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淡 江 軟 體 工 程 實 驗 室
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行動通訊管理導論

本教材僅供修習學生閱讀使用，敬請尊重智慧財產權，勿非法使用本教材內容及相關參考資料

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Date :4/22/2012

基本規定

- 上課用書
  - Mobile Computing　Raj Kamal 著　Oxford出版　開發圖書代理
  - 請尊重智慧財產權，勿非法影印使用教科書與參考書籍及使用盜版軟體
- 參考資料
  - ICE聯盟編撰教材
- 成績評定
  - 出席15%、平時作業40% 、期中報告15%、期末報告20%
  - 出席成績僅考核出席與否，故不接受任何請假，但每人每學期有三次免責，全勤者於學期成績另加3分
  - 演講一場：需繳交隨堂聽講報告(10%) ，若無法安排演講，此項分數併入平時作業成績
  - 一般作業遲交每24小時扣10分、隨堂作業、期中與期末報告不可遲交
  - 期中報告繳交時間：4/10 1500前、期末報告繳交時間：5/15 1500前
- 上課方式
  - 投影片爲主、板書爲輔
- 上課規定
  - 手機改設震動或關機、不要私下講話

課程目標

- 瞭解行動通訊基本運作原理
- 學習行動通訊各類『資源管理』方法與技術

調整上課心態與學習態度

- 以前修課的想法可能是求過關就好
- 以前的學習態度可能是可以順利畢業就好
- 現在妳(你)應該要爲即將就業作準備
- 現在的妳(你)應該要知道爲什麼要學、要學什麼
- 現在的妳(你)應該要開始思考如何面對競爭
- 現在的妳(你)應該要準備如何打贏一場又一場的競賽
- 現在的妳(你)應該思考如何成爲企業需要的人才

對同學們的建議

- 在專業養成上 (Hard Skills)
  - 奠定紮實的基礎
  - 養成終身學習的習慣
- 在人格養成上 (Soft Skills)
  - 建立正確的態度
  - 處事三態：真誠、負責、合群

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Agenda

- Overview
- Revolution of Wireless Communication Networks
- Concept of PCS (Personal Communication Services)
- Revolution of Mobile Communication Systems
- Architectures and Operations of Mobile Communication System
- Basic Technologies of Mobile Communication

Agenda (Cont.)

- Wireless Systems and Standards

Overview

- Communication vs. Network
- Wirelined vs. Wireless
- Mobile Communication vs. Wireless Network
- Infrastructure vs. Non-Infrastructure

Overview

- Communication
  - Communication— a two-way transmission and reception of data streams
  - Signals for Voice, data, or multimedia streams transmitted
  - Signals received by a receiver.
  - Signals from a system transmit through a fibre, wire, or wireless medium.
  - According to defined regulations, recommended standards, and protocols

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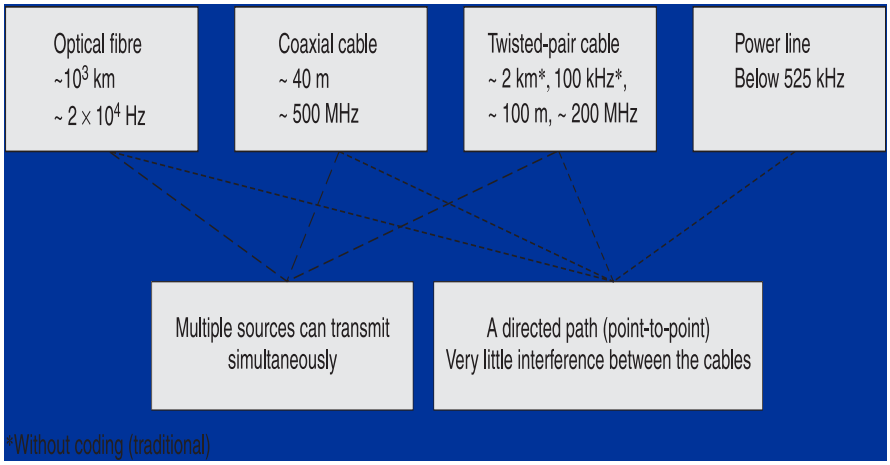
Overview

- Network
  - Computer Network— is a collection of hardware components and computers interconnected by communication channels that allow sharing of resources and information
  - Where at least one process in one device is able to send/receive data to/from at least one process residing in a remote device, then the two devices are said to be in a network.
  - Networks may be classified according to a wide variety of characteristics such as the medium used to transport the data, communications protocol used, scale, topology, and organizational scope.

Wirelined Materials and their Range



Wireless Techniques and their Range

- **Wireless telecommunications** is the transfer of information between two or more points that are not physically connected
- **Radio** is the transmission of signals through free space by modulation of electromagnetic waves with frequencies significantly below those of visible light. Electromagnetic radiation travels by means of oscillating electromagnetic fields that pass through the air and the vacuum of space.
- Information is carried by systematically changing (modulating) some property of the radiated waves, such as amplitude, frequency, phase, or pulse width.

Wireless Techniques and their Range

- **Radio Spectrum**
- **Radio spectrum** refers to the part of the electromagnetic spectrum corresponding to radio frequencies – that is, frequencies lower than around 300 GHz (or, equivalently, wavelengths longer than about 1 mm).
- Different parts of the radio spectrum are used for different radio transmission technologies and applications. Radio spectrum is typically government regulated in developed countries and, in some cases, is sold or licensed to operators of private radio transmission systems (for example, cellular telephone operators or broadcast television stations).

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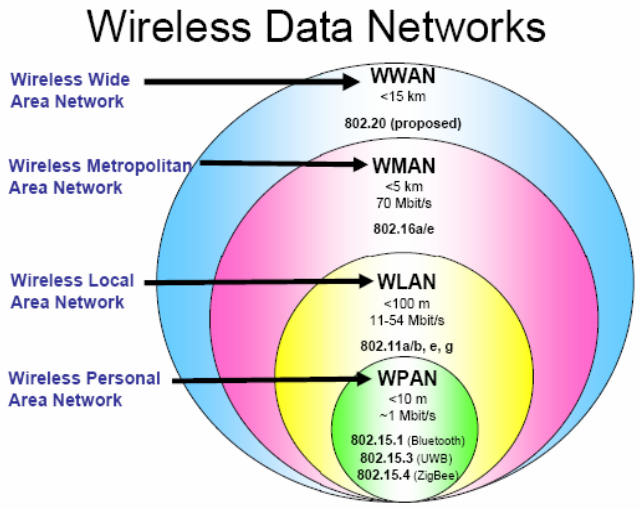
Wireless Techniques and their Range

- **Hz**
  - The hertz (symbol Hz) is the SI unit of frequency defined as the number of cycles per second of a periodic phenomenon.
  - SI means *International System* of Units
  - One of its most common uses is the description of the sine wave, particularly those used in radio and audio applications.
  - The hertz is equivalent to cycles per second.
  - 1 Hz = 1/s

Wireless Techniques and their Range



Mobile Communications

- Entails transmission of data to and from handheld devices
- Two or more communicating devices
- At least one is handheld or mobile
- Location of the device can vary either locally or globally
- Communication takes place through a wireless, distributed, or diversified networks

Wireless Networks

- **Wireless network** refers to any type of computer network that is not connected by cables of any kind.
- It is a method by which homes, telecommunications networks and enterprise (business) installations avoid the costly process of introducing cables into a building, or as a connection between various equipment locations.
- Types of wireless networks
  - Wireless PAN
  - Wireless LAN
  - Wireless Mesh Network
  - Wireless MAN
  - Wireless WAN

Non-Infrastructure

- It is also called, **Ad Hoc networks,** or, **Ad Hoc communications**.
- It means that there is no any constructing equipments, such as cable, switch (base station), router (PBX), etc. are built.
- **Infrastructure** is revised.

Wireless Communication Networks

- Development Trend between Telecommunications and Computer Networks is same.
- Communicate and Access (Transmit/Receive) by real time or non-real time in any place and any time
- General Title is **Wireless Communication Networks (無線通訊路網路)**

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Revolution of Wireless Communication Networks

- Part One - Mobile Communication Systems
  - Mobile Radio Communication
    - 無線電通訊(對講機)—軍用及民用
    - 火腿族行動無線系統
    - 可攜式家用無線電話
    - 傳呼機 (Pager)
    - 二哥大
    - 行動電話 (Cellular Phone/Mobile Phone)
      - First Generation (1G)
      - Second Generation (2G)
      - GPRS (2.5G)
      - Third Generation (3G)
      - HSDPA (3.5G)
      - WiMax/LTE-A (4G)

Revolution of Wireless Communication Networks

- Part Two - Wireless Network Systems
  - WiFi (Infrastructure)
    - Wireless LAN
    - Access Point
  - Ad-Hoc (Non-infrastructure)
    - Wireless Point-to-Point Network
    - Mobile Host acts as a router
    - without Access Point

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Revolution of Wireless Communication Networks

- Radio Frequency Technologies
  - Before 1930s, using Amplitude Modulation
  - Middle 1930s, Mobile Phone using Frequency Modulation was born
  - last of 1940, Cellular concept was built by AT&T Bell Lab.

