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Telecommunications Convergence

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It's a Mobile World

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Outline of Talk

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- Introduction to the Radio Environment
- Survey of "Routes" to the Universal Mobile Telecommunications System (UMTS)
- Developments in second generation systems
- Capabilities of 3rd generation systems
- Personal view of the evolution mobile communications networks towards 3G and beyond.

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Some Background Statistics and Forecasts

- Mobile voice subscribers will considerably exceed fixed network subscribers (already happened in some countries)
- 600×10^6 computers connected worldwide by end of 2000
- 120% growth in Internet anticipated by 2005
- Business to business transactions will exceed $\$1.5 \times 10^{12}$ by 2002
- 50% of world trade will be conducted over the Internet by 2006

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Radio Environment

- Radio spectrum is a finite resource and the amount of spectrum available for mobile communications is strictly limited
- The radio environment is subject to multipath propagation, shadow fading and interference and is not therefore an ideal transmission medium
- The subscriber is able to move and this movement must be accommodated by the communications system

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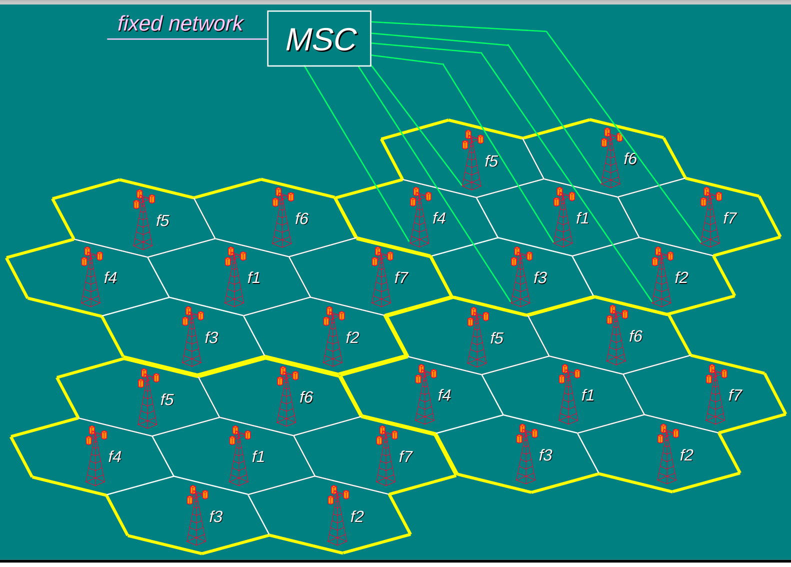
Cellular Layout



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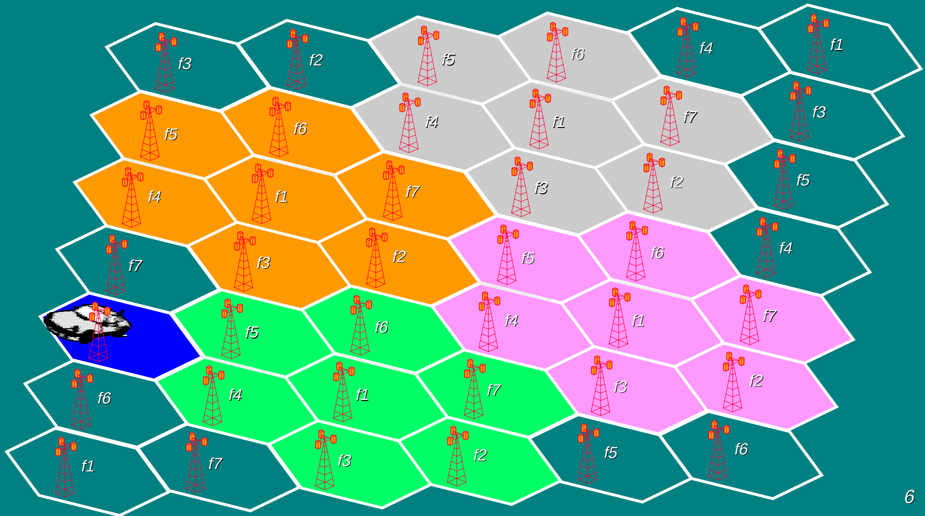
Handover (f2)



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Frequency re-use and Interference

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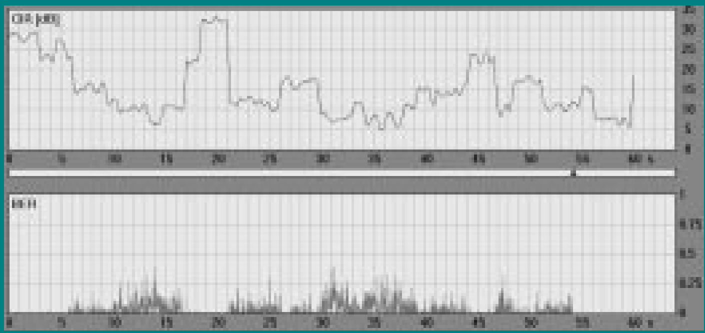
The capacity of the system can be increased only by re-using the carrier frequencies more often (smaller cells)

- This increases interference and handover rates



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Air Interfaces for 3G

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- ITU-DS for CDMA-DS or WCDMA
- ITU-MC for CDMA-MC or cdma2000
- ITU-TC for TC/CDMA or TDD/CDMA
- ITU-SC for IS-136, UWC-136, EDGE
- ITC-FT for DECT
- In addition, evolution of second generation systems is occurring at a rapid rate.
- Several contenders for the evolution mobile communications networks towards 3G and beyond.

