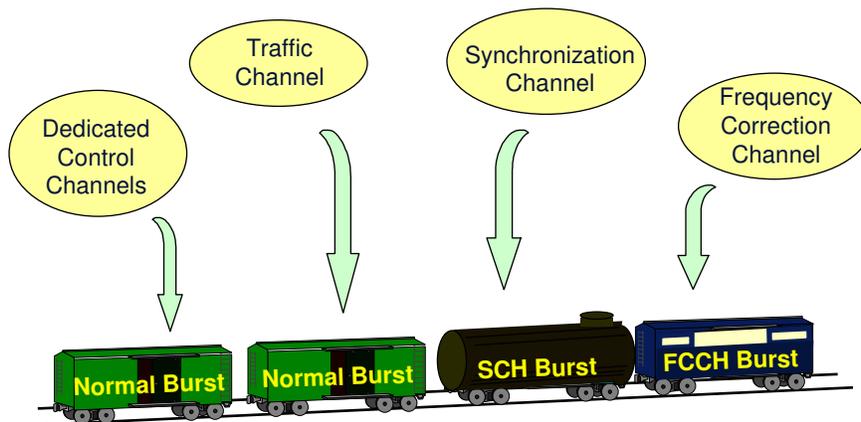
**Dummy Burst**

T. Seq. = Training Sequence  
 T = Tail Bits  
 GP = Guard Period

**“Physical Channel” - The time slot on a certain frequency.**

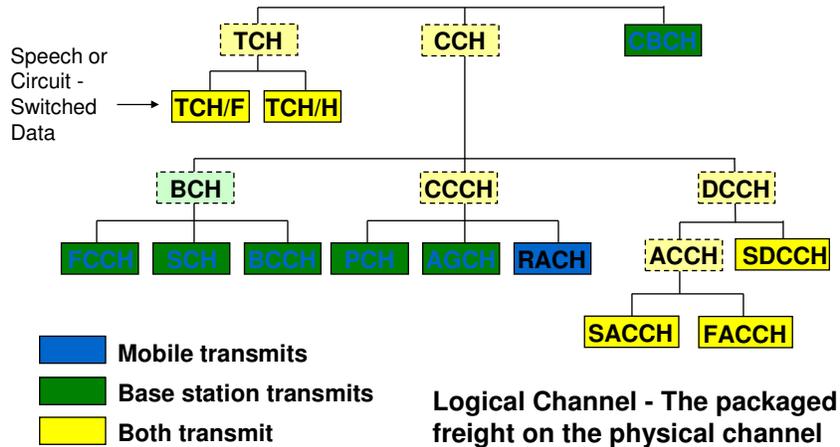


## Logical Channel Mapping





## Logical Channel Structure – Voice Only

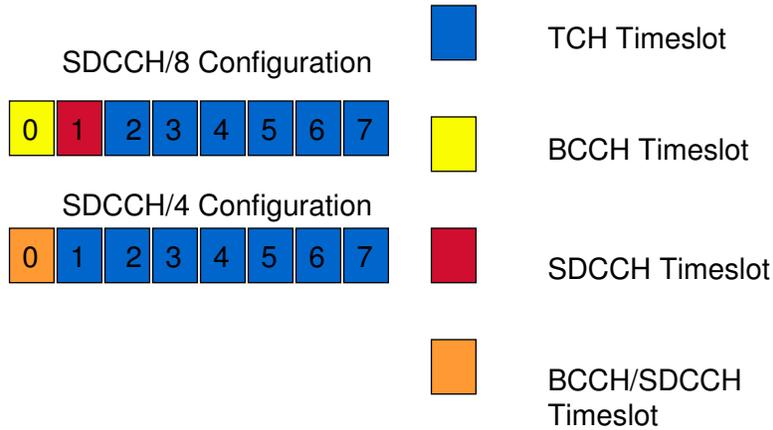


## Acronyms from Previous Slide

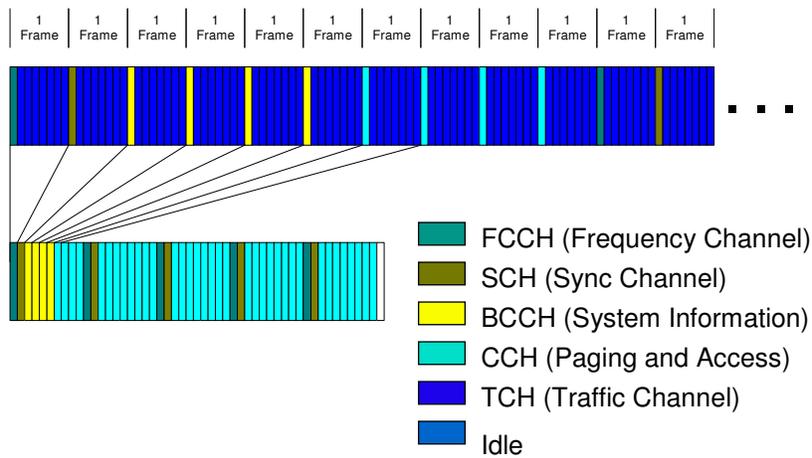
- TCH – Traffic Channel
- TCH/F – Traffic Channel Full Rate
- TCH/H – Traffic Channel Half Rate
- CCH – Control Channels
- BCH – Broadcast Channels
- FCCH – Frequency Correction Channel
- SCH – Synchronization Channel
- BCCH - Broadcast Control Channel
- CCCH – Common Control Channels
- PCH – Paging Channel
- AGCH – Access Grant Channel
- RACH – Random Access Channel
- DCCH – Dedicated Control Channels
- ACCH – Associated Control Channels
- FACCH – Fast Associated Control Channel
- SACCH – Slow Associated Control Channel
- SDCCH – Stand Alone Dedicated Control Channel
- CBCH – Cell Broadcast Channel