Revolution of Wireless Communication Networks

- Wireless Communication Systems的分類
  - One - 以下列三個座標軸分類
    - 電傳(Telecommunication) v.s. 數據(Data communication)
    - 窄頻(Baseband) v.s. 寬頻(Broadband)
    - 區域(Local area) v.s. (廣域)Wide area)
- 分類如下表

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Revolution of Wireless Communication Networks

通訊系統	Tele/Data	Base/Broad	Local/Wide
無線傳呼	Data comm.	Baseband	Wide Area
數位無線電話	Telecomm.	Baseband	Local Area
蜂巢式行動電話	Tele & Data	Baseband	Wide Area
中繼式無線行動通訊	Telecomm.	Baseband	Local Area
衛星通訊	Tele & Data	Baseband	Wide Area
無線行動數據通訊	Data comm.	Baseband	Local Area
無線網路寬頻服務	Telecomm.	Broadband	Local Area

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Revolution of Wireless Communication Networks

- Two - 以服務型態可分為
  - 固定型服務 (Fixed service): 通訊設備位置固定不動
  - 靜態型服務 (Stationary service)；通訊設備位置可移動，但移動過程不提供通訊服務
  - 可攜型服務 (Portable service)；通訊設備在移動時可持續通訊，但僅限於徒步
  - 行動型服務 (Mobile service)；通訊設備可在車輛高速行進時持續通訊

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Revolution of Wireless Communication Networks

- Three - 依傳送訊息型態可分為
  - 無線語音傳輸服務 (Wireless voice service)
  - 無線數據傳輸服務 (Wireless data service)
  - 無線多媒體傳輸服務 (Wireless multimedia service)

Concept of PCS

- Personal Communication Services (PCS)
  - included various wireless access and personal mobility services
  - Ultimate goal to communication, through a small terminal, with a person at any time, any place, and any form.
- Functions of PCS
  - Terminal mobility
  - Personal mobility
  - Service mobility

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Concept of PCS

- Practices of PCS
  - Mobile Communication Systems
- Two tiers of Mobile Communication Systems
  - High Tier Digital Cellular Systems
  - Low Tier Cordless Telecommunication Systems

Concept of PCS

- Comparison of the Two tiers of Mobile Communication Systems
  - High tier digital cellular systems
    - 提供高移動性通信服務
    - 設計較複雜
    - 基地台射頻功率大、涵蓋範圍廣
    - 需作頻率重複使用安排
    - Terminal的輸出功率高、體積與重量大、通話與待機時間短
    - 適合話務量低、高速移動的通訊服務
  - Low tier cordless telecommunication systems
    - 反之

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Concept of PCS

	High Tier	Low Tier
基地台體積	大	小
基地台價格	昂貴(以百萬爲單位)	便宜(以萬爲單位)
每一基地台涵蓋範圍	最高數十公里(<35)	小於1.5公里
系統容量	低～中等	高
手機續話時間	短(1~2小時)	長(>4小時)
通話品質	較有線差	接近有線
單位電路成本	高	低
預期話務量	低	高
手機移動速度	快(可達250公里/時)	慢(<100公里/時)

Revolution of Mobile Communication Systems

- Generations of Cellular Mobile Phone (High Tier based)
  - First generation: Analog systems
    - AMPS (Advance Mobile Phone System) of America
    - TACS (Total Access Communication System) of England
    - NMT450/900 of North Europe
  - Second generation: Digital systems, Circuit switching
    - Digital speech with low-bit-rate data services
    - GSM, IS-136, IS-95, and low-tier systems
  - 2.5 generation: Digital systems, support Packet switching
    - WAP: Wireless Application Protocol
    - GPRS: General Packet Radio Service
    - EDGE: Enhanced Data rates for Global(GSM) Evolution

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Revolution of Mobile Communication Systems

  - Third Generation: Broadband, High speed, support multimedia communication
    - Better system capacity
    - High-speed and wireless Internet access (to 2Mbps)
    - Wireless multimedia services (audio and video)
    - CDMA2000. WCDMA, TD-SCDMA
  - 3.5 Generation:
    - HSDPA (High Speed Downlink Packet Access)
    - Extended from WCDMA
    - 8-10 Mbit/s at 5MHz carrier bandwidth
  - Forth Generation:
    - WiMax
    - LTE Advanced (LTE-A)

Revolution of Mobile Communication Systems

- The new features for 3G includes
  - 3G Data Rate Requirement
    - Vehicular -- 144 Kbps
    - Pedestrian --- 384 Kbps
    - Indoor --- 2Mbps
  - QoS, Bit rates dependent on distance
  - Asynchronous Transfer Mode (ATM) backbone
  - Wideband CDMA (WCDMA、DS-CDMA FDD), TD-SCDMA and cdma2000 (multi-carrier FDD) for air interface
    - cdma2000 (evolved from cdmaOne)
    - W-CDMA (proposed by Europe)
    - TD-SCDMA (proposed by China/Europe)

Revolution of Mobile Communication Systems

- HSDPA
  - WCDMA Downlink Data Rate Requirement
    - 8-10Mbit/s at 5MHz carrier bandwidth
    - 20Mbit/s at 5MHz carrier bandwidth with MIMO
  - AMC (自適調變與編碼)
  - MIMO (多輸入多輸出)
  - HARQ (混合自動重傳請求)
  - 更快速的排程(Scheduling)方法
  - 更快速的重傳方法
  - Incremental Redundancy (增量冗餘)

Revolution of Mobile Communication Systems

- WiMAX (Worldwide Interoperability for Microwave Access)
  - 由美國**Intel**所主導
  - 是目前傳輸距離最遠的4G技術也是目前發展最快技術
  - 在移動通訊環境下可以讓下行與上行最高速率各可達到75Mbps及75Mbps
  - 新一代的**IEEE 802.16m** (WiMAX 2)標準可讓行動接收下行與上行最高速率可達到300Mbps，在靜止定點接收可高達1Gbps

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Revolution of Mobile Communication Systems

- LTE-A
  - 使用「正交頻分復用」（**OFDM**）的射頻接收技術
  - 採2x2和4x4 MIMO的分集天線技術規格
  - 同時支援FDD（頻分雙工）和TDD（時分雙工）
  - LTE是**GSM**超越3G與HSDPA階段邁向4G的進階版本
  - 2010年12月6日國際電信聯盟把LTE正式稱爲4G
  - LTE Advanced (LTE-A)
    - 是**LTE**的增強
    - 完全向後兼容**LTE**，通常通過在**LTE**上通過軟體升級即可
    - 升級過程類似於從WCDMA升級到HSPA

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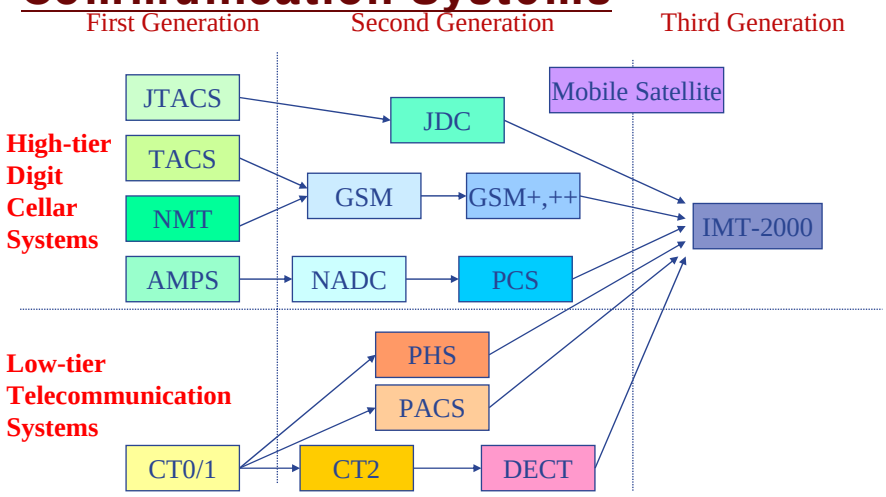
Revolution of Mobile Communication Systems



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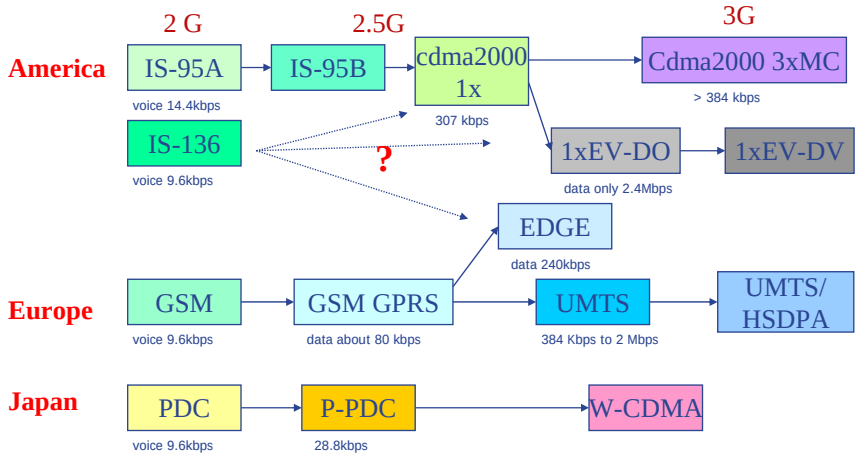
Revolution of Mobile Communication Systems



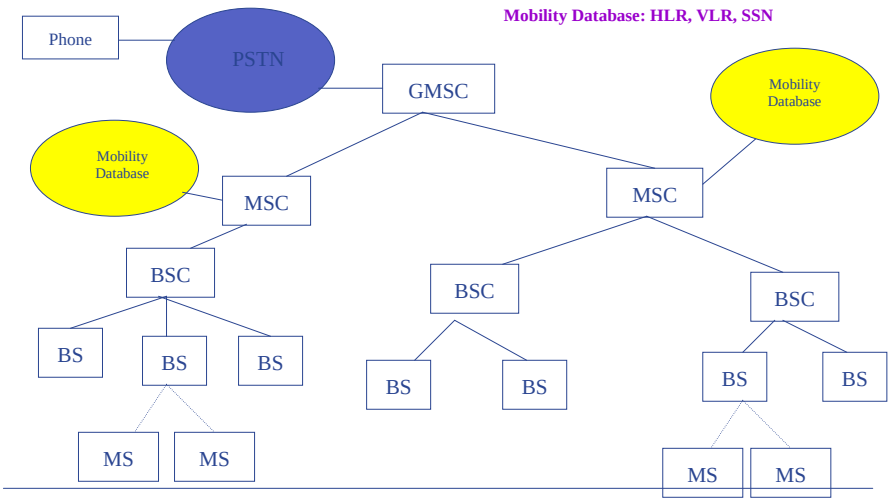
Revolution of Mobile Communication Systems

- High tier digital cellular systems
  - GSM (Global System for Mobile communication) of Europe
  - ADC (American Digital Cellular or IS-54 or D-AMPS) of America
  - DCS-1800 (Digital Communication System-1800) of Europe
  - PDC (Personal Digital Cellular) of Japan
  - LTE (Long Term Evolution) of Europe
- Low tier cordless telecommunication systems
  - CT2 (Cordless Telephone 2) of Europe
  - DECT (Digital European Cordless Telephone) of Europe
  - PACS (Personal Access Communication Systems) of America
  - PHS (Personal Handy phone System) of Japan

Architectures of Mobile Communication Systems

- Mobile Communication System/PCS Architecture: both cellular system and cordless system have similar architectures as following:
- The basic architecture consists of two parts
  - The Radio Network
    - Handsets (mobile phones, or mobile stations), MSs
    - Base stations, BSs
    - Base station controller, (BSCs)
  - The Wireline Transport Network
    - Mobile Switching Controller, (MSCs)
    - Gateway MSC, (GMSC)
    - Mobility Database
    - Public Switched Telephone Network, (PSTN)