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Current Status

- 2G networks ⇒ circuit-switched voice services, low-rate circuit-switched and "limited" packet-switched data services.
- Coupled to the evolution of second generation systems is the development of 3rd generation interfaces (mainly WCDMA and cdma2000).
- Clear prediction that wireless systems and the internet will merge in the near future.
- Massive activity to offer IP-based wide area mobile packet communications with data rates of at least 384 kb/s at pedestrian speeds, 144 kb/s at vehicular speeds, and up to 2 Mb/s in an indoor environment.

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Evolution of GSM

- Introduction of higher quality voice services via link adaptation (AMR).
- Move towards packet based services.
  - GPRS: architecture enhancements that allow mobiles to connect to IP or X.25 based networks.
  - Further evolution of GSM/GPRS to support higher data rates: Enhanced Data Rates for GSM Evolution (EDGE), up to 384 kb/s.
- WCDMA proposal provides a new air interface for GSM networks - supporting higher data rates that will meet or exceed UMTS/IMT-2000 specifications.

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Enhanced Speech Quality, Operation of the AMR codec

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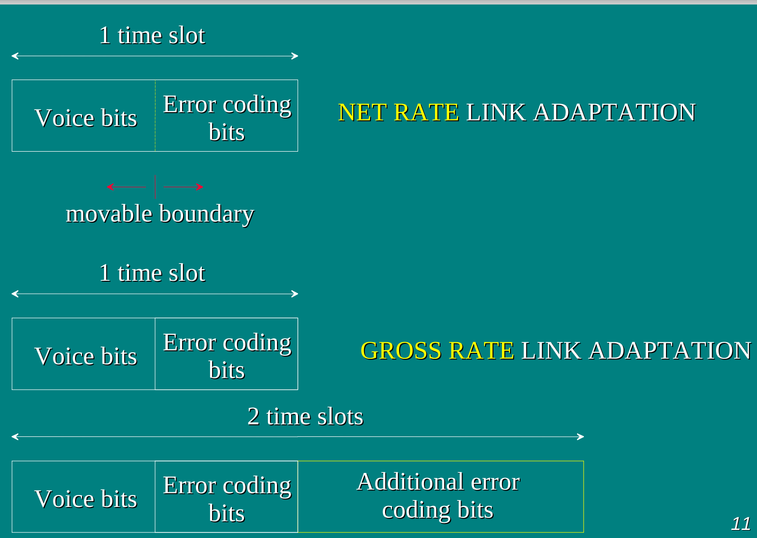

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PDF of Mobile Channel Quality

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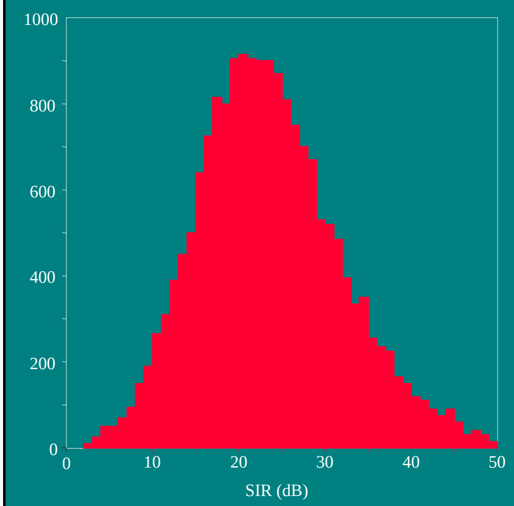

- Designed to ensure that a low number of users are below the minimum SIR.
- This results in a high number of users having a high SIR from which they cannot benefit.
- Link Adaptation adapts the channel coding to even out quality.

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Typical Coder Performance Characteristics

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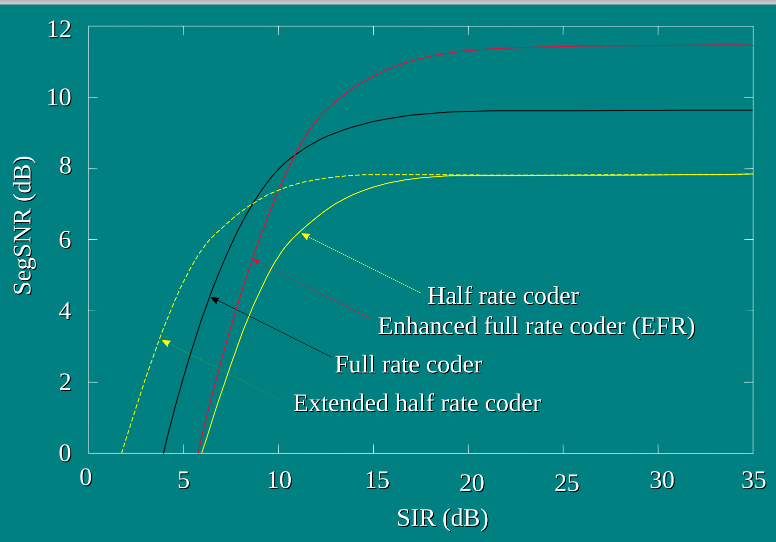

