MSc(Eng) Wireless Communication Systems

Module EEE-6431: Broadband Wireless Techniques

Contact Details

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Key Aims of the Module

- Appreciate how broadband wireless systems operate
- Understand how OFDM or CDMA techniques are used in broadband wireless systems
- Understand how frequency selective fading due to multipath propagation impairs system performance
- Understand how spectrally efficient wireless transmission is achieved using high order modulation
- Appreciate current broadband wireless systems, standards and deployment practices

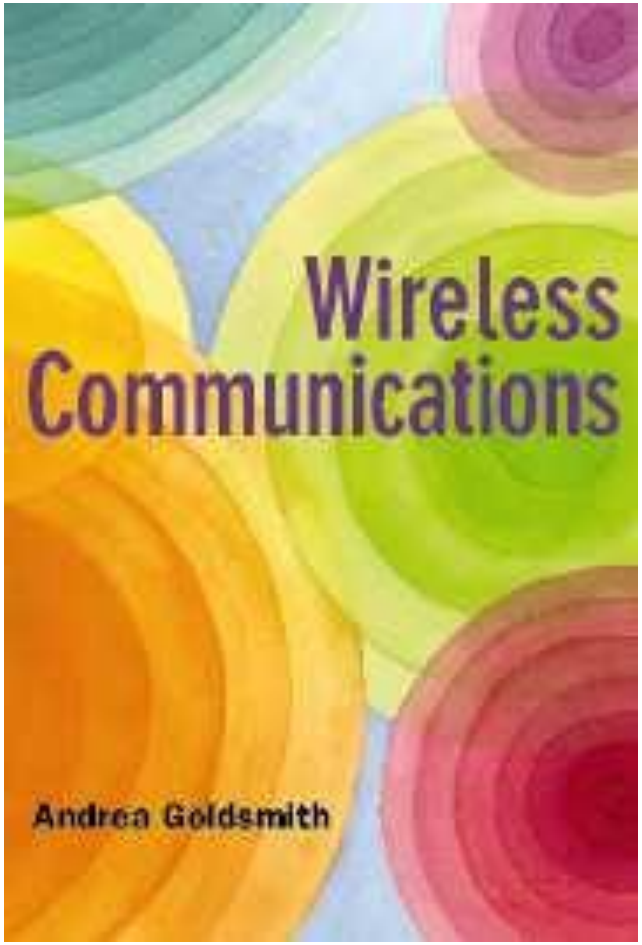
Syllabus Highlights

1. **Introduction - Overview of Broadband Wireless Systems**
2. Signal Propagation, Pathloss Models and Shadowing
3. Statistical Fading Models: Narrowband & Wideband Fading
4. Capacity of Wireless Channels
5. Multicarrier Modulation
6. Spread Spectrum and CDMA

Reading List

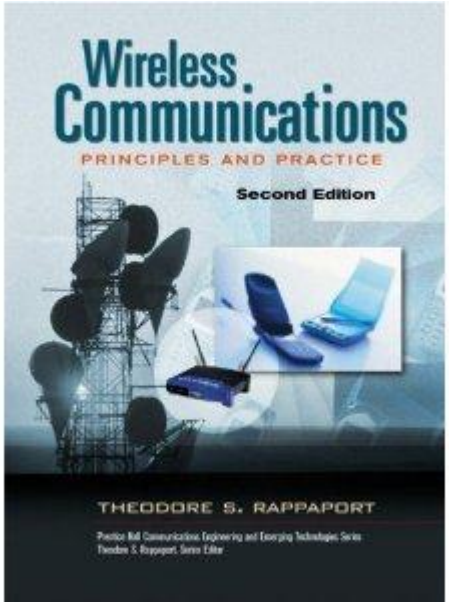
Recommended Course Text

- **Wireless Communications, Andrea Goldsmith, Cambridge University Press 2005, ISBN-13 978-0-521-83716-3**



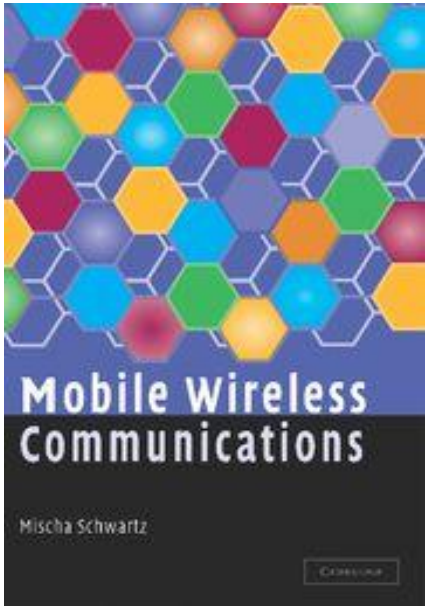
Reading List - Contd

Further Suggested Reading



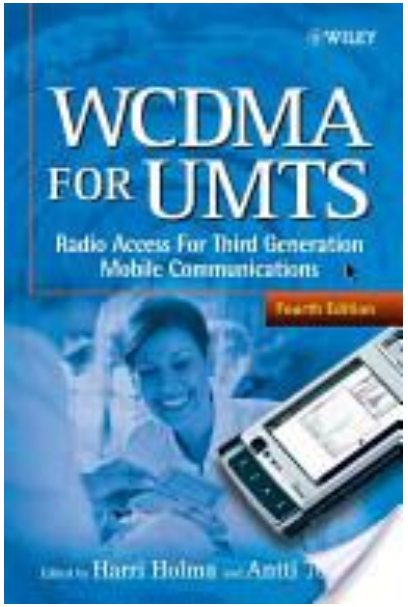
Wireless Communications: principles and practice 2nd Edition, Rappaport, Prentice Hall 2002

ISBN: 978-0-13-042232-3



Mobile Wireless Communications, Mischa Schwartz, Cambridge 2005

ISBN: 978-0-52-184347-8



WCDMA for UMTS: HSPA evolution and LTE, Holma & Toskala, John Wiley & Sons 2007

ISBN: 978-0-47-031933-8

Module Assessment

Assessment Methods

- **2 hr written examination: 75 %**
- **Continual assessment: 25 % (Semester Test – after Easter break)**

Lecture Notes

- **Lecture material will be made available on EEE Intranet & MULE as it becomes scheduled**