Basic Architecture of Cellular Communication



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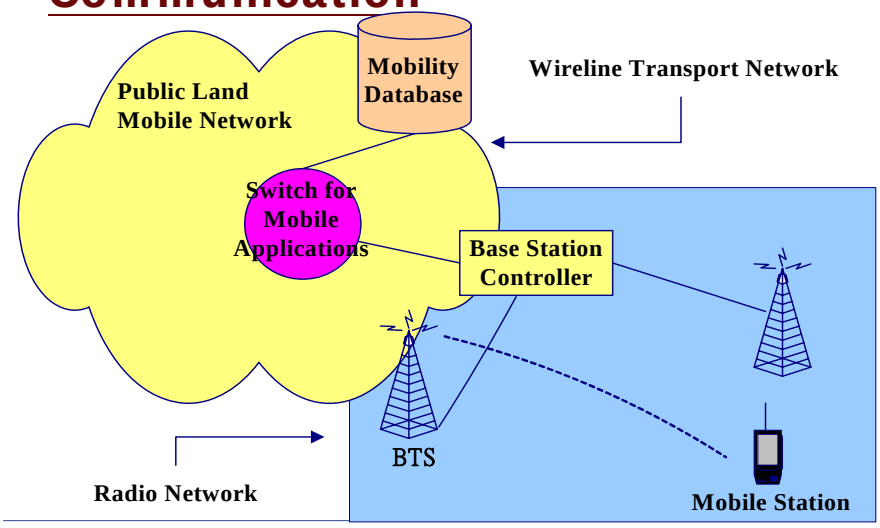
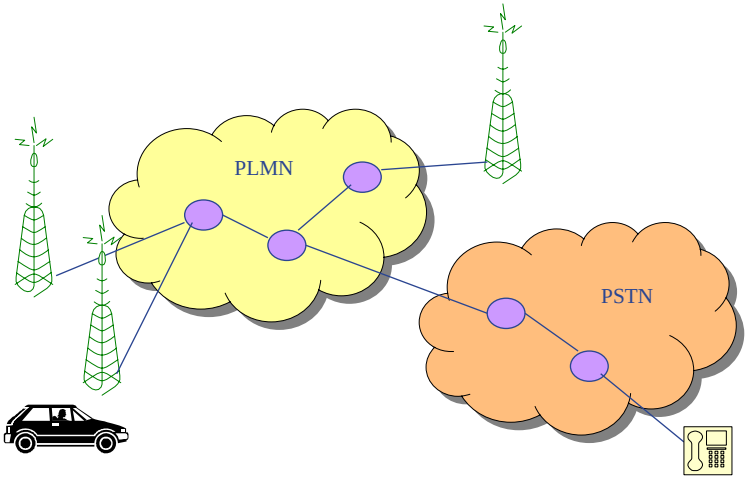
Basic Architecture of Cellular Communication



Public Land Mobile Network (PLMN)



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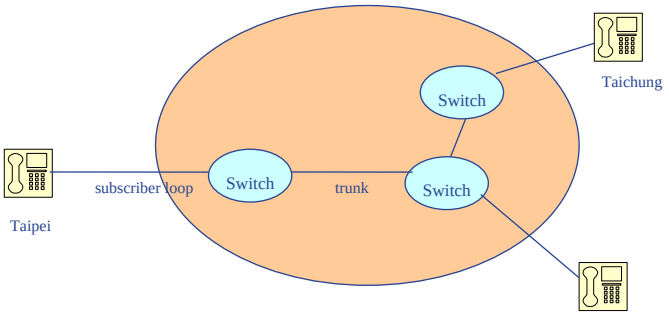
Public Switched Telephone Network (PSTN)



Basic Operations of Cellular Communications

- Cellular coverage (Cell): 無線與有線電信網路的兩大差異點
  - ❶ Mobility management of Subscribers
  - ❷ Transmission and Management of Radio
    - Transmission propriety of Radio：真空情形下，無線電波的功率會隨距離的平方衰減。實際情形，無線電波的功率會隨距離的四次方衰減
    - The little of Frequency spectrum：At any time, the number of frequency channel is little of a base station (BS).
  - Cell：一個基地台(Base station)可以接收到行動台所發射的無線電波之涵蓋範圍稱爲一個細胞(Cell)。理想情況下，全向形天線的無線電波涵蓋範圍是圓形，但爲了規劃細胞服務區的方便性，多以六角形爲示意圖

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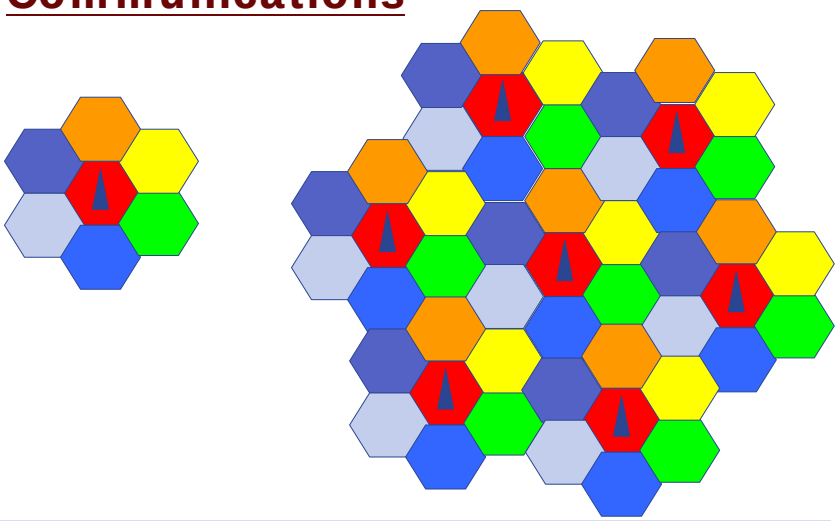
Basic Operations of Cellular Communications

- Frequency reuse: 爲了解決頻率稀少的問題，則有Frequency reuse的利用。Frequency reuse是指每一個細胞使用所有可用頻譜中的一部份，且相鄰的細胞使用頻譜中不同的頻率部分，而間隔幾個細胞以外的細胞，在不產生干擾的原則下，又可使用相同的頻譜。以七個細胞的結構爲例，每個細胞使用可用頻譜的七分之一，且互不相同。
- Cell cluster：而上述的七個相鄰的細胞稱爲一個Cell cluster
- Sub-cell (Micro-cell): 若想增加系統頻道容量，可以把細胞區域縮的更小，亦即利用細胞分裂法，把一個細胞在細分成多個相銜接的Sub-Cell，(或稱微細胞)，並降低每個Sub-cell的發射功率，以縮小Sub-cell的涵蓋範圍。
  - Thinking:細胞分得愈小，Frequency reuse的程度愈高，系統的頻道容量即愈高。但細胞範圍愈小，代表基地台要更密集，亦即要增加系統的建置成本，同時代表一個行動主機(Mobile Host)會更容易跨細胞移動，會增加技術上的困難。GSM的細胞半徑爲2~35Km

Basic Operations of Cellular Communications



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Basic Operations of Cellular Communications

- **Location Management:**
  - 行動台位置隨時會改變，系統必須知道目前行動台的位置，以便有呼叫時，可以找到該行動台。Mobile Telephone System 採用一種Location Area的管理方式，一個Location Area可能包含數個Cells或數個Cell Clusters。當行動台從一個Location Area移動到另一Location Area時，必須向系統回報目前的Location Area。所以當有呼叫時，系統則對該Location Area內的所有Cells發出呼叫。
  - Concerns Problem:
    - Location Area包含的Cells個數愈少， Mobile Station要愈常向系統回報目前的Location Area，Message Transfer的Cost高。
    - Location Area包含的Cells個數愈多，當有呼叫要找該行動台時(a call to mobile station)，系統要同時對愈多的細胞發出呼叫(Paging)訊號，才能找到該行動台。

Basic Operations of Cellular Communications

- **Handoff Management:**
  - 當用戶在通話過程中，行動台由一細胞跨越到另一細胞時，系統會自動將其使用的頻率與頻道轉換到另一基地台的頻道與頻道，以維持用戶的通話得以維持。這個動作就稱爲Handoff或稱爲Handover。
  - 當基地台與行動台間的通訊品質降到一臨界值以下時，基地台會對行動交換中心(Mobile Switching Center, MSC)傳送請求Handoff的訊息。在請求Handoff時，MSC會尋找目前行動台收訊最強的細胞，以代替原有細胞的通話頻道。Handoff的過程中，用戶在過程中會有短暫的訊號中斷，但用戶不易察覺。

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Basic Operations of Cellular Communications

- **Roaming Management:**
  - Roaming是指Mobile station在未通話狀態下，尤其所屬的MSC跨越到另一個MSC時，仍能繼續享有行動通訊的服務。

Basic Technologies of Mobile Communication

- **Basic concept of Radio:**
  - 基本理論：無線電訊號的傳輸乃是利用加速電荷來產生電磁場。而因加速電荷所產生的電磁場還會去加速空間上的其他電荷，因此，當我們移動某一位置上的電荷時，它所產生的電磁場會使其他位置的電荷跟著移動。
  - 電磁場強度：當我們移動的電荷愈多，訊號就愈強，在更遠的地方就可以偵測到它。
  - 移動電子是很簡單，主要的技巧是如何將它們往特定方向以特定的方式移動。

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Basic Technologies of Mobile Communication

- **Two standards of Radio:**
  - AM: 以固定頻率傳送電波，電波會隨著傳送的資料訊息而改變**強度**，稱之爲Amplitude Modulation (AM)，調幅。
  - FM: 電波強度不變，但**頻率**會隨著傳送的資料訊息而稍作改變，稱之爲Frequency Modulation (FM)，調頻。

Radio Access Techniques for Wireless Communication

- **Radio Access Techniques:**
  - Full Duplexing Service Technique
  - Multiple Access Technique
- **Techniques for Device Connection**
  - 單工(Simplex)：通訊裝置的兩端分別只擔任傳送與接受一種工作，如鍵盤、螢幕之於電腦主機
  - 雙工 (Duplex)：通訊裝置的兩端同時可擔任傳送與接受二種工作
    - 半雙工 (Half Duplex)：一次只能執行一種功能
    - 全雙工(Full Duplex)：可同時執行收與送兩種功能