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GSM AMR Codec

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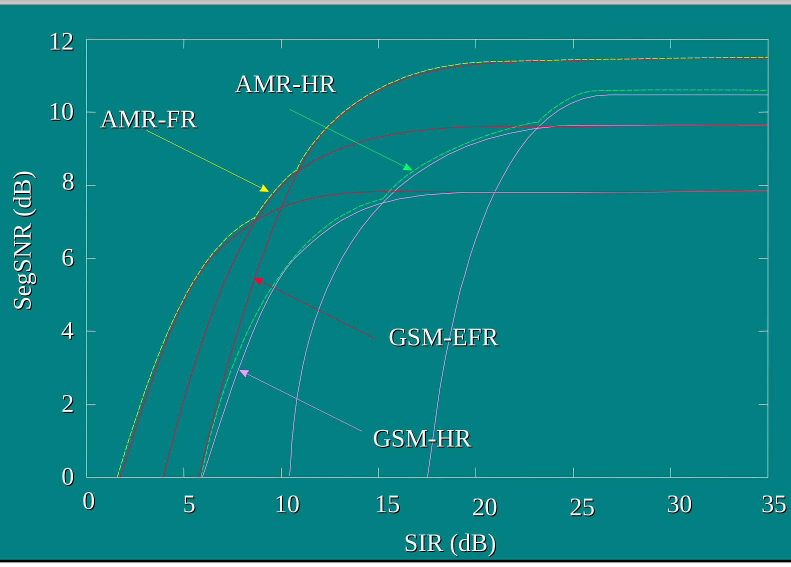

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The General Packet Radio Service (GPRS)

- Allows GSM mobile subscribers to connect to an IP-based or X.25-based network.
- Two new network elements are introduced:
  - the serving GPRS support node (SGSN): provides authentication and mobility management.
  - the gateway GPRS support node (GGSN): provides the interface between the mobile and the IP or X.25 network and tunnels packets from the packet data network using the GPRS tunnelling protocol.

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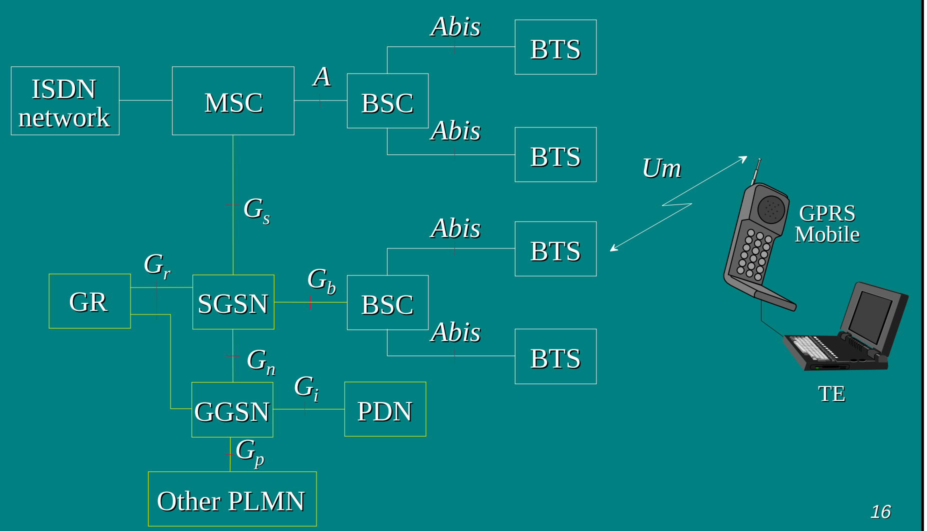
GPRS Network Architecture



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GPRS Channel Coding Options

- The channel coding options are given below, in which a radio block is equivalent to 4 time slots with a nominal capacity of $4 \times 114 = 456$ bits.

Coding Scheme (SIR Range)		Code Rate	USF bits	Payload (bits/block)	User Data Rate (kb/s)
CS-1	(< 9 dB)	1/2	3	181	9.05
CS-2	(9dB - 20 dB)	2/3	6	268	13.4
CS-3	(9dB - 20dB)	3/4	6	312	15.6
CS-4	(> 20dB)	1	12	428	21.4

- The mobile monitors the Uplink Status Flag (USF) from which it identifies the PDCHs which it may use to transmit data.

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Background to EDGE

- EDGE will use the GSM 200 kHz carrier and multi-slot operation, which will allow service providers to deploy EDGE transceivers among existing GSM/GPRS transceivers.
- In addition, EDGE re-uses the GSM/GPRS time slot structure.
- One of the main differences between GSM and EDGE is that EDGE will use 8-PSK modulation, which encodes 3 bits per modulated symbol (in good SIR conditions), and GMSK (1 bit per symbol) in poor SIR conditions.