### BCCH Configuration



### Multiplex Control Channels on Timeslot 0





### Paging Configuration on BCCH

BCCH Configuration	SDCCH Configuration
<b>Non-Combined</b>	<ul style="list-style-type: none"> <li>• SDCCH/8</li> <li>• SDCCH/8 + CBCH</li> </ul>
<b>Combined</b>	<ul style="list-style-type: none"> <li>• SDCCH/4</li> <li>• SDCCH/4 + CBCH</li> </ul>



Non-Combined : 9 CCH x 2 Multiframes = 18 Paging Groups



Combined - SDCCH/4 : 3 CCH x 2 Multiframes = 6 Paging Groups



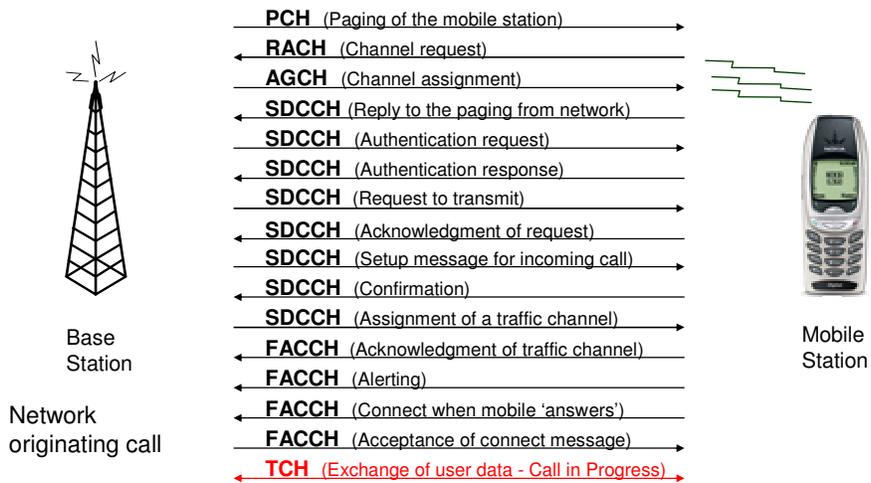
Combined - SDCCH/4 + CBCH: 3 CCH x 2 Multiframes = 6 Paging Groups

- FCH + SCH
- BCCH
- CCCH
- SDCCH
- CBCH
- Idle

Mobile only pages during assigned multiframe



### Sample Call Setup





### Layer 3 Message Example

Layer 3 messages	
UL:	CHANNEL REQUEST
DL:	IMMEDIATE ASSIGNMENT
UL:	CM SERVICE REQUEST
DL:	CIPHERING MODE COMMAND
UL:	CIPHERING MODE COMPLETE
UL:	SETUP
DL:	CALL PROCEEDING
DL:	<b>ASSIGNMENT COMMAND</b>
UL:	ASSIGNMENT COMPLETE
DL:	PROGRESS
DL:	CONNECT
UL:	CONNECT ACKNOWLEDGE
UL:	DISCONNECT
DL:	RELEASE
UL:	RELEASE COMPLETE
DL:	CHANNEL RELEASE