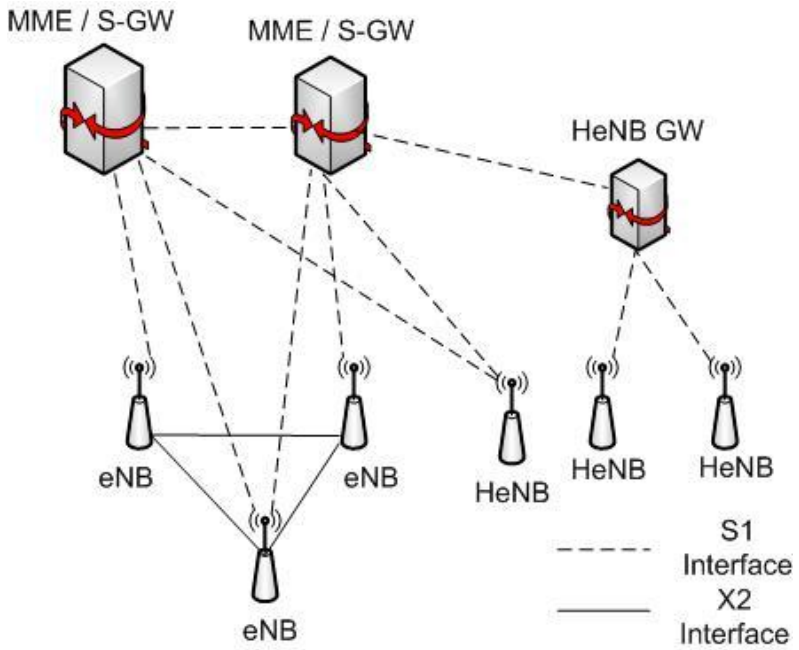
Class Schedule

- **Lectures typically held on Monday and Thursday (with exceptions announced)**
- **Exercise classes typically be held on Tuesday when announced, i.e. not every Tuesday**

1. Introduction: Overview of Broadband Wireless Systems

Two salient examples of Broadband Wireless Communication Systems are:

- **Cellular Mobile – 2G/3G and now developing 4G**
  - **Enjoyed exponential growth since 1988, with about 3 billion users worldwide today**
- **WiFi - IEEE802.11b/g/a/n and soon 802.11ac/ad**



LTE Radio Access Network

WiFi Access Network

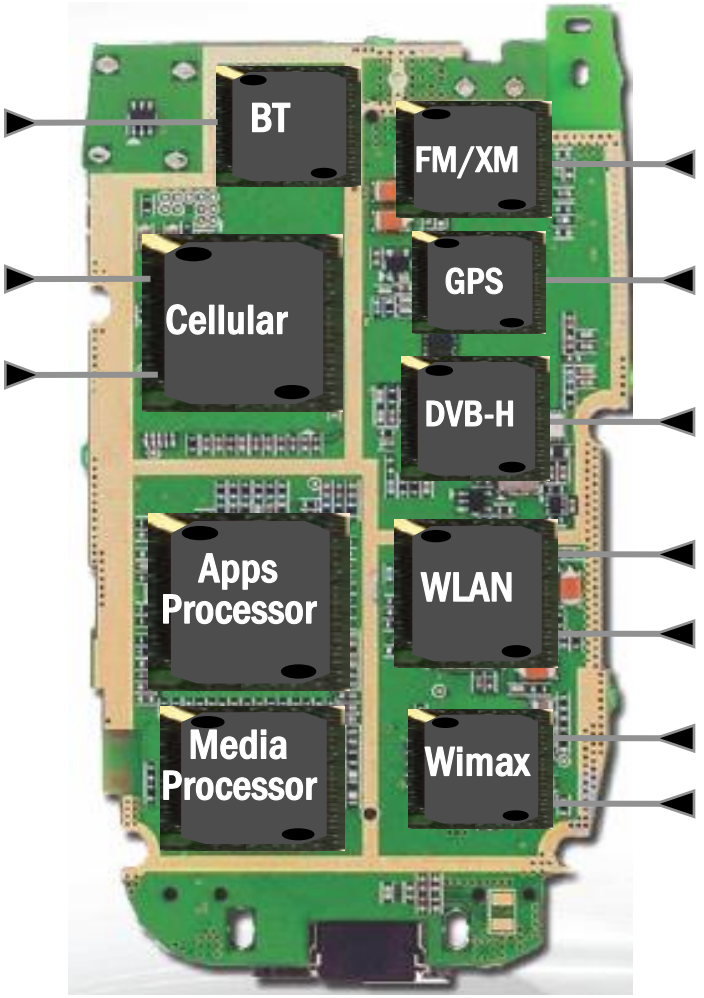
1. Introduction - contd

Future wireless networks span a greater range of scenarios:

- **Next-generation Cellular; Wireless Internet Access; Wireless Multimedia; Sensor Networks; Smart Homes/Spaces; Automated Highways; In-Body Networks; etc…**

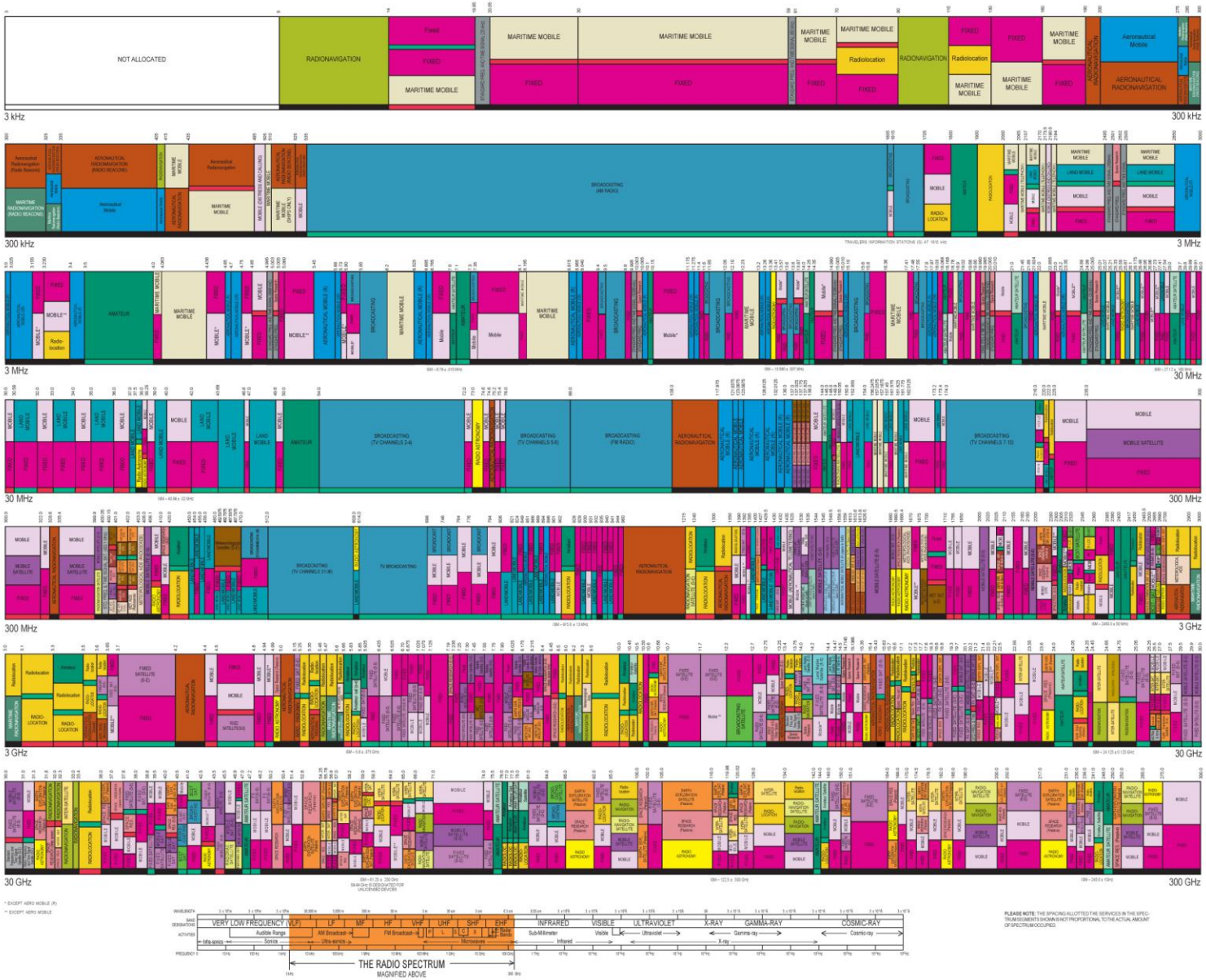
But there are major challenges:

- **Network Challenges**
  - **Scarce spectrum**
  - **Demanding/diverse applications**
  - **Reliability**
  - **Ubiquitous coverage**
  - **Seamless indoor/outdoor operation**
- **Device Challenges**
  - **Size, Power, Cost**
  - **Multiple Antennas in Silicon**
  - **Multiradio Integration**
  - **Coexistance**



1. Introduction & Overview of Broadband Wireless Systems - contd

The spectrum is over crowded making available spectrum scarce and hence costly:



1. Introduction - contd

Evolution of Cellular and WiFi systems:

Wireless systems today

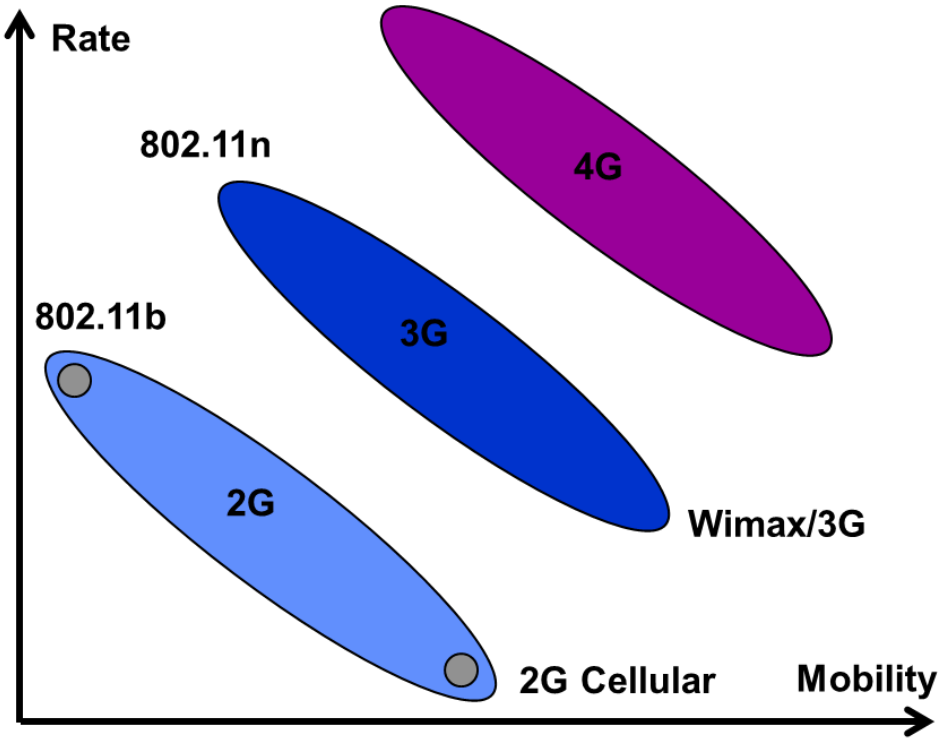
- **3G Cellular: ~200-300 Kb/s.**
- **WLANs: ~450 Mb/s (and growing).**

Next Generation is on the road map

- **4G Cellular: OFDM/MIMO; ~100 Mb/s**
- **4G WLANs: Wide open, 3G just being finalized; > 1 Gb/s**

Technology Enhancements

- **Hardware: Better batteries; better circuits/processors.**
- **Link: More bandwidth, more antennas, better modulation and coding, adaptive, cognition.**
- **Network: better resource allocation, cooperation, relaying, femtocells.**
- **Application: Soft and adaptive Quality of Service (QoS).**



Other Tradeoffs:
- **Rate vs. Coverage**
- **Rate vs. Delay**
- **Rate vs. Cost**
- **Rate vs. Energy**

1. Introduction - contd

Quality of Service: QoS refers to the requirements associated with a given application, typically data rate and delay requirements.

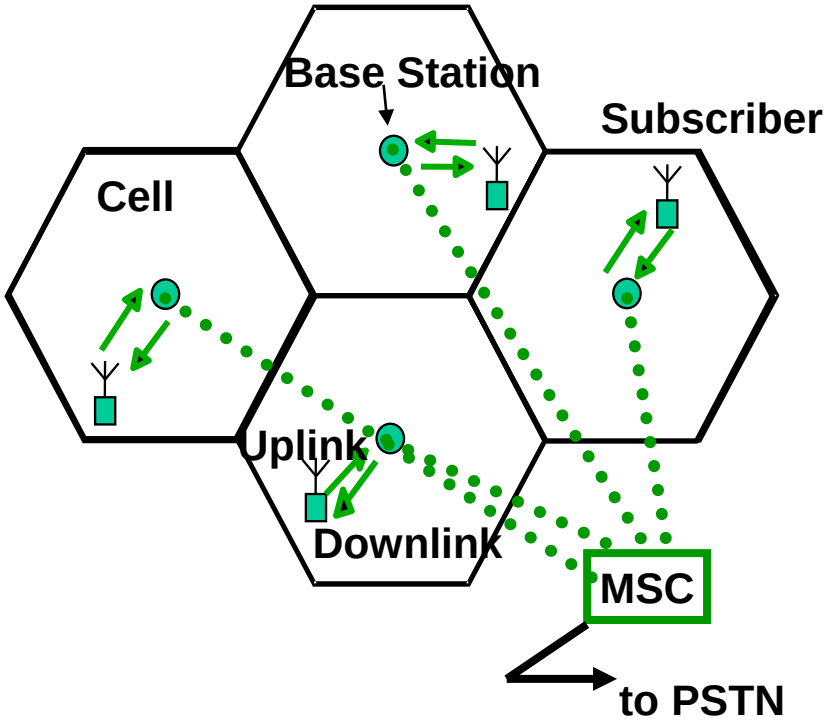
- It is difficult to make a "*one-size-fits all network*" that supports the requirements of different applications (i.e. what is known as differentiated QoS).
- Wired networks use this approach with poor results; by over dimensioning in terms of higher data rates and better transmission reliability than wireless.
- But wireless does not have the bandwidth allocation to over dimension, therefore QoS for all applications often requires a *cross-layer design* approach.