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Link Quality Control Mechanisms

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- Link Adaptation
  - estimates the link quality and selects the most appropriate modulation/coding scheme to maximise the user bit rate.
- Incremental Redundancy
  - Information is first sent with very little coding, yielding a high bit rate if decoding is successful.
  - If decoding fails additional coded bits (redundancy) are sent until decoding succeeds.
  - The more coding that has to be sent, the lower the resulting bit rate and the higher the delay.

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Channel Coding in EGPRS

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- The different initial code rates are obtained by puncturing a different number of bits from a common convolutional code (rate 1/3).
- The resulting coding schemes are listed in on the next slide (schemes CS-1 to CS-4 are identical to GPRS).
- Incremental redundancy operation is enabled by puncturing a different set of bits each time a block is retransmitted, the code rate is gradually decreased towards 1/3 for every new transmission of the block.
- The selection of the initial modulation and code rate to use is based on regular measurements of link quality.

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Channel Coding Schemes for EGPRS

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Coding Scheme	Code Rate	Modulation	Radio Interface Rate per timeslot (kb/s)
CS-1	0.49	GMSK	11.2
CS-2	0.64	GMSK	14.5
CS-3	0.73	GMSK	16.7
CS-4	1	GMSK	22.8
PCS-1	0.33	8-PSK	22.8
PCS-2	0.5	8-PSK	34.3
PCS-3	0.6	8-PSK	41.25
PCS-4	0.75	8-PSK	51.6
PCS-5	0.83	8-PSK	57.35
PCS-6	1	8-PSK	69.2

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User bit rates for 8 slot GPRS and EGPRS

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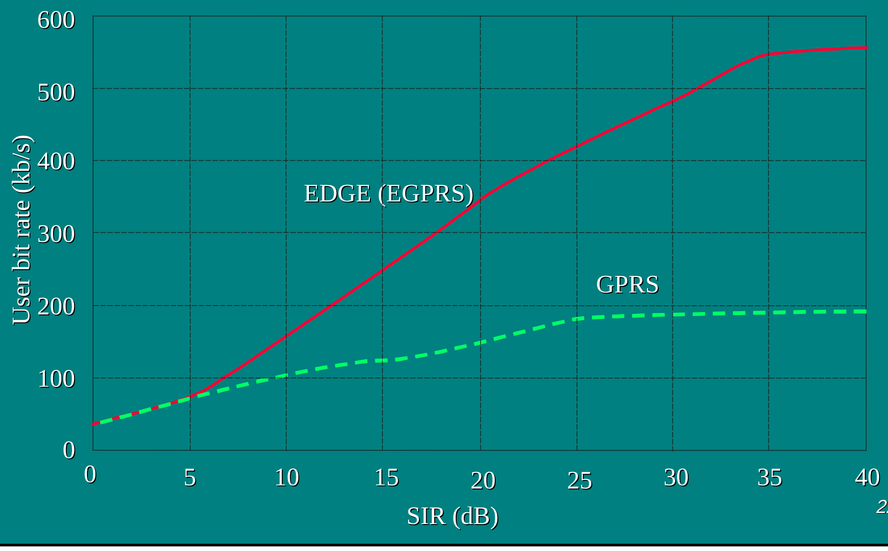

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Wideband CDMA

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- WCDMA introduces a new air interface based on a 5 MHz channel bandwidth and a chip rate of 3.84 Mc/s.
- WCDMA will also utilise a 10 ms, 15 slot/frame structure and perform closed power control on both the forward and reverse link at a rate of 1,600 times per second.
- The interest in 3G has been intense as witnessed by the recent spectrum auctions in the UK which netted an income of £22.48 × 10^9.

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3G spectrum allocation, UK

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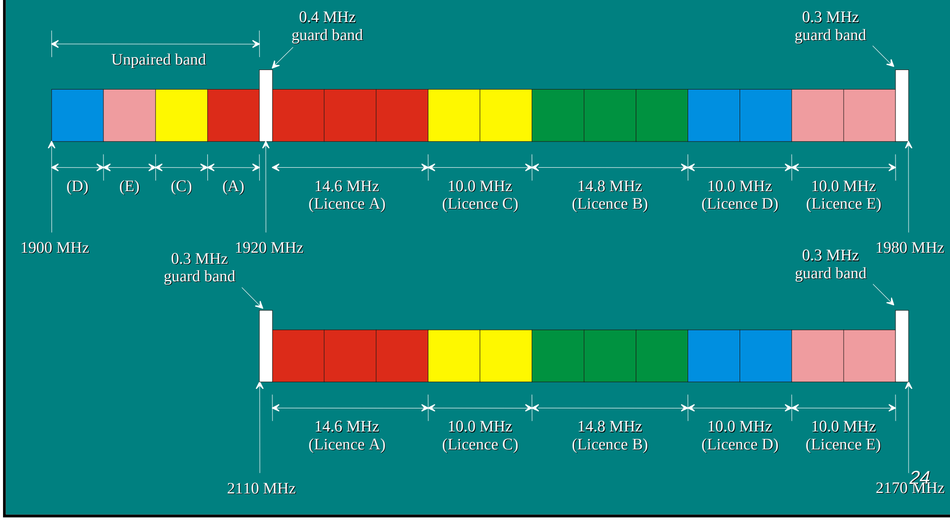