#### Mobile Originating Call

Assignment Command on the downlink contains the most critical setup information

DL: ASSIGNMENT COMMAND	
Time: 17:24:48.58	
Lat: not valid Lon: not valid	
Frame number: 2604239	
Channel description	
Channel type: TCH/F + ACCHs	
Timeslot number [TN]: 6	
Training sequence code [TSC]: 1	
Hopping channel: Single RF channel	
FB-NO: undefined	
Absolute RF channel number [ARFCN]: 516	
Power level: 2	
Channel mode: Speech full rate version 1	

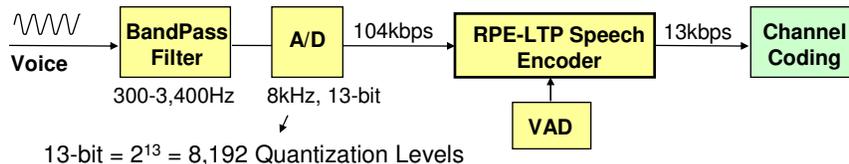


### GSM Speech Coding

Original vocoder (below) used RPE-LTP, producing blocks of 260 bits at 13 kb/s

Most common vocoder today is the Enhanced Full Rate (EFR) vocoder, producing 244 bits at 12.2 kb/s

Adaptive Multi-Rate Vocoder will support variable rates, 12.2 kb/s to 4.75 kb/s



13-bit = 2<sup>13</sup> = 8,192 Quantization Levels

**Note:** Decoder includes interpolation, a lowpass filter, 13-8 bit converter, and does not include VAD.

RPE - Regular Pulse Excitation  
LTP - Long Term Prediction  
VAD - Voice Activity Detection

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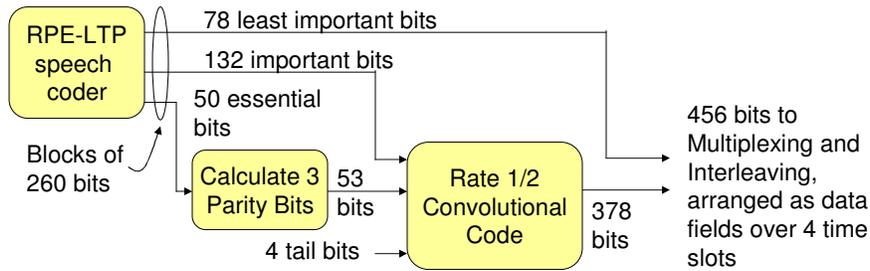


## Channel Coding Process

GSM (like most standards) uses a combination of Block and Convolutional Coding

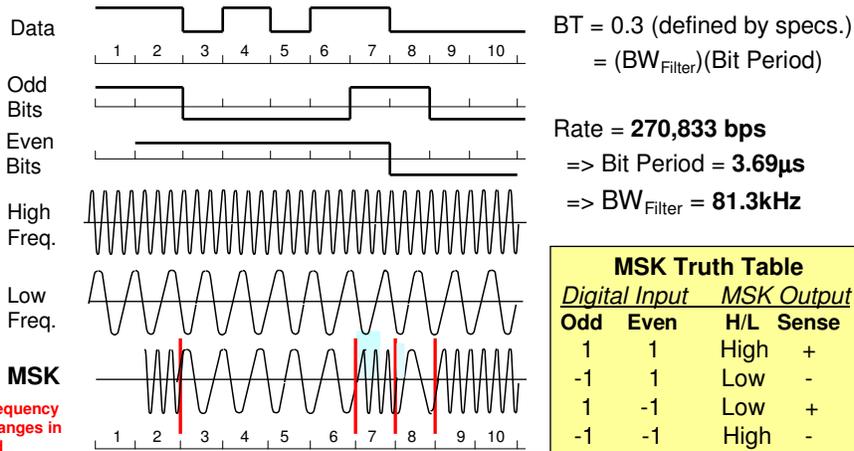
**Note:** the 456 bits output = 4 x 114 = data in 4 bursts

TheEFR vocoder delivers 244 bits, thereby freeing 16 bits for additional channel coding (channel coder output is still 456 bits)



## Modulation

### • GMSK = Gaussian Minimum-Shift Keying



MSK Truth Table			
Digital Input		MSK Output	
Odd	Even	H/L	Sense
1	1	High	+
-1	1	Low	-
1	-1	Low	+
-1	-1	High	-