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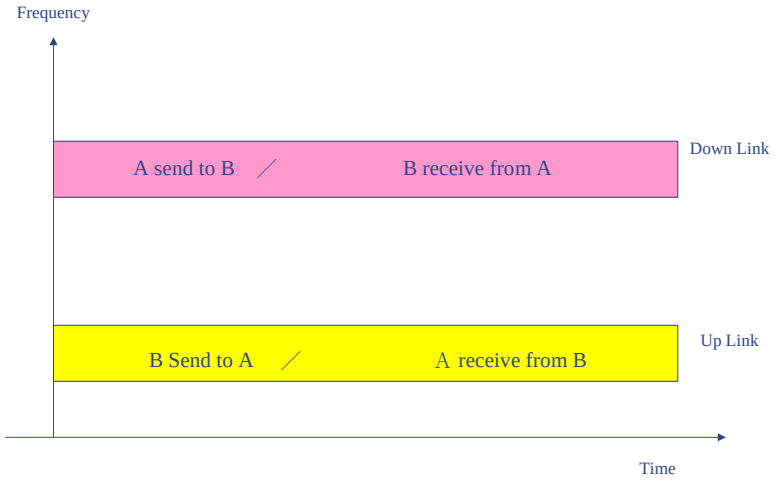
Full Duplexing Techniques

- **Full Duplexing Service Techniques:**
  - Frequency Division Duplexing (FDD): 上傳資料與下載資料使用不同的頻道。從BS到MS的頻道稱爲Forward Link(或稱Down-link)，從MS到BS的頻道稱爲Reserve Link(或稱Up-link)。
  - Time Division Duplexing (TDD):上傳資料與下載資料使用相同的頻道。但在同一頻道上分成兩個時槽，分別提供作爲Forward Link and Reserve Link.

FDD



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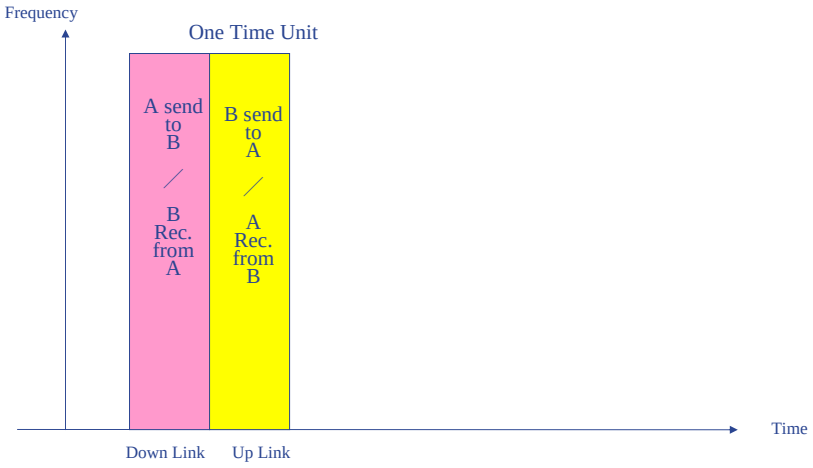
TDD



Comparison of FDD and TDD

	FDD	TDD
成對的頻譜	需要	不需要
基地台之間保持同步	不需要	需要
雙工造成延遲	不會	會
射頻訊號雙工器	需要	不需要
基地台設備利用率	TDD的兩倍	FDD的一半

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Multiple Access Techniques for Wireless Communication

- **FDMA (Frequency Division Multiple Access):**
  - Assigns individual channels to individual users
  - During the period of the call, no other user can share the same frequency band
  - In the FDD system assigns a channel as a pair of frequencies; one frequency for forward channel, and one for reserve channel.
  - The features of FDMA:
    - The FDMA channel carries only one phone circuit at a time
    - If an FDMA channel is not in use, then it sits idle and cannot be used by other users to increase or share capacity.
    - After the assignment of a voice channel, the base station and the mobile station transmit simultaneously and continuously.
    - The bandwidths of FDMA channels are relatively narrow (30kHz) as each channel supports only one circuit per carrier. FDMA is usually implemented in narrowband systems

Multiple Access Techniques for Wireless Communication

- The symbol time is large as compared to the average delay spread. This implies that the amount of intersymbol interference is low and, thus, little or no equalization is required in FDMA narrowband systems
- The complexity of FDMA mobile systems is lower when compared to TDMA systems, though this is changing as digital signal processing methods improve for TDMA
- Since FDMA is a continuous transmission scheme, fewer bits are needed for overhead purposes as compared to TDMA
- FDMA systems have higher cell site system costs as compared to TDMA systems, because of the single channel per carrier design, and the need to use costly bandpass filter to eliminate spurious radiation at the best station
- The FDMA mobile unit uses duplexers since both the the transmitter and receiver operate at the same time. This results in an increase in the cost of FDMA subscriber units and base stations.
- FDMA requires tight RF filtering to minimize adjacent channel interference

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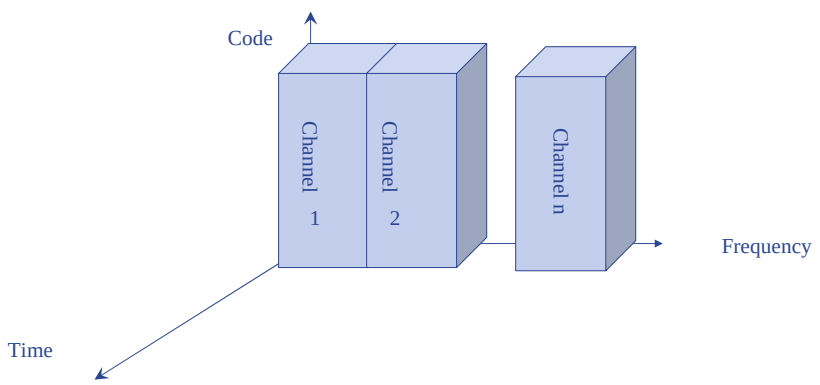
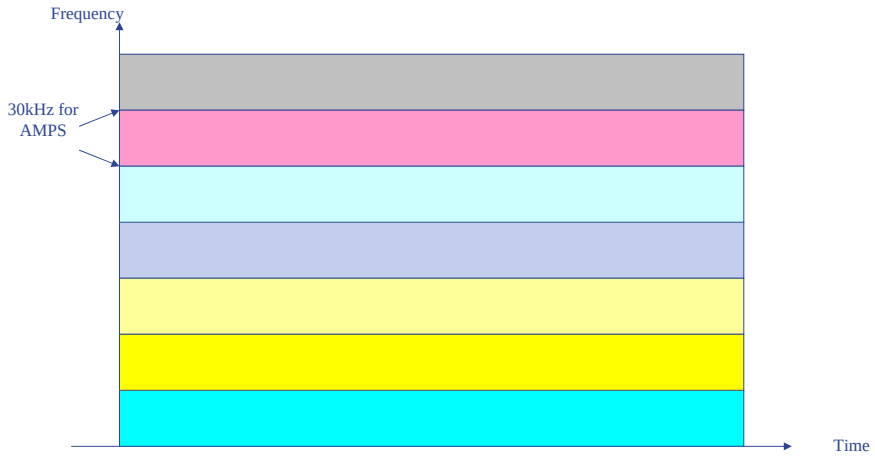
Multiple Access Techniques for Wireless Communication



FDMA

Multiple Access Techniques for Wireless Communication



From BS view, each frequency band for one MS at same time

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Multiple Access Techniques for Wireless Communication

- TDMA (Time Division Multiple Access):
  - Divide the radio spectrum into time slots
  - Each one user is allowed to either transmit or receive.
  - TDMA systems transmit data in a buffer-and-burst method, thus the transmission for any user is non-continuous.
  - Unlike in FDMA systems which accommodate analog FM, digital data and digital modulation must be used with TDMA.
  - In TDMA/TDD, half of the time slots in the frame information message would be used for the forward link channels and half would be used for reserve link channels.

Multiple Access Techniques for Wireless Communication

- In TDMA/FDD systems, an identical or similar frame structure would be used solely for either forward or reserve transmission, but carrier frequencies would be different for the forward and reserve links.
- In general, TDMA/FDD systems intentionally induce several time slots of delay between the forward and reserve time slots of a particular user, so that duplexers are not required in the subscriber unit.
- In a TDMA frame (see frame structure in next page), the preamble contains the address and synchronization information that both the base station and the subscribers use to identify each other.

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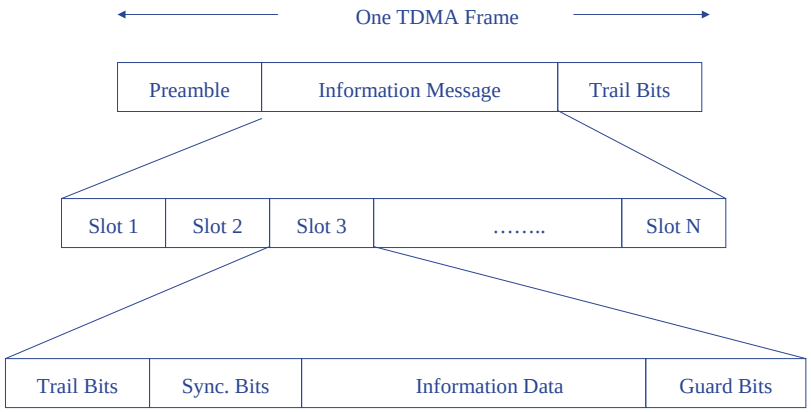
Multiple Access Techniques for Wireless Communication



Multiple Access Techniques for Wireless Communication

- Guard times are utilized to allow synchronization of the receivers between different slots and frames.
- The features :
  - TDMA shares a single carrier frequency with several users, where each user makes use of nonoverlapping time slots. The number of time slots per frame depends on several factors, such as modulation technique, available bandwidth, etc.
  - Data transmission for users of a TDMA system is not continuous, but occurs in bursts. This results in low battery consumption, since the subscriber transmitter can be turned off when not in use (which is most of the time).
  - Because of discontinuous transmissions in TDMA, the handoff process is much simpler for subscriber unit,, since it is able to listen for other base stations during idle time slots. An enhanced link control, such as that provided by *mobile assisted handoff* .