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3G Operator Licences UK

- Licence A $(2 \times 14.6$ MHz + 5 MHz) TIW (£4.3847×10^9)
- Licence B $(2 \times 14.8$ MHz) Vodafone (£5.964×10^9)
- Licence C $(2 \times 10$ MHz + 5 MHz) BT Cellnet (£4.03×10^9)
- Licence D $(2 \times 10$ MHz + 5 MHz) One2One (£4.003×10^9)
- Licence E $(2 \times 10$ MHz + 5 MHz) Orange (£4.095×10^9)

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Potential of WCDMA

- WCDMA has the capacity to offer user bit rates up to 2 Mb/s, in limited environments.
- Recent predictions suggest that, in the wider context, WCDMA will offer increased bit rates which are only twice as high as those offered by second generation systems and will require a higher number of base stations than enhanced GSM owing to the higher frequencies allocated.
- A significant competitive advantage to be gained by *offering 3G services over enhanced 2G systems*.

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Wireless Applications Protocol (WAP)

- WAP is a standard that defines the way in which a mobile network communicates directly with the Internet or Intranets.
- WAP has been designed essentially to be independent of the air interface and is thus applicable to both 2G and 3G systems.
- It is estimated that several hundred million WAP enabled mobile telephones will be in use by the end of 2000.

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Wireless Applications Environment (WAE)

- WAP is part of the Wireless Applications Environment which has adopted a model that closely follows the WWW model.
- The essence of the WAE is the existence of a gateway functionality which is responsible for encoding and decoding the data transferred from and to a mobile client.

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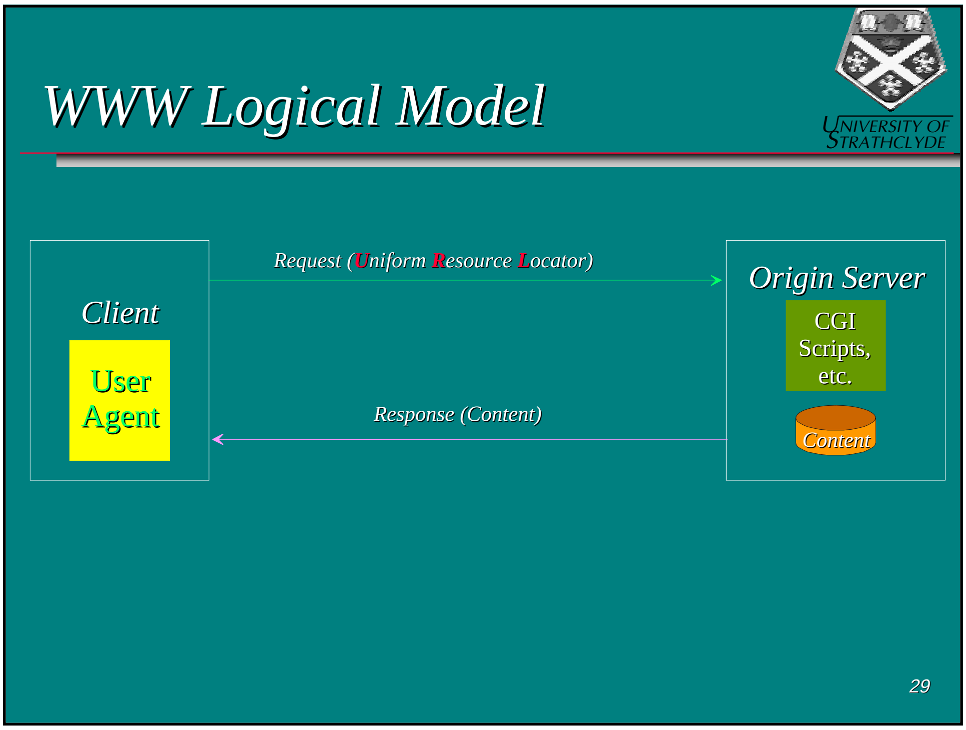
WWW Logical Model
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Client
User Agent
Request (Uniform Resource Locator)
Response (Content)
Origin Server
CGI Scripts, etc.
Content
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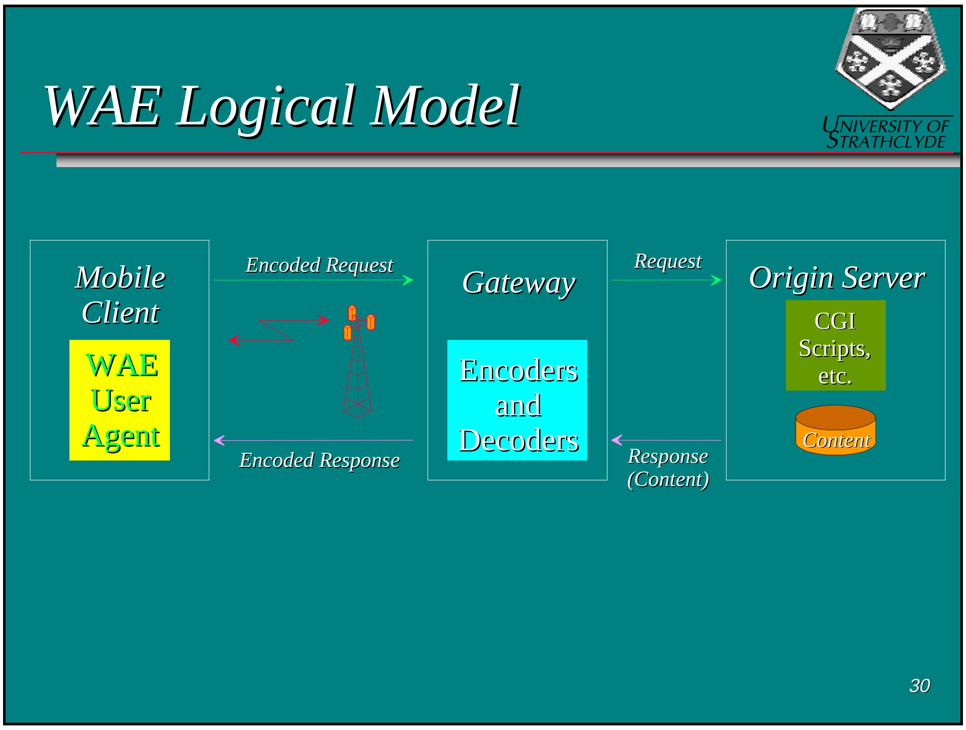
WAE Logical Model
UNIVERSITY OF STRATHCLYDE
Mobile Client
WAE User Agent
Encoded Request
Encoded Response
Gateway
Encoders and Decoders
Request
Response (Content)
Origin Server
CGI Scripts, etc.
Content
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Bluetooth