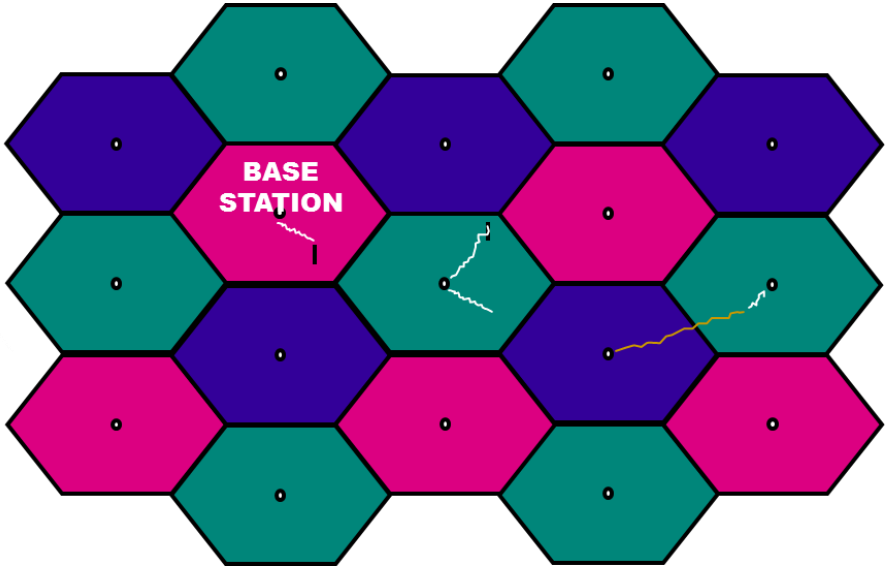
	Voice	Data	Video
Delay	<100ms	-	<100ms
Packet Loss	<1%	0	<<1%
BER	10^{-3}	10^{-6}	10^{-6}
Data Rate	8-32 Kb/s	10-1000 Mb/s	10-1000 Mb/s
Traffic	Continuous	Bursty	Continuous

1. Introduction - contd

The Cellular Deployment Concept:

- Geographic region divided into cells
- Frequency/timeslots/codes/ reused at spatially-separated locations
- Co-channel interference between same colour cells
- Base stations/MSC coordinate handoff and control functions
- Shrinking cell size increases capacity, as well as networking burden

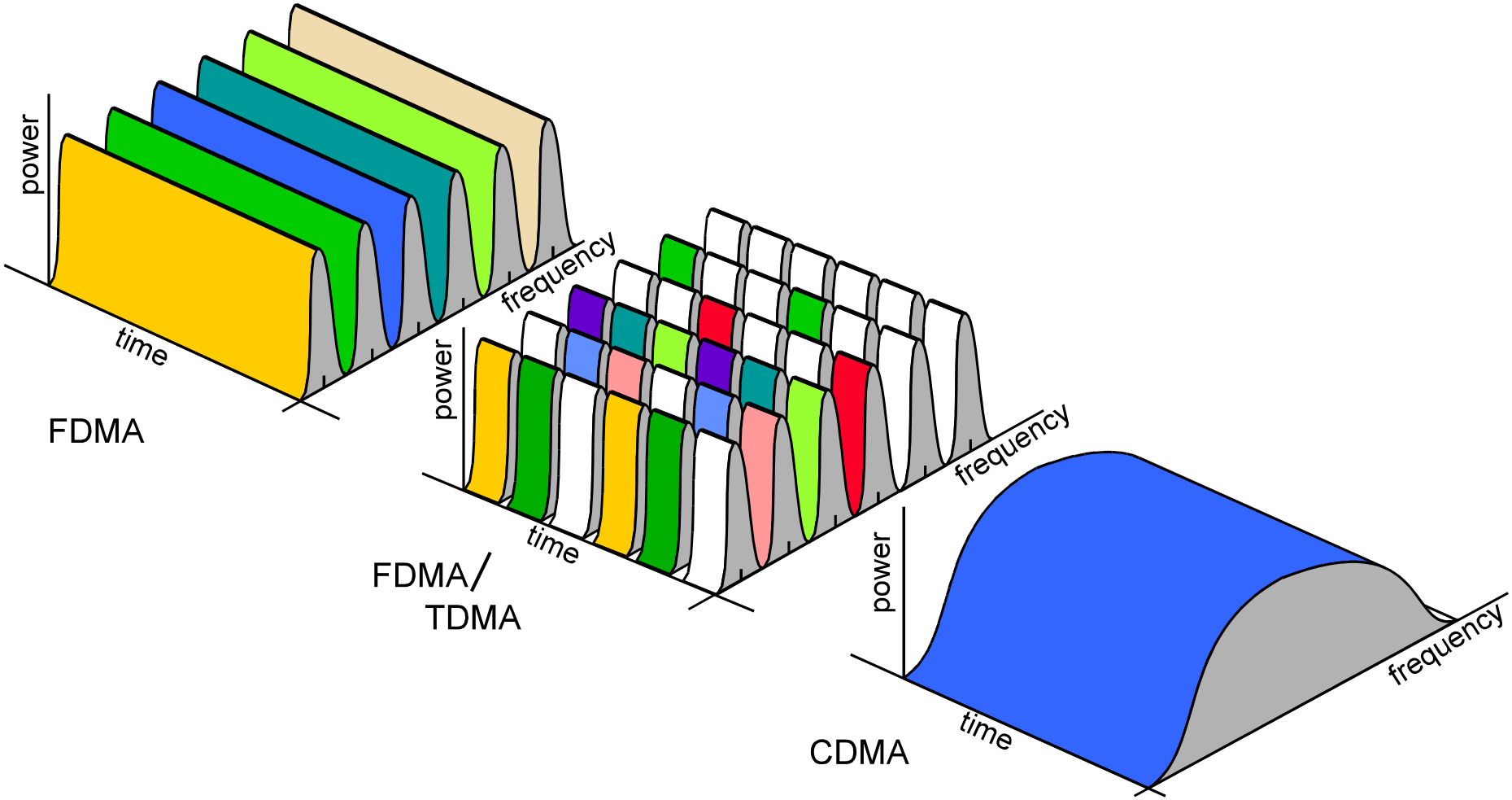




1. Introduction - contd

The Cellular Multiple-Access Concept:

- **Frequency/timeslots/codes/ reused at spatially-separated locations.**



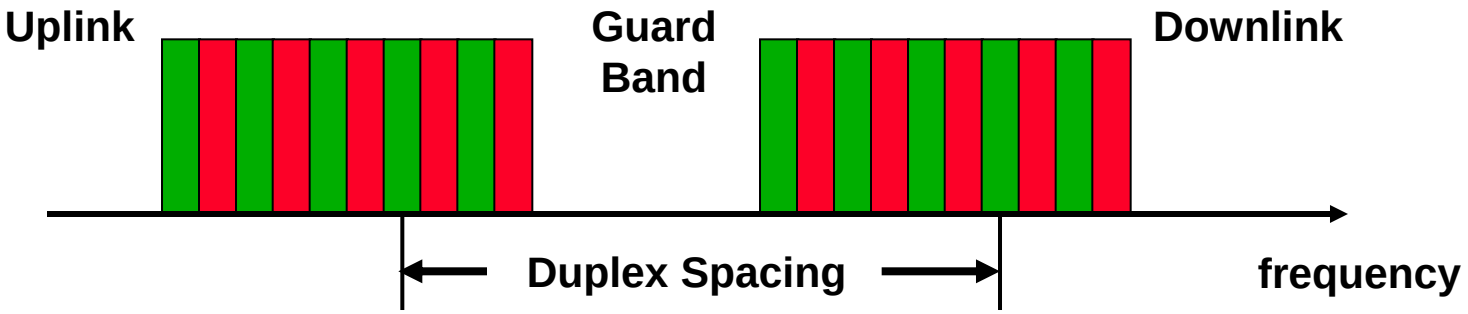
1. Introduction - contd

The Cellular Duplexing Concept: **Duplexing allows separation between the uplink and downlink in a cellular system**

FDD = Frequency Division Duplexing.
Uplink and Downlink on different (usually paired) frequencies.

TDD = Time Division Duplexing.
Uplink and Downlink on same frequency, at different times (usually paired).

CDD = Code Division Duplexing.
Uplink and Downlink on same frequency at same time using orthogonal spreading codes.

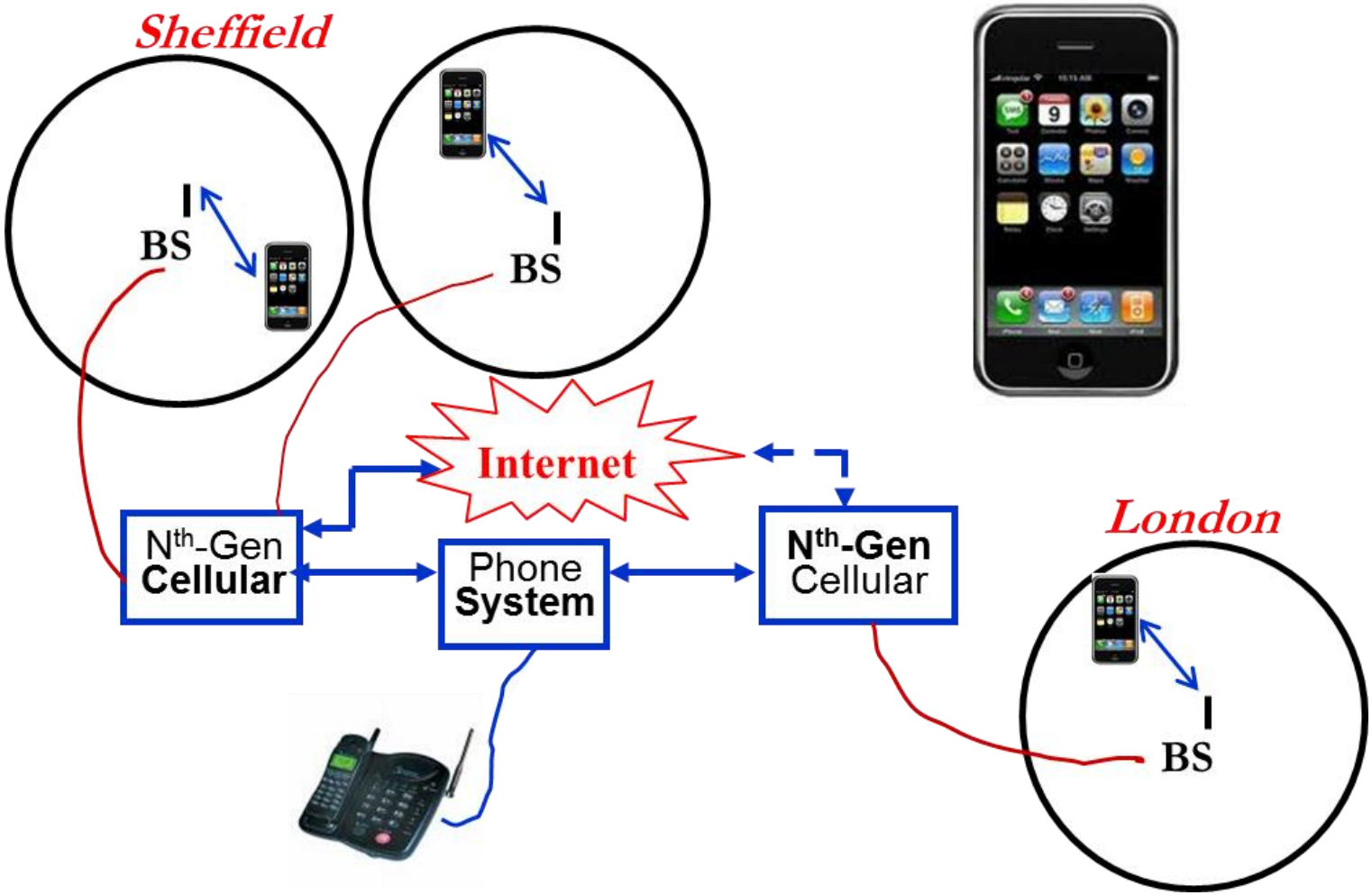


Frequency Division Duplexing

1. Introduction - contd

The Cellular Network Concept:

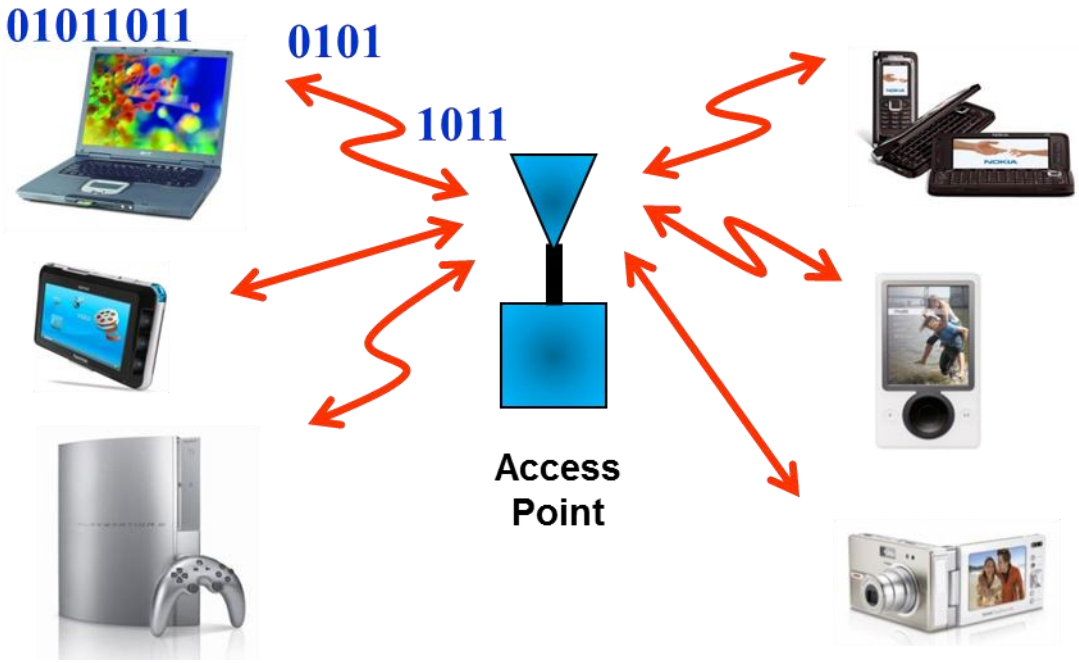
Future networks want better performance and reliability – Gb/s rates, low latency, 99% coverage indoors and out!



1. Introduction - contd

The WLAN Concept:

- WLANs connect “local” devices (30m range)
- Segments data into packets for transmission
- Channel access is shared (random access – e.g. carrier sense multiple access)
- Backbone Internet provides best-effort service
- Poor performance in some Apps (e.g. video)



1. Introduction - contd

Evolution of WLAN Standards - WiFi:

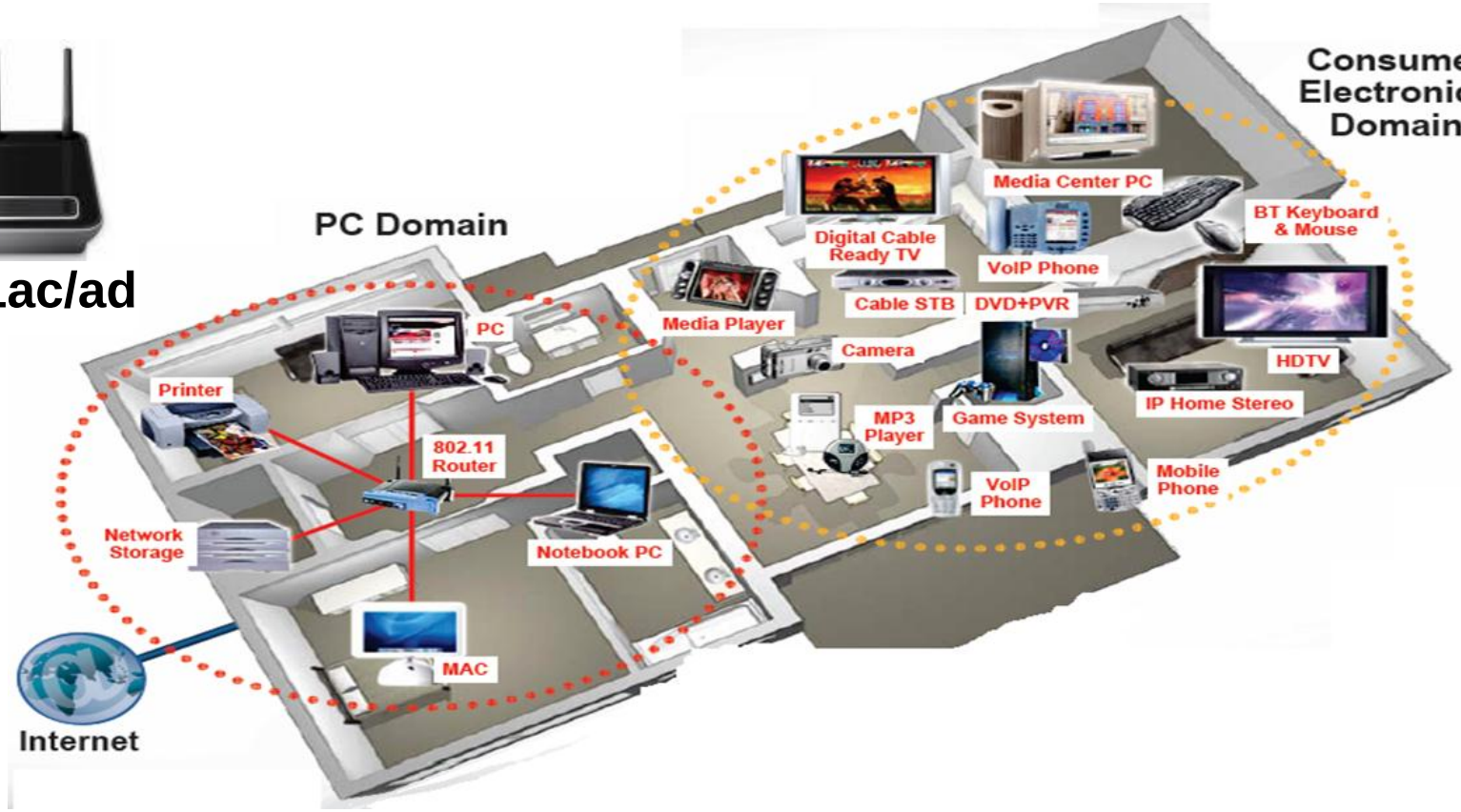
- **802.11 DSSS (in 80MHz @ 2.4GHz ISM band)**
  - Early 1990s
  - Used length 11 Barker Sequence as Spreading Sequence
  - BPSK and QPSK modulation
  - Rate up to 2 Mb/s in 20MHz, ~30m range
- **802.11b (in 80MHz @ 2.4GHz ISM band)**
  - Late 1990s
  - Also DSSS using length 11 CCK complex spreading sequences
  - BPSK and QPSK modulation
  - Rates up to 11 Mb/s in 20MHz, ~30m range
- **802.11a/g (.11a in 300MHz @ 5GHz & .11g in 80 MHz @ 2.4GHz ISM bands)**
  - Early 2000s
  - OFDM with adaptive rate/codes
  - BPSK, QPSK, 16 QAM & 64QAM modulation
  - Rates up to 54 Mb/s in 20 MHz, ~30m range
- **802.11n (in 300MHz @ 5GHz & in 80 MHz @ 2.4GHz ISM bands)**
  - Early 2010
  - Adaptive OFDM /MIMO in 20/40 MHz (2-4 antennas)
  - BPSK, QPSK, 16 QAM & 64QAM modulation
  - Rates up to 600Mb/s, ~30m range
- **Next → 802.11ac (@ 5GHz), 802.11ad @ 60 GHz and 802.11AF (TV White Spaces)**