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Multiple Access Techniques for Wireless Communication

- *Mobile assisted handoff* (MAHO) can be carried out by a subscriber by listing on an idle slot in the TDMA frame.
- TDMA uses different time slots for transmission and reception, thus duplexers are not required. Even if FDD is used, a switch rather than a duplexer inside the subscriber unit is all that is required to switch between transmitter and receiver using TDMA.
- Adaptive equalization is usually necessary in TDMA systems, since the transmission rates are generally very high as compared to FDMA channels.
- In TDMA, the guard time should should be minimized. If the transmitted signal at the edges of a time slot are suppressed sharply in order to shorten the guard time, the transmitted spectrum will expand and cause interference to adjacent channels.

Multiple Access Techniques for Wireless Communication

- High synchronization overhead is required in TDMA systems because of burst transmissions. TDMA transmissions are slotted, and this requires the receivers to be synchronized for each data burst. In addition, guard slots are necessary to separate users, and this result in the TDMA systems having large overheads as compared to FDMA.
- TDMA has an advantage in that it is possible to allocate different numbers of time slots per frame to different user. Thus bandwidth can be supplied on demand to different users by concatenating or reassigning time slots based on priority.

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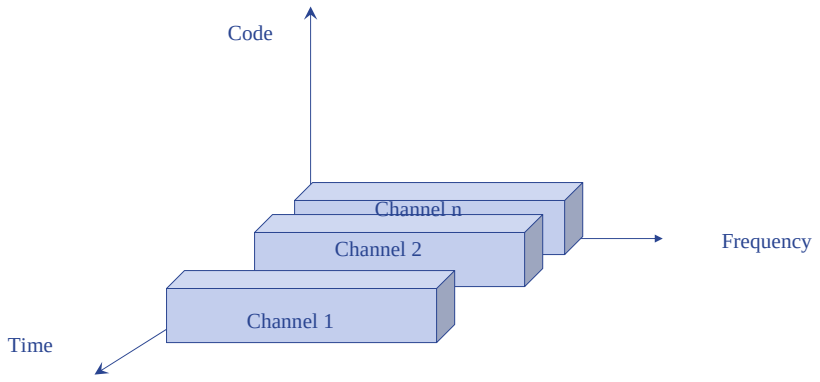
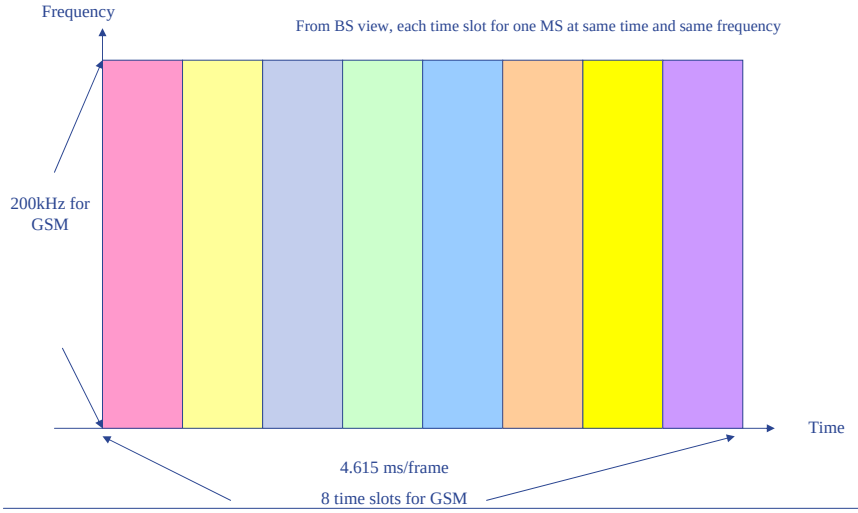
Multiple Access Techniques for Wireless Communication



TDMA

Multiple Access Techniques for Wireless Communication



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Multiple Access Techniques for Wireless Communication

- SSMA (Spread Spectrum Multiple Access):
  - SSMA uses signals which have a transmission bandwidth that is several orders of magnitude greater than the minimum required RF bandwidth.
  - A pseudo-noise (PN) sequence converts a narrowband signal to a wideband noise-like signal before transmission.
  - SSMA provides immunity to multipath interference and robust multiple access capability.
  - Many users can share the same spread spectrum bandwidth without interfering with one another, spread spectrum systems become bandwidth effcient in a multiple user environment.
  - There are two main types of spread spectrum multiple access techniques: *Frequency Hopped Spread Spectrum* (FHSS) and *Direct Sequence Spread Spectrum* (DSSS).
  - DSSS code division multiple access is called DS-CDMA.

Multiple Access Techniques for Wireless Communication

- CDMA (Code Division Multiple Access):
  - In CDMA systems, The narrowband message signal is multiplied by a very large bandwidth signal called the *spreading signal*.
  - every signal is processed with PN sequence (pseudo-noise sequence).
  - Faster-rate, wide-bandwidth digital signal
  - Each PN sequence is a unique *orthogonal* code.
  - User signals are distinguished by different PN sequences.
  - The spreading signal is a pseudo-noise code sequence that has a chip rate which is orders of magnitudes greater than the data rate of the message.
  - All users in CDMA systems, use the same carrier frequency and may transmit simultaneously.

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Multiple Access Techniques for Wireless Communication

- Each user has its own pseudorandom codeword which is approximately orthogonal to all other codewords.
- The receiver performs a time correlation operation to detect only the specific desired codeword. All other codewords appear as noise due to decorrelation.
- For detection of the message signal, the receiver needs to know the codeword used by the transmitter. Each user operates independently with no knowledge of the other users.

Multiple Access Techniques for Wireless Communication

– The features:

- Many users of a CDMA system share the same frequency. Either TDD or FDD may be used.
- Unlike TDMA or FDMA, CDMA has a soft capacity limit. Increasing the number of users in a CDMA system raises the noise floor in a linear manner.
- There is no absolute limit on the number of users in CDMA. Rather, the system performance gradually degrades for all users as the number of users is increased, and improves as the number of users is decreased.

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Multiple Access Techniques for Wireless Communication

– The features(continuous)：

- Multipath fading may be substantially reduced because the signal is spread over a large spectrum. If the spread spectrum bandwidth is greater than the coherence bandwidth of the channel, the inherent frequency diversity will mitigate the effects of small-scale fading.
- Channel data rates are very high in CDMA systems. Consequently, the symbol (chip) duration is very short and usually much less than the channel delay spread.
- Since CDMA uses co-channel cells, it can use macroscopic spatial diversity to provide soft handoff. Soft handoff is performed by the MSC, which can simultaneously monitor a particular user from two or more base stations. The MSC may chose the best version of the signal at any time without switching frequencies.

Multiple Access Techniques for Wireless Communication

– The features(continuous)：

- Self-jamming is a problem in CDMA system. Self-jamming arises from the fact that the spreading sequences of different users are not exactly orthogonal, hence in the despreading of a particular PN code, non-zero contributions to the receiver decision statistic for a desired user arise from the transmissions of other users in the system.
- The near-far problem occurs at a CDMA receiver if an undesired user has a high detected power as compared to the desired user.
- What is Spread Spectrum:
  - 所謂「直序展頻」(又稱DSSS；Direct Sequence Spread Spectrum)是將原來1個位元的訊號，利用10個以上的位元來表示，使得原來高功率、窄頻率的訊號，變成低功率、寬頻率。

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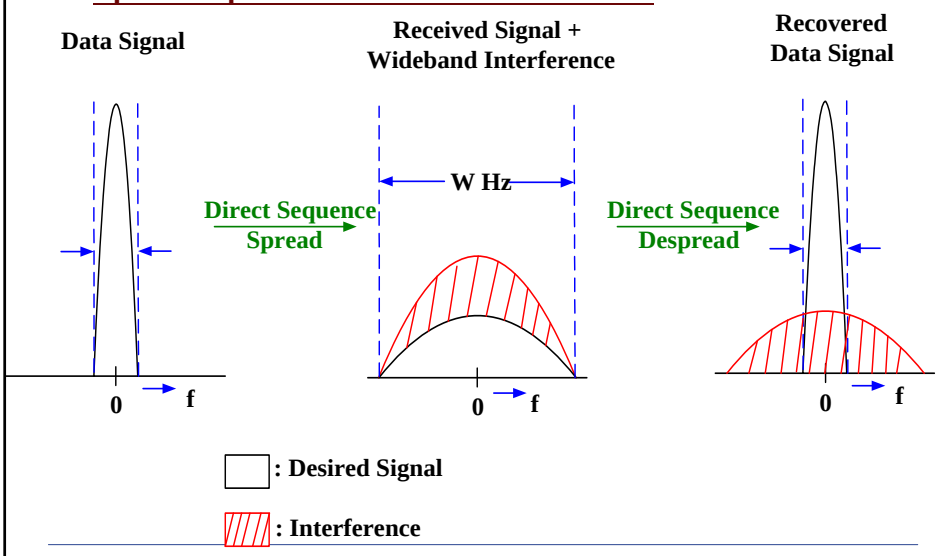
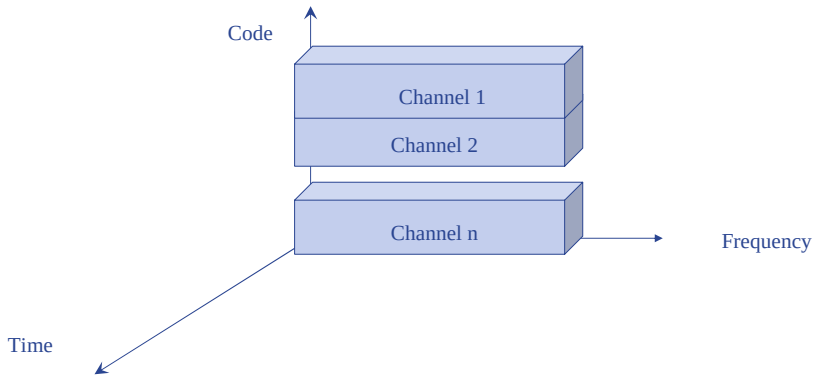
Spread Spectrum Correlation Process