- Bluetooth eliminates the need for wires, cables, and the corresponding connectors between cordless or mobile phones, modems, headsets, PDAS, computers, printers, projectors, etc., and paves the way for new and completely different devices and applications.
- The technology enables the design of low-power, small-sized, low-cost radios that can be embedded in existing (portable) devices.
- This will lead toward ubiquitous connectivity without any explicit user interaction.

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Allocated spectrum

- The first applications are targeted at the business user and thus requires a global radio allocation.
- An unlicensed band centred around 2.45 GHz has been allocated worldwide for commercial use.
- In most countries of the world, free spectrum is available from 2400 MHz to 2483.5 MHz.
- (There are some regional variations e.g. France, Spain)

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Bluetooth Technology

- Bluetooth is based on FH-CDMA.
- In the 2.45 GHz ISM band, a set of 79 hop carriers has been defined at a 1 MHz spacing with a nominal hop dwell time of 625 μs.
- A large number of pseudo-random hopping sequences have been defined.
- The hop carriers are orthogonal but the hop sequences will not be orthogonal
- Narrowband and co-user interference is experienced as short interruptions in the communications, which can be overcome with measures at higher-layer protocols.

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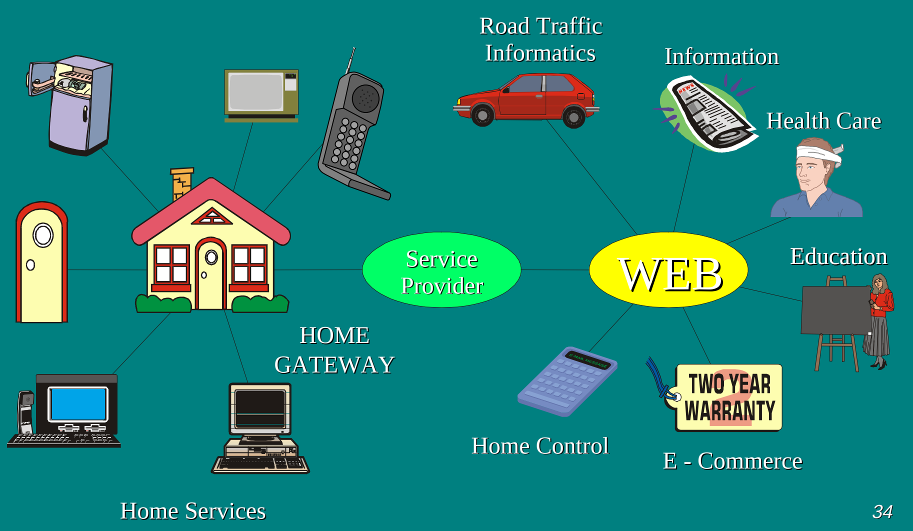
Typical Bluetooth Environment



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Cellular IP

- This is a development of the Internet Engineering Task Force (IETF) to provide local mobility and handover support in 3G systems.
- It can inter-work with Mobile IP to provide wide area mobility support.
- Mobile IP is suited to slow infrequent movement (macro mobility).
- Cellular IP is being designed for frequent mobile host migration (micro mobility).