1. Introduction - contd

WiFi Networks:

- **Multimedia everywhere without wires**
  - **Streaming video**
  - **Gb/s data rates**
  - **High reliability**
  - **Coverage in every room**

802.11ac/ad

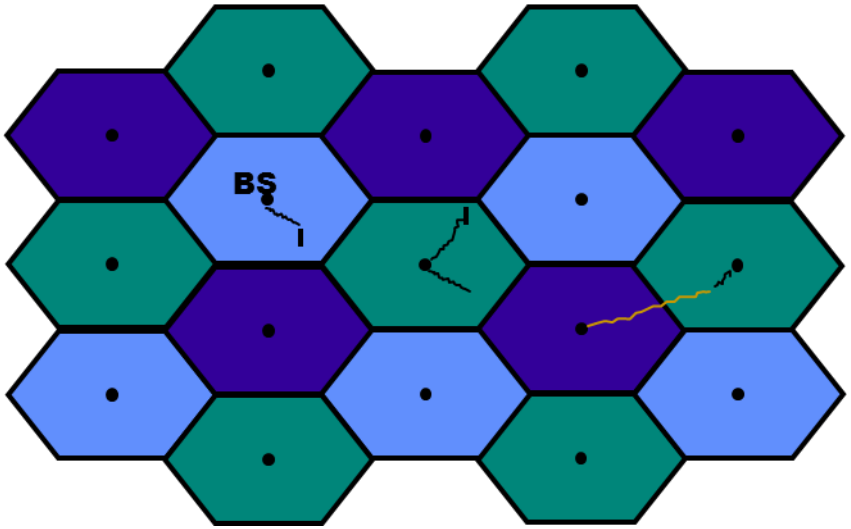


1. Introduction - contd

Spectrum Regulated: Due to its scarcity -

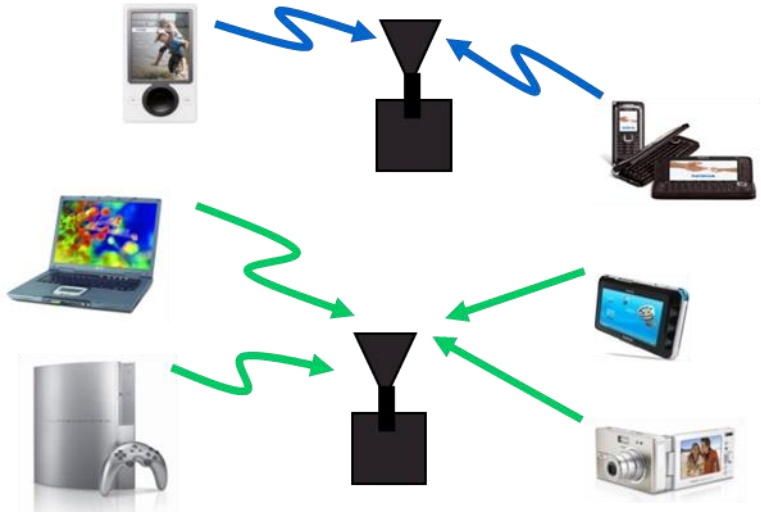
- **In cellular systems spectrum is reused**
- **In WiFi systems spectrum is shared**
- **This leads to cochannel interference**

licensed bands



Cellular

unlicensed bands



Wifi, BT, Zigbee,…

1. Introduction - contd

Radio Spectrum Regulation Bodies:

- In the UK, spectrum is regulated by OFCOM
- In the USA, spectrum is regulated by the FCC
- Worldwide, spectrum is regulated by the ITU via the WRC

Communications Standards Bodies:

- Interconnecting communication systems require standardisation
  - Companies want their systems adopted as standard
  - Alternatively try for de-facto standards
- In the USA, communications standards are determined by TIA/CTIA
  - IEEE standards often adopted
  - Process fraught with inefficiencies and conflicts
- In Europe, standards determined by ETSI
- Worldwide standards determined by ITU

1. Introduction – Contd.

Radio regulations **are necessary to ensure an efficient and economical use of the radio-frequency spectrum by all communications systems, both terrestrial and satellite. While so doing, the sovereign right of each state to regulate its telecommunication must be preserved. It is the role of the International Telecommunication Union (ITU) to promote, coordinate and harmonise the efforts of its members to fulfil these possibly conflicting objectives.**

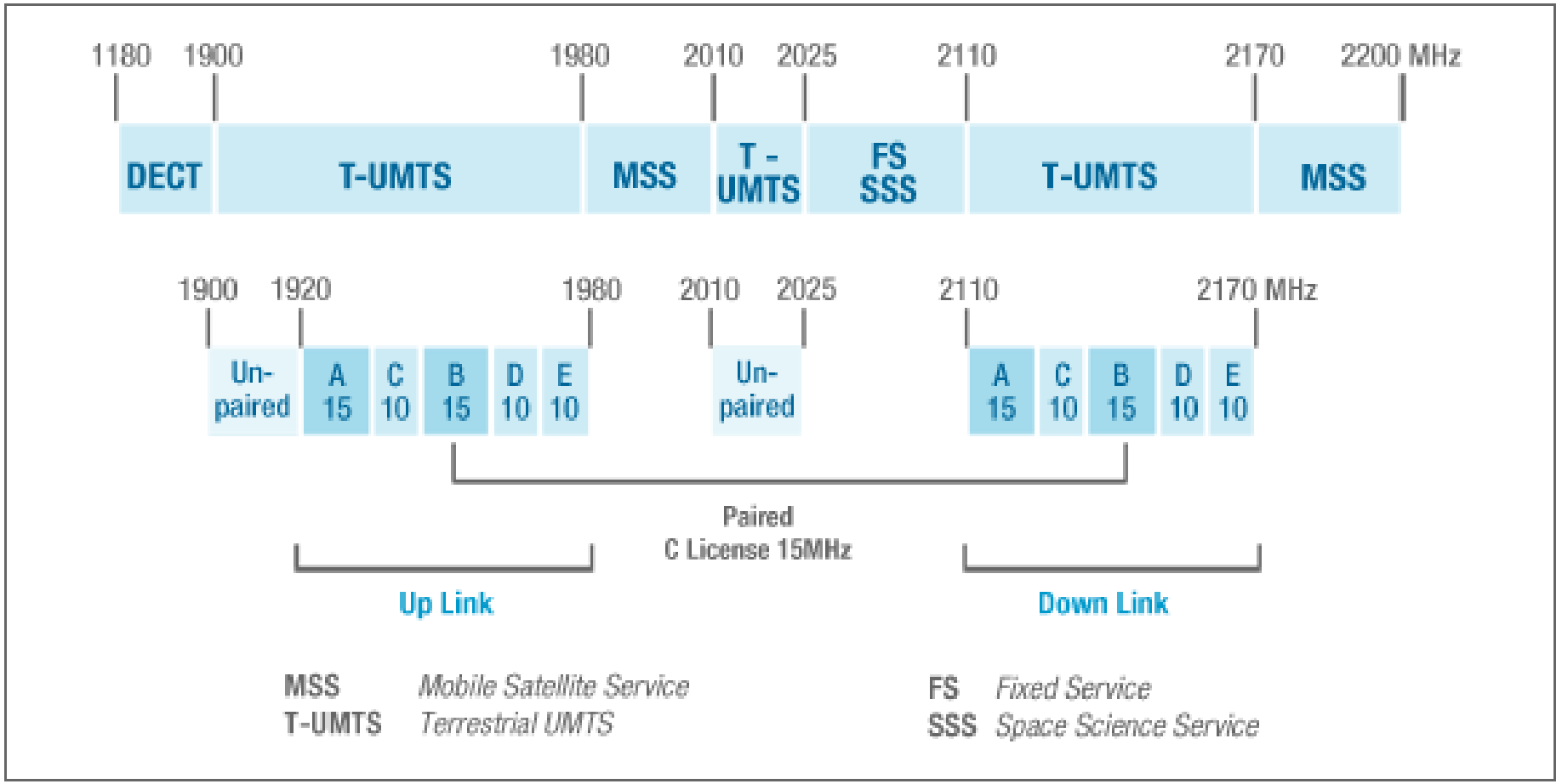
The ITU Organisation**: The International Telecommunication Union (ITU), a United Nations organisation, operates under a convention adopted by its member administrations. The ITU publishes the Radiocommunication Regulations (RR), which are reviewed by the delegates from ITU member administrations at periodic World/Regional Radio Conferences (WRC/RRC).**