## Crunching the Numbers

1 Multiframe - 120ms  
 - 26 Frames - 4.615.. ms per frame  
 - 8 Timeslots - 0.577.. ms per slot  
 - 156.25 Bits - 3.692.. μs per bit

$$\frac{1}{3.692\mu\text{s}} = \mathbf{270.833.. \text{ kb/s}} \\ \mathbf{\text{Bit Rate}}$$

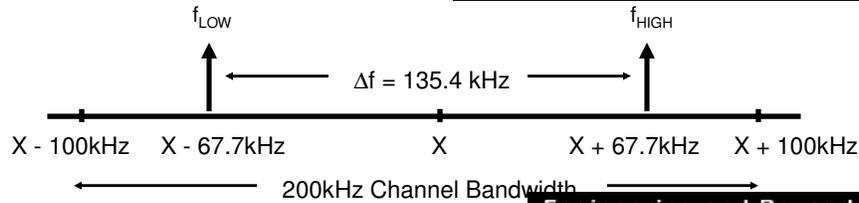
**Bandwidth Efficiency = 1.35**

Modulating signals are coherently orthogonal if:

$$\int_0^{T_{\text{bit}}} (\sin \omega_{\text{LOW}}t) (\sin \omega_{\text{HIGH}}t) = 0$$

Modulation Index = 0.5 allows this.

$$\mathbf{\text{Mod. Index} = 0.5 = \frac{\Delta f}{R_b} = \frac{135.4\text{kHz}}{270.8\text{kBps}}}$$



## Many Radio Network Features in GSM

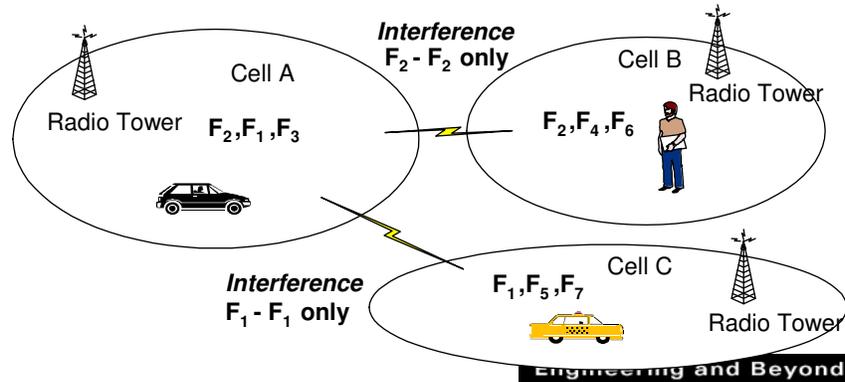
- Hierarchical Cell Structures
- Dynamic Overlaid/Underlaid
- Combined Control Channels
- Adaptive Configuration of SDCCH
- Frequency Allocation Support
- Efficient Priority Handling
- Immediate Assignment on TCH
- Discontinuous Transmission
- Differential Channel Allocation
- Directed Retry
- Idle Channel Measurements
- Frequency Hopping
- Power Control
- Dynamic HR Allocation
- Double BA List
- Handover on SDCCH
- Intracell Handover
- Handover Power Boost
- Neighbor Cell Support
- Cell Load Sharing
- Channel Administration

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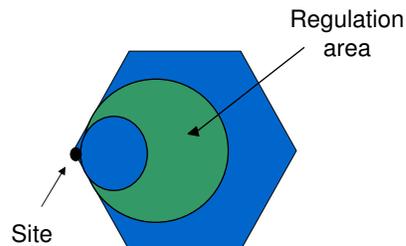
## Frequency Hopping

- Important feature for interference averaging in high capacity networks and frequency diversity
- Random and cyclic sequences supported



## Power Control

- Regulates the transmit power, in steps of 2 dB to give a fixed (optimal) receive power at the receiver
- Implemented in both the BTS and MS
- Considers both signal strength and quality
- Reduces risk of receiver saturation
- Conserves battery power
- Reduces Interference





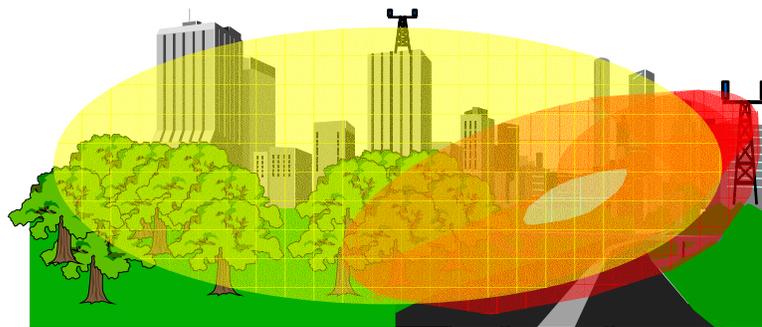
## Discontinuous Transmission (DTX)