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Cellular IP Architecture

- Base Stations periodically emit beacon signals.
- Mobile hosts use these beacon signals to locate the nearest Base Station.
- A mobile host can transmit a packet by relaying it to the nearest Base Station.
- All IP packets transmitted by a mobile host are routed from the Base Station to the Gateway by hop-by-hop shortest path routing, regardless of the destination address.

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Cellular IP Networks

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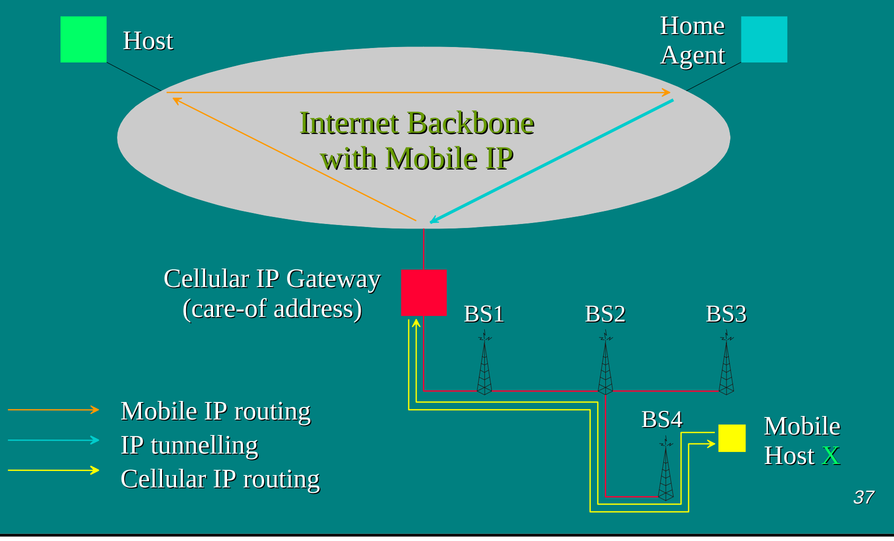

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Principles of Cellular IP

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- Cellular IP nodes maintain a Route Cache.
- Packets transmitted by the mobile host create and update entries in each node's Cache, which maps the mobile host's IP address to the neighbour from which the packet arrived.
- The chain of cached mappings referring to a single mobile host constitutes a reverse path for downlink packets addressed to the same mobile host.
- As the mobile host migrates, the chain of mappings always points to its current location because its uplink packets create new and change old mappings.

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Handover in Cellular IP

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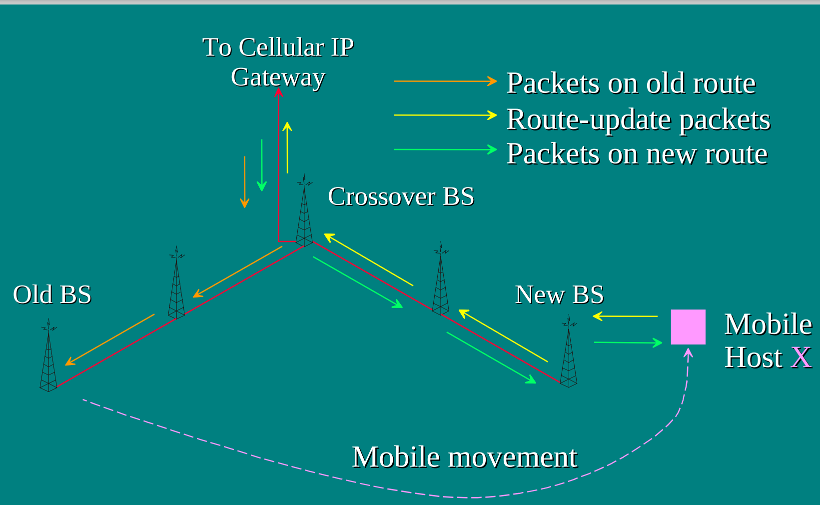

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Inactive Mobile Hosts

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- IP packets addressed to a mobile host are routed by the chain of cached mappings associated with the said mobile host.
- Inactive mobile hosts let their Route Cache mappings time out but maintain Paging Cache mappings.
- IP packets addressed to these mobile hosts will be routed by Paging Caches.
- Paging Caches have a longer timeout value than Route Caches and are not necessarily maintained in every node.

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Mobile Access Networks

- Large numbers of Microcells envisaged for 3G services
- Signalling explosion to be avoided
- *VIRTUAL BUS* hierarchical systems minimise signalling by using a bus broadcast mode.
- DCA, macrodiversity and soft handovers easily implemented
- Compatible with Cellular IP
- Can handle a mixture of air interfaces