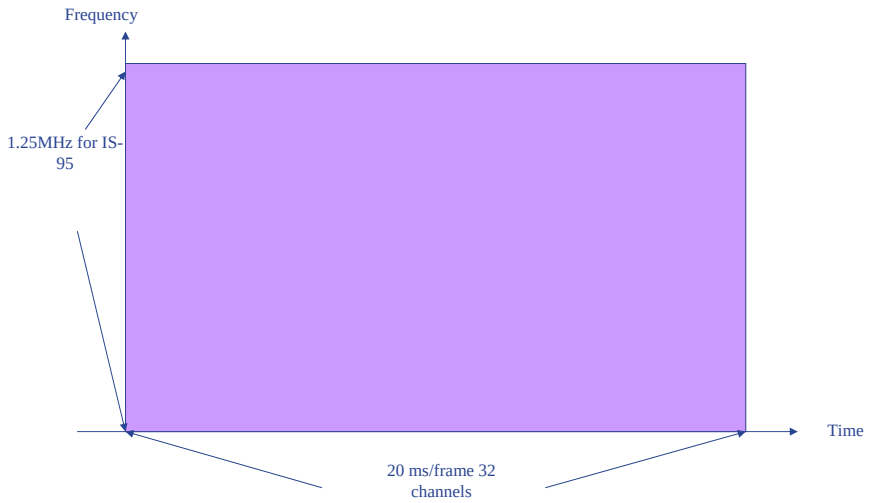


Multiple Access Techniques for Wireless Communication



CDMA

Multiple Access Techniques for Wireless Communication



Multiple Access Techniques for Wireless Communication

Cellular system	Multiple Access Technique
Advanced Mobile Phone System (AMPS)	FDMA/FDD
Global System for Mobile (GSM)	TDMA/FDD
U.S. Digital Cellular (USDC)	TDMA/FDD
Japanese Digital Cellular (JDC)	TDMA/FDD
Cordless Telephone –2 (CT2)	FDMA/TDD
Digital European Cordless Telephone (DECT)	FDMA/TDD
U.S. Narrowband Spread Spectrum (IS-95)	CDMA/FDD

Wireless Systems and Standards

- AMPS (advanced Mobile Phone System)
- D-AMPS (Digital AMPS)
- GSM (Global System for Mobile)
- Comparison of AMPS and GSM
- DCS-1800 (Digital Communication System – 1800)
- Comparison of GSM-900 and DCS-1800
- GPRS(General Packet Radio Services)
- IS-95
- 3G & 3.5G
- WiMAX & LTE
- CT-2
- DECT
- Comparison of CT-2 and DECT
- PHS
- PACS
- Comparison of DECT, PHS, and PHS

AMPS

- 簡介
  - AMPS是第一個蜂巢式系統
  - 構想始於1964年，Bell Lab.於1970年代開發完成
  - 1983年商業化
  - 1989年引進台灣，有68萬用戶。全球有7500多萬用戶
  - 優點是比較沒有回音干擾，通話品質較清晰
  - 缺點是無隱密性，及無線電波可輕易地被監聽、手機可被輕易地盜拷
- 系統特性
  - 採用FDMA技術
  - 類比式行動電話系統

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AMPS

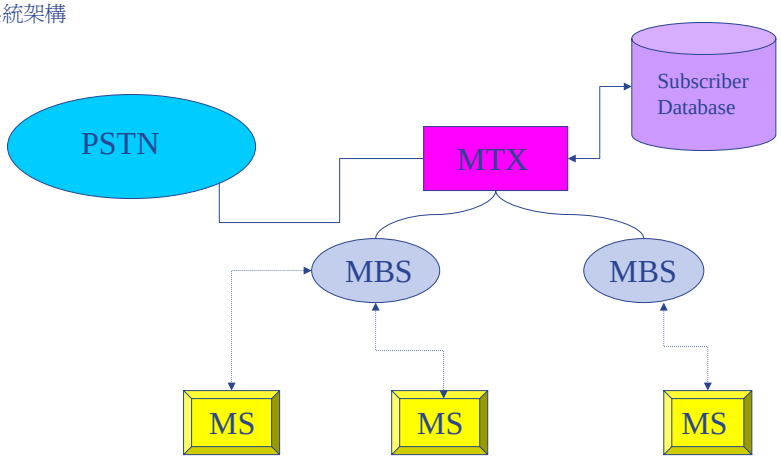
- 頻段爲800MHz
  - Up-link (即行動台到基地台)：824MHz ~849MHz
  - Down-Link (即基地台到行動台) ：869MHz ~894MHz
- Cellular Infrastructure Network:
  - 如果基地台使用全向性天線(Ommidirectional antenna)，則以12個Cells組成一個Cluster
  - 如果基地台使用三方向性天線(Three directional antenna)，則以7個Cells組成一個Cluster
- Frequency Reuse Mechanism
- Handoff supporting
- Roaming Management 遵守IS-41 standard
- 傳輸距離較GSM-900或DCS-1800遠，所需基地台數少

AMPS

- 缺點
  - 通訊亦受干擾
  - 通信內容易被截取
  - 有被盜拷的隱憂
  - 體積大、價格高：因爲所需電池容量大，相對地體積大且造價高
  - 門號擴充困難：AMPS採大區域之巨細胞，雖然所需基地台少，但是Frequency Reuse程度低，相對地系統容量較少
  - 語音以外的個人通信服務難以擴充

AMPS

- 系統架構



AMPS

- MTX (Mobile Telephone eXchange)
  - 是整個AMPS行動通信系統的中樞
  - 負責PSTN (Public Switched Telephone Network)與MBS之間介面銜接工作
  - 具有監視及測試功能
- MBS (Mobile Base Station)
  - 是MTX與MS間的銜接介面
  - MBS在Radio Coverage Area的特定範圍內可與任何MS通信
  - 包含無線電收發訊機(Radio Transceiver)、天線及監測器等
    - Transceiver: Transmitter & Receiver
  - Up-link爲824~849MHz、Down-link爲869~894MHz，共50MHz
  - 分成832個Radio channels
  - 每個Cell均有一個特定的Channel作爲Control channel

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AMPS

  - Control channel只傳送Data messages，用來呼叫MS或MS要求產生New call
  - 其他Channels爲voice channel，作爲實際連接通話用之頻道
- MS (Mobile Subscriber或Mobile Station):
  - 是行動通信系統的用戶終端設備
  - 包括Radio Transceiver、天線及控制撥號的邏輯迴路，藉以與MBS維持無線通信鏈路
  - MS爲開機狀態並遭遇收訊不良時、會自動掃描所有控制頻道，並自動調至收訊最佳之細胞的控制頻道且鎖住該頻道
  - 當MS被Called或要Call其他用戶時，即透過Control channel產生Hand shaking，並建立MBS與MS之間的Voice channel path
  - MS與MBS之間是藉由空氣中的無線電頻道交換資料，無固定專線連接

AMPS

- 爲了驗證話機是否爲合法使用者，話機內部存有一個全世界唯一的序號(Serial NumBer, SNB)，俗稱內碼；及一個由電信公司指定的行動台號碼(Mobile Station NumBer, MSNB)所轉換而成的行動台識別碼(Mobile Identification Number, MIN)，俗稱外碼。這兩個號碼會被登陸於行動電話系統的用戶資料庫(Subscriber Database)內，以便對行動台進行認證

– Subscriber Database
  - 記錄每一個用戶的基本資料，如姓名、地址、SNB、MIN等
  - 記錄用戶的使用情形與帳單資料
  - 記錄用戶的附加服務(Supplementary services)
  - 其他

D-AMPS

- 簡介
  – D-AMPS是AMPS的改良版本
  – 1987年開始發展
  – 早期的規格使用IS-54，IS-54後來又被修訂爲IS-136
  – 又稱爲IS-54 Digital Cellular System、或稱American Digital Cellular(ADC)、或稱North American TDMA(NA-TDMA)
- 系統特性
  – 採用TDMA技術
  – 數位式行動電話系統
  – 每個負載頻率可提供8個語音頻道，因此系統容量是AMPS的三倍，語音編碼速率爲7.95kb/s

D-AMPS

- 使用頻段(Radio frequency band)與AMPS相同
- 除語音服務外，尚可提供下列功能
  - 點對點短訊服務 (point to point short messaging)
  - 廣播訊息 (Broadcast messaging)
  - 私用客戶群 (Private user group)
  - 階層式細胞架構 (Hierarchy cell structure)
  - 時槽呼叫通道 (Time slotted paging channel)
  - 手機睡眠模式 (Sleep mode) 以降低手機耗電量
- Cellular Infrastructure Network
- Frequency Reuse
- Support Handoff
- Roaming management亦遵守IS-41 standard

GSM

- 簡介
  - 1982年由CEPT(Conference of European Postal and Telecommunication Administrations)成立GSM工作小組
  - 1985年決定採用TDMA
  - 1987年決定窄頻TDMA被選定爲泛歐系統標準
  - 1989年開始建構測試系統
  - 1990年開始被全球推廣使用，至今除美、日外全球103個國家都有GSM營運系統、用戶超過5000萬人
  - 頻譜使用效率較高，通信較安全
  - 訊號經壓縮處理，通話會有回音，品質較不穩定
  - 除語音通訊外，尚可提供行動數據、行動傳真功能
  - Roaming Management採用GSM MAP standard

GSM

- 系統特性
  - 900MHz頻帶
  - 載波頻率間隔200KHz
  - 收發頻率間隔45MHz
  - 細胞半徑0.5~35km
  - Access方式爲TDMA與FDMA結合
  - 調變方式爲GMSK
  - 傳送速度270kbps
  - 自動等化 (Equalization)
  - 可調適頻率跳躍(跳頻，Adaptive Frequency hopping)
  - 可聲音符碼化RPE-LPT (Regular Pulse Excited Long Term Prediction)

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GSM

- TDMA將每一個負載頻率切割成固定時槽(Time slot)
- 每一個時槽可當一個語音通道
- GSM系統將一個負載頻率分成8個語音通道，每個語音通道之語音編碼速率爲13kb/s
- TDMA的基地台無線電硬體設備可讓8個語音通道共用，FDMA則是每個語音通道皆須一組Transmitter與Receiver
- GSM的Mobile station分成硬體與軟體兩部分
  - 硬體包括基頻(Baseband)處理單元及射頻(Radio Frequency, RF)處理系統
  - 軟體由一層通訊協定軟體、兩層資料堆疊處理的通訊協定軟體及使用者介面共同組成
- Up-link: 890~915MHz (25MHz)
- Down-Link: 935~960MHz (25MHz)

GSM

- 每個頻段切割成124個Channels
- 每個Channel的頻寬爲200KHz (124*200K = 24.8MHz)
- 完全數位式
- 開放式介面標準 (OSI)
- Support International communication
- More supplementary services:
  - 指定轉接
  - 發話限制
  - 話中插接
  - 通話保留
  - 忙線呼叫
  - 封閉式用戶群
  - 話中轉接
  - 多方通話