- Stops transmitting during periods of silence (approximately 50% of the time)
  - *Voice Activity Detector (VAD) determines if voice is present*
  - *VAD uses complex adaptive algorithm*
- Implemented in both the BTS and MS
- Silence Descriptor (SID) frames are sent periodically to generate "Comfort Noise" in the receiver
- Reduces intermodulation at the BTS
- Conserves battery power
- Reduces interference



## Hierarchical Cell Structures (HCS)

- HCS allows traffic to be directed to a preferred cell
- Each cell is defined in a particular layer
- The lower the layer, the higher the priority
  - *Mobiles will select a cell on the lowest layer as long as it has "sufficient" signal strength, even if higher layer cells are stronger*

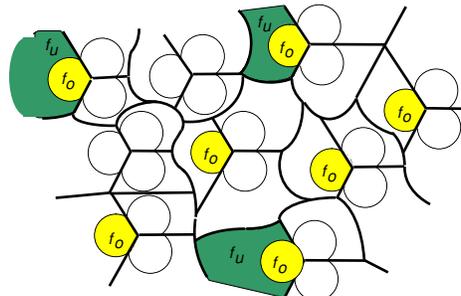




## Overlaid/Underlaid Cells

- Increases traffic capacity without adding new sites
- Overlaid cells are smaller, with lower power
- Load is balanced by handing over between overlaid and underlaid cells

Tighter frequency reuse in overlaid cells can be supported

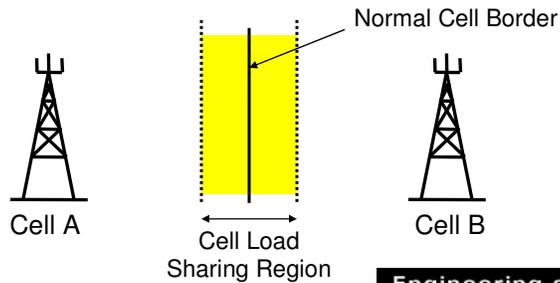


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## Cell Load Sharing

- Distributes traffic load between neighboring cells during heavy load
- Handover hysteresis borders are shifted
- Network can be dimensioned for a higher load

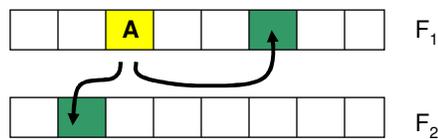


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## Intracell Handover

- Handover within a cell, either on the same frequency (different timeslot) or a different frequency
- Solves temporary co-channel and adjacent channel interference problems, in addition to avoiding intermodulation



## Networking Points About GSM

- Global roaming supported by GSM
  - Including roaming between all frequency bands
  - Most operators support roaming with more than 50 countries
- Mobile Application Part (MAP) is the primary networking protocol in GSM, based on SS7 protocol
  - Used to transfer all service information from HLR to VLRs
- IN services commonly used
  - Soon to be provisioned across networks with "Customized Applications for Mobile network Enhanced Logic (CAMEL)"
- GAIT standard recently introduced
  - Siemens first handsets



## Wireless Data Over GSM

- Rates of 9.6 kb/s and 14.4 kb/s have been available for a long time
- Short Message Service (SMS) very popular, particularly in Europe
- High Speed Circuit Switched Data (HSCSD) available from some vendors/operators
  - 38.4kb/s and 57.6 kb/s by combining 4 timeslots
  - Timeslots can be dynamically assigned asymmetrically
- General Packet Radio Service (GPRS) launching now
  - Packet data using up to 8 timeslots to provide 115.2 kb/s
  - Suitable for bursty data such as web browsing



## Additional Information

- GSM Frequency Chart
  - [http://www.acterna.com/commex/commex\\_pdf\\_win/index.html?PDF=/united\\_states/technical\\_resources/downloads/posters/gsmworld\\_2004\\_poster.pdf](http://www.acterna.com/commex/commex_pdf_win/index.html?PDF=/united_states/technical_resources/downloads/posters/gsmworld_2004_poster.pdf)