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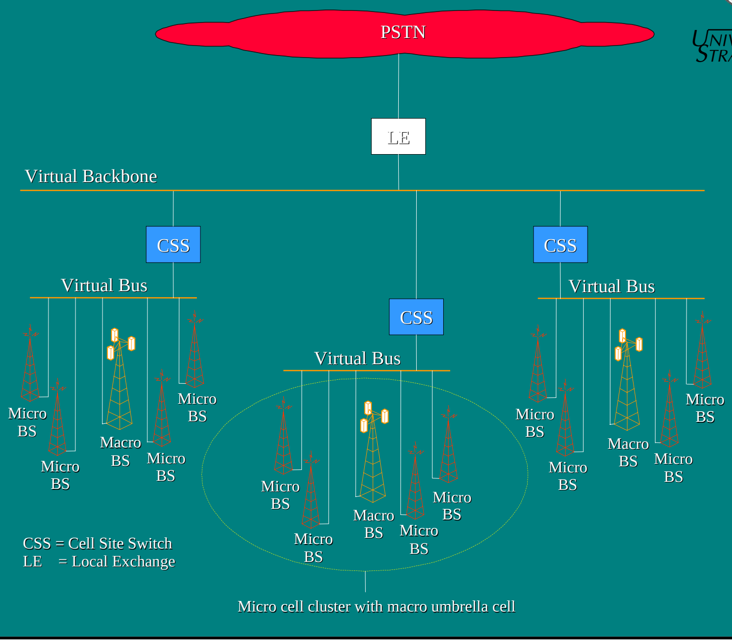
Virtual Bus Mobile Access Network



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Multi-provider Environments

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Business Models		Services
Network Provider is the Service Provider	2G	Voice and Limited Data
↓	↓	↓
Multi-provider Environment	3G	Multimedia Services

- Requirements to support this evolution
  - *Integration of service provision platforms over heterogeneous networks*
  - *Management of QoS in a Multi-provider environment*

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Digital Market Place Concept

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- Dissociation of service provider and network operator roles will result in Mobile Virtual Network Operators (MVNO).
- Service providers will exploit QoS and associated cost parameters to allow an objective comparison of what can be delivered by competing technologies.
- Service providers will select, dynamically, the serving network operator according to the users' price and quality requirements, so adding an explicit competition in the digital marketplace.

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Digital Market Place Framework

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- Based on 4 layers (lowest layer is air-interface dependent)
- The Logical Market Channel (LMC) is introduced to cope with the fact that service providers do not own a network or control channel.
- The LMC is physically supported by one or more network operators.
- The market provider links LMC contracts to network operators into its own digital marketplace, at system initialisation.

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Generic Quality of Service Management Architecture

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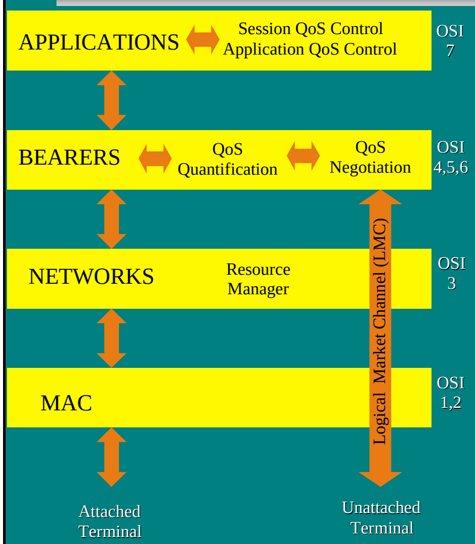

- ***Application layer***, user applications (service provider domain).
- ***Bearer layer***, a generic interface representing the QoS management domain.
- ***Network/MAC layers*** air interface specific (network operator domain)

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Scope of Digital Market Place

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- The primary result of the digital market place concept in mobile communications systems is the scope given for contract negotiation at the point of service provision.
- This is regarded by many as the essence of 4G mobile communications systems.

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Bearer Contracts (TETRA) for BER = 10^{-2}

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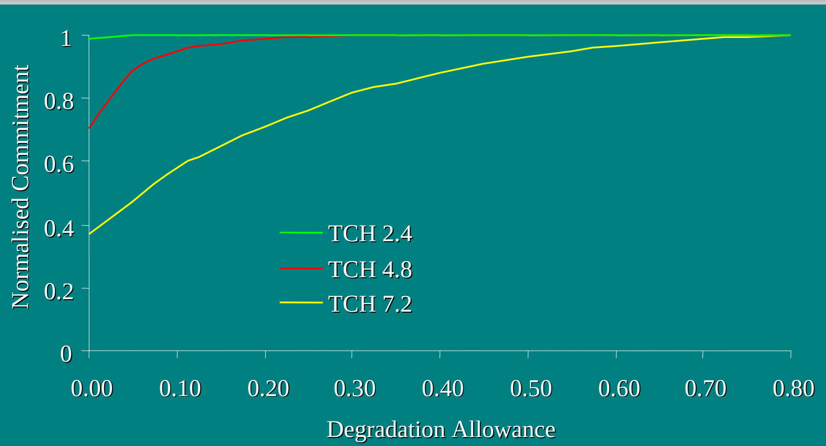

- Each Bearer Service can achieve a Contract Commitment at a specific Resource Cost.

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Conclusions

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- It is clear that routes to UMTS will be provided by a combination of evolving 2G and standard 3G systems.
- In all cases the major developments will be in the services which are offered by these systems and the concepts of contracts between users and service providers with guaranteed quality of service.
- There is now intense interest in this area and the digital market place will become a central feature in the further development communications networks and services which offer mobility (in the general sense) .

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