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GSM

- 加強安全防護措施
- 用戶識別卡(Subscriber Identity Module, SIM)
- Frequency hopping:採用交錯頻道編碼(Interleaving channel coding)
- TDMA技術，8個用戶共用一個負載頻率
- Adaptive Equalization
- 與ISDN相容
- 數位語音傳輸
  - First Level: 13Kbit/sec，每個載波有8個Time slots
  - Second level: 6Kbit/sec，每個載波有16個Time slots
- 抗干擾能力強、頻率再用性高、頻譜效率佳
- 系統較複雜

GSM

- GSM的優點
  - 通信品質較好
  - 提供的服務業務較好
  - 通信保密性較佳，不易遭盜拷或竊聽
  - 通信系統容量較高，擁有較高的頻譜
  - 與ISDN、PSTN等網路相互連結較容易

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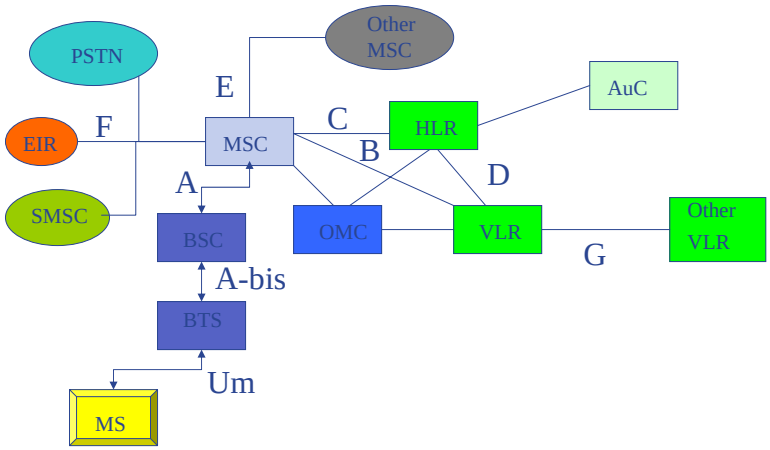
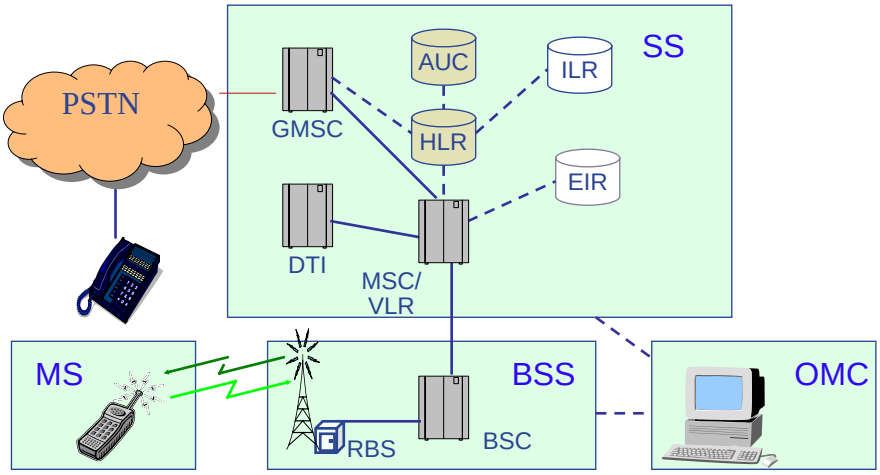
GSM

- GSM的系統架構



GSM System Structure



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GSM

- GSM架構基本尚可分成三大部分
  - 行動台次系統
  - 基地台次系統
  - 網路次系統
- 行動台(Mobile Station, MS)
  - 主要裝置有
    - 無線收發機(Transceiver)
    - 顯示器
    - 數位訊號處理器
    - 用戶識別模組(Subscriber Identity Module, SIM)
  - SIM實現了Terminal Mobility的行動通訊，可讓使用者在任何GSM的話機上進行通訊或接取服務

GSM

- Mobile station是屬於用戶擁有的設備，主要分成兩個部分：行動話機與用戶識別模組，簡稱SIM卡
- 行動話機儲存的資訊有二：
  - 負責通信資料的加密/解密演算法
  - 國際行動台設備識別碼(International Mobile Equipment Identity, IMEI)
  - IMEI是GSM網路中唯一識別行動話機之識別碼，由於IMEI是每一支話機的全世界唯一識別號碼，因此可以設定遺失話機後即無法使用
- SIM卡
  - GSM系統以SIM卡來識別用戶
  - 用戶需將SIM卡插入行動話機後方可通信

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GSM

- SIM卡含有一微電腦晶片，提供用戶認證及通信保密之功能
- SIM卡內亦含有記憶體，可儲存各種用戶資料，如密碼、電話簿等
- SIM卡提供的密碼PIN是用來保護SIM卡以免被盜用
- 開機時如果連續輸入三次錯誤的PIN時，SIM卡即會被鎖住，需由電信業者辦理解鎖程序，SIM卡才能繼續使用
- SIM卡滿足安全及保密功能、提供辨識用戶所需資訊、並可隨身攜帶，達成隨身通訊之功能

GSM

- 基地台系統(Base Station System, BSS)
  - 主要功能：負責服務區內所有行動台之通信
  - 主要裝置：
    - 基地收發台 (Base Transceiver Station, BTS)
      - 基地收發台由一群無線電波涵蓋
      - 是無線與有線的分野
      - 提供服務範圍內行動台通信所需之無線空中介面
      - 具無線收發器(Transceiver)負責細胞區域之涵蓋，並負責處理與行動台之間的無線連結
    - 基地控制器 (Base Station Controller, BSC)
      - 一個BSC可同時控制多個BTS
      - BSC負責管轄區內之BTS的無線電資源管理
      - 提供建立/釋放呼叫所需之功能

GSM

      - 負責所管轄內之行動台信號的量測、行動台功率控制、Handoff 控制
      - 負責管理一或多個基地收發台的頻道分配、回收、與Handoff
      - 負責在行動台與行動交換中心(MSC)之間建立連結，使j無線頻道傳輸的GSM 13kbps語音傳送到PSTN/ISDN上的64kbps頻道上

- 網路次系統
  - 又稱行動交換中心 (Mobile Switching Center)
  - 以Signaling System No.7, SS7與有線網路系統連接
  - 作用與一般交換機功能相同
  - 負責呼叫之
    - 註冊
    - 認證
    - 位置變換
    - 換手(交遞, Handoff)
    - 漫遊轉接

GSM

- MSC具有四個資料庫子系統
  - 本籍位置記錄器(Home Location Register, HLR)
  - 客籍位置記錄器(Visitor Location Register, VLR)
  - 認證中心(Authentication Center, AuC)
  - 設備識別資料器(Equipment Identity Register, EIR)
- 主要功能
  - 系統的交換
  - 基地控制台交遞的協調
  - 用戶資料庫管理
  - 用戶移動位置管理
  - 提供路徑交換功能
  - 協調呼叫建立的程序
  - 透過數據轉換器(IWF)可與數據網路相連
- 一個MSC可同時控制數個基地台系統
- 是網路的中心

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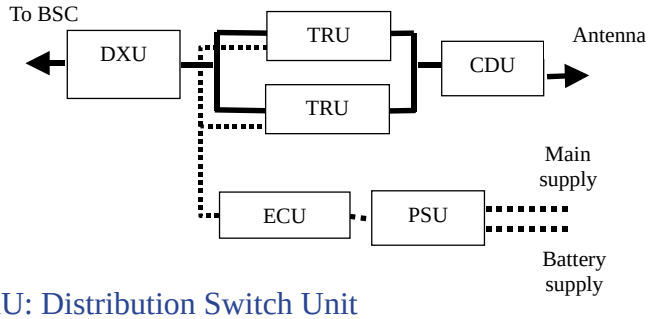
GSM

- 界面標準
  - GSM各元件間均以制定公開之標準界面
  - 符合界面標準，不同製造廠商所生產之元件即能彼此相互連接
  - GSM制定之界面標準有:
    - A界面(MSC與BSS間之界面)
    - A-bis界面(BSS內BSC與BTS間之界面)
    - B界面(MSC與VLR間之界面)
    - C界面(MSC與HLR間之界面)
    - D界面(VLR與HLR間之界面)
    - E界面(MSC與另一MSC間之界面)
    - F界面(MSC與EIR間之界面)
    - G界面(VLR與另一VLR間之界面)
    - Um界面(MS與BSS間之界面，即空中界面)

Radio Base Station



- DXU: Distribution Switch Unit
- TRU:Transceiver Unit
- CDU:Combining and Distribution Unit
- ECU: Energy Control Unit
- PSU: Power Supply Units

GSM

- GSM系統元件
  - 行動台(Mobile Station, MS)：主要元件
    - 行動話機：儲存資訊有
      - A5演算法：負責加密/解密之演算法
      - International Mobile Equipment Identity (IMEI)：全球唯一識別行動話機之識別碼，共15碼
    - Subscriber Identity Module(SIM)卡：儲存資訊有
      - Mobile Station ISDN number(MSISDN)：是PSTN/ISDN網路中識別一行動用戶之號碼，亦即GSM中行動用戶之電話號碼。MSISDN不可超過15碼
      - International Mobile Subscriber Identity(IMSI)：全世界唯一識別行動用戶的GSM識別碼，IMSI會被儲存於HLR，並燒錄於SIM卡內，IMSI不可超過15碼

GSM

- Temporary Mobile Subscriber Identity(TMSI)：爲了保持IMSI的機密性，載GSM行動用戶第一次進接GSM行動電話網時，IMSI才會經由無線電空中界面傳送給系統。系統同時指定一個新的TMSI號碼給用戶，至此，GSM用戶與系統之間均以TMSI來相互傳遞辨識。TMSI最常不可超過4個字組(Octets)，可由系統經營業者自訂。TMSI在同一位置區(Location Area)或同一VLR服務區內有效，當用戶漫遊致另一新位置區或VLR服務區時，系統將重新指派一個TMSI識別碼給用戶。
- Ki：用戶個人認證密碼，由製卡中心隨機產生128位元之Ki。Ki會被同時記錄在SIM卡內及HLR內
- Personal Identification Number(PIN)：每張SIM卡有4到6位數的SIM卡密碼，可保護SIM卡遺失時，遭到他人非法使用。連續輸入三次錯誤的PIN號碼，則SIM卡即被鎖住