Technical and operational matters are administrated by three streams or sectors:

- **The Radiocommunications Sector (ITU-R) deals with all regulatory and technical matters on radio communications;**
- **The Telecommunication Standardisation Sector (ITU-T) deals with the regulatory and technical aspects of public networks and therefore includes the interconnection of radiocommunication systems with public networks.**
- **The Development Sector (ITU-D) acts as a forum and an advisory structure for the development of communications worldwide.**

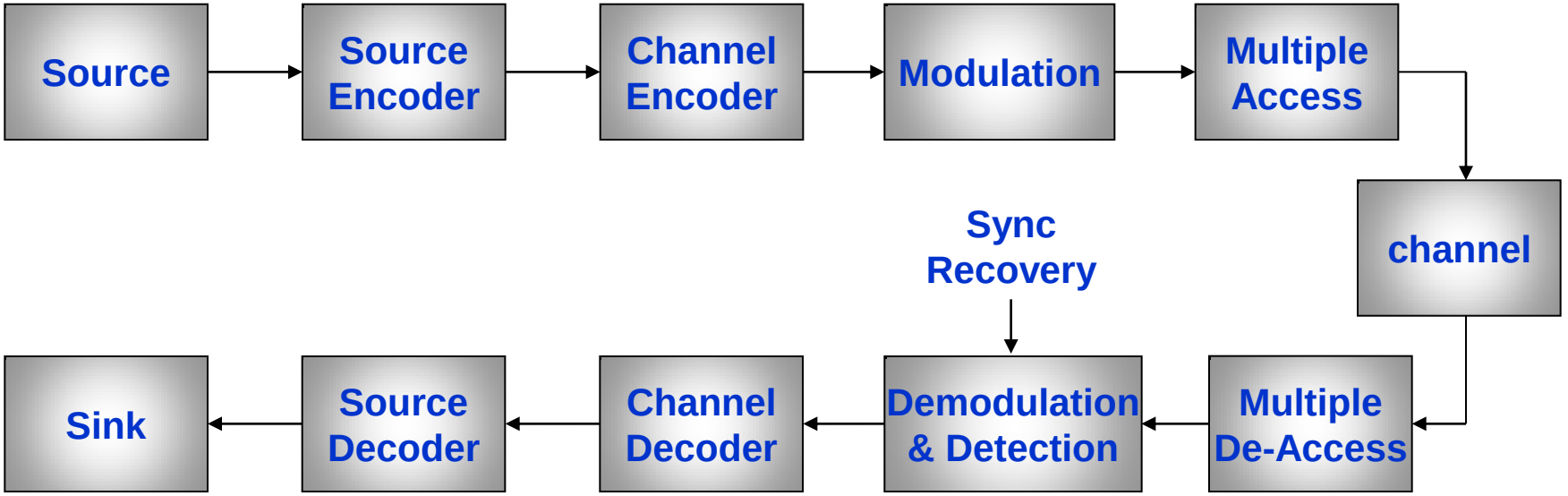
1. Introduction-contd

- **Radio spectrum for UMTS (Universal Mobile Telecommunication System)**



1. Introduction – Contd.

To appreciate the wireless version of a digital communication system, we must first appreciate what the essential elements of a digital communications system are. A general block diagram of a digital data communication system is shown below :-



The objective of any communication system can be summarised as:

Received Information = Transmitted Information

In such a system we are concerned with the transmission of information from sources that produce discrete symbols. The primary measure of system performance is probability of data bit error P_E and we are primarily interested in receiver structures that minimise P_E .

1. Introduction-contd

- Information source: any entity having information to transmit (audio, image, data...).
- Source encoder: Source coding involves digitisation (e.g. A/D conversion), and compression (i.e. the removal of redundant information to reduce bandwidth).
- Channel encoder: Channel coding adds controlled redundancy (i.e. additional bits) to allow for the detection and/or correction of errors at the receiver (e.g. linear block codes, convolutional codes and turbo-codes).
- Modulation: translation of the baseband message signal to a format suitable for transmission over the physical medium.
- Multiple access: techniques which allow more than one transceiver pair to share a common transmission medium (FDMA, TDMA, CDMA etc...)
- Channel: the physical medium by which information-bearing signals are transferred from the transmitter to the receiver (e.g. coaxial cable, optical fibre, radio etc...). The channel typically distorts the transmitted signal by two processes:
  - Band-limited filtering (e.g. devices, multipath)
  - Additive White Gaussian Noise (AWGN) – spectrally flat random signal with Gaussian distributed amplitudes.
- The receiver performs the complementary operations of the transmitter, it has the task of overcoming the noise and distortion introduced by the channel.
- Sinks of information: people or various types of information storage and display devices.

1. Introduction-contd

Summary & Main Points:

- **The wireless vision encompasses many exciting systems and applications**
- **Technical challenges transcend across all layers of the system design**
- **Cross-layer design emerging as a key theme in wireless**
- **Existing and emerging systems provide excellent quality for certain applications but poor interoperability**
- **Standards and spectral allocation heavily impact the evolution of wireless technology**