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GSM

- PIN Unlock Key(PUK)：當SIM卡被所住時，可用PUK來解鎖，若連續輸入10次錯誤的PUK號碼，則SIM卡會被永久鎖死，不能在使用
- Location Area Identity(LAI)：包含
  - » A3演算法：負責身分認證程序的演算法
  - » A8演算法：負責產生Ki密碼鍵的演算法

GSM

- 基地台系統(Base Station System, BSS)：主要元件
  - 基地收發台(Base Transceiver Station, BTS)
    - 由一群無線電載波所涵蓋
    - 是有線與無限的分界點
    - 提供Radio Air Interface
  - 基地台控制器(Base Station Controller, BSC)
    - 一個BSC可控制多個BTS
    - BSC負責其所管轄內BTS的無線電資源管理
    - 提供建立/釋放呼叫所需之功能
    - BSC負責Mobile Station信號的量測、 Mobile Station功率的控制、交遞功能
    - BSC可處理所管轄各BTS之間的交遞功能，故可減輕MSC的負擔

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GSM

- 行動交換中心(Mobile Switching Center, MSC)：
  - 是整個GSM行動通信系統的中樞，主要功能
    - 對所管轄內之行動用戶，進行交換續接與轉接功能
    - 與HLR及VLR相連接，以便執行位置註冊所需的程序
    - 向HLR查詢以獲得Mobile Station目前位置及越區號碼，以便處理呼叫建立的依據
    - 向VLR查詢以獲得Mobile Station的相關資料，以便處理呼叫建立的依據
    - 無線電資源(Radio Resource, RR)之管理
    - 執行不同基地台控制器之間交遞管理(Inter-BSC handoff)所需的程序

GSM

- 本籍位置記錄器(Home Location Register, HLR)：
  - 是一大型資料庫
  - 主要是儲存系統所有用戶之相關資料
  - 並記錄用戶越區資料
  - HLR可爲一獨立實體、或與GSM之其他系統整合
  - HLR記錄的用戶相關資料及功能如下：
    - 國際行動用戶識別碼(IMSI)
    - 行動台ISDN號碼(MSISDN)
    - 附加服務(Supplementary Services)
    - 行動台越區號碼(Mobile Station Roaming Number, MSRN)
    - 位置註冊
    - 提供用戶認證參數給VLR
    - 與其他元件(如VLR, MSC, AuC)之間的訊號傳送功能

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GSM

- 客籍位置記錄器(Visitor Location Register, VLR)：
  - 主要是儲存目前到此服務區來訪之越區行動用戶的相關資料
  - 目的是使行動用戶到一新的VLR服務區時仍繼續享有GSM行動通信服務
  - VLR記錄的用戶相關資料及功能如下：
    - 國際行動用戶識別碼(IMSI)及臨時行動用戶識別碼(TMSI)
    - 行動台ISDN號碼(MSISDN)
    - 行動台越區號碼(MSRN)
    - 行動台註冊之位置區域(Location Area, LA)
    - 從HLR所查詢得知的用戶資料
  - VLR會在適當時機向HLR取得用戶相關資料
  - 負責執行認證、位置更新、加密支援、計費產生、IMSI失聯(Detached)/已聯(Attached)以及使用IMSI或TMSI之管理
  - VLR可爲一獨立實體、或與MSC合併在一起。大多數是合併

GSM

- 認證中心(Authentication Center, AuC)：
  - 儲存所有用戶之國際行動用戶識別碼(IMSI)與對應之認證密碼(Ki)
  - 儲存兩個重要的演算法(A3/A8)
    - A3演算法負責身份認證程序
    - A8負責產生Ki密碼鍵
  - 儲存一亂數產生器以產生隨機亂數(Random, RAND)
  - AuC對每一用戶產生認證三參數(Triples)
    - 隨機亂數(RAND)
    - 認證回簽(Signed Response, SRES)
    - 密碼運算鍵(Ki)
  - AuC會對每一用戶產生五組三參數以提供系統對用戶認證使用、用戶通話內容或相關信號資料加密與解密使用、以及提供給HLR與VLR使用
  - 用戶每做一次認證，便使用一組三參數，當五組三參數使用完畢，系統便會再產生另外五組三參數
  - GSM系統行動台(Mobile Station)無論是主呼叫(Calling)或被呼叫(Called)，系統均會要求透過AuC認證無誤後，才允許通信

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GSM

- 設備識別記錄器(Equipment Identity Register, EIR)：
  - 提供系統經營者核對國際行動台設備識別碼(IMEI)之能力，以避免失竊或未經授權之行動台設備進入GSM系統
  - 可連線至愛爾蘭CEIR取得國際IMEI資料
  - EIR是一個儲存IMEI的資料庫，儲存內容包括
    - 白名單(White list)：已通過型式認證合格的話機，系統將允許其通信
    - 黑名單(Black list)：存放所有被限制服務的IMEI，通常是客戶已申告遺失的話機，系統將不允許其通信
    - 灰名單(Gray list)：即觀察名單，存放一些功能有瑕疵之話機的IMEI，或未經型式認證合格之行動台設備的IMEI，通常系統會允許其通信，但會將這些行動台用戶之IMEI回報給系統維運人員觀察或追蹤其使用情形，如有影響網路正常運作，將被改至於黑名單中禁止其通信

GSM

- 短訊服務中心(Short Message Service Center, SMSC)：
  - 爲了避免GSM行動用戶攜帶兩種行動通信設備 (行動話機與呼叫器) 之困擾
  - GSM可提供短訊服務(Short Message Service)
  - 每封信息可發送或接收達160Characters
  - 發送端行動台發送的短信息會儲存於SMSC中，並由SMSC回應給發送端確認信號，以確認短訊已被SMSC收到並儲存
  - 接收端行動台無論是閒置狀態或是通話中均可接收短訊
  - 若接收端行動台是關機狀態，則短訊會被儲存在SMSC中，直到接收端行動台開機時，行動台已開機的狀態會被通知到SMSC，SMSC再把短訊送出
  - 接收端行動台正確無誤地接收到短訊後，會回應確認信號給SMSC。所以GSM系統能確保短訊可以正確無誤地送達對方

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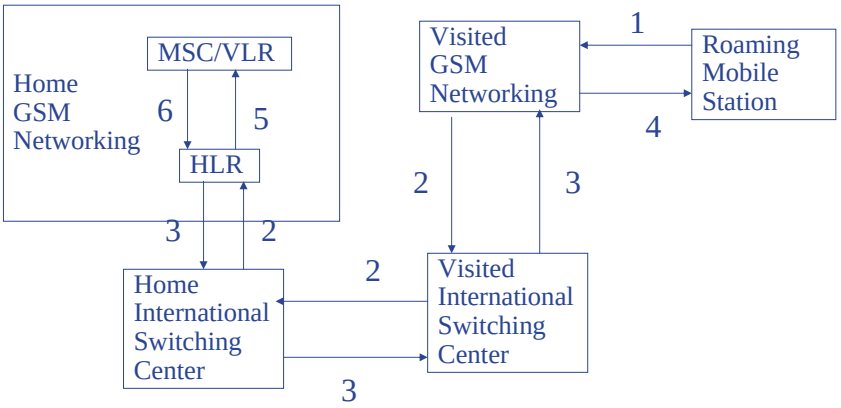
GSM

- 維運中心(Operation and Maintenance Center, OMC)：
  - 維運中心透過數據分封交換網路連接至系統經營業者在全國的行動電話系統，集中監控並維護系統正常運作

GSM

– 漫遊服務(Roaming)：



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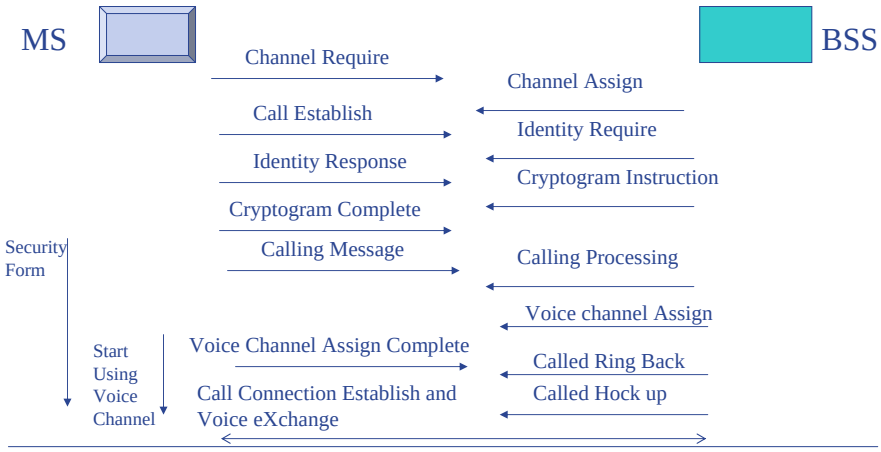
GSM

– 呼叫建立(Call Establishing)：



GSM

- GSM之交遞(或稱換手)(Handoff, or Handover)：
  - Handoff的發生
  - Handoff的種類
    - Handoff in same Cell but among different Channels
    - Handoff in same Base Transceiver station but among different Cells
    - Handoff in same Base Station Controller but among different BTSs
    - Handoff in same Mobile Switching Center but among different BSCs
    - Handoff among different MSCs
  - Handoff標準規劃
    - 依通話品質
    - 依訊號強度
    - 依距離遠近
    - 依功率估算

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Comparison of (D-)AMPS and GSM

	類比AMPS	數位D-AMPS	GSM
每一細胞承載話務量(Erl)(佔線小時)	64.5	240	121.2
細胞半徑(Km)	1	0.84	0.57
細胞面積(Km^2)	2.6	1.83	0.84
每平方公里承載話務量(Erl)	24.8	131.3	144.3
可容納用戶數	1.495	7.714	8.847
與類比AMPS容量比較	1	5.29	5.82

DCS-1800

- DCS-1800是1991年才從歐洲發展出來，台灣自1997年引進
- DCS-1800基本上與GSM採用同一種技術
- DCS-1800的頻率比GSM高二倍，但頻率愈高，傳送距離愈短
- DCS-1800的手機功率也較小，只有1瓦。GSM的手機功率爲2瓦
- DCS-1800使用頻段爲1710MHz~1785MHz for Uplink，1805MHz~1880MHz for Downlink
- 採微細胞技術

Comparison of GSM and DCS-1800

	GSM-900	DCS-1800
使用頻段	890~915MHz (上傳), 935~960MHz (下載)	1710~1785 MHz (上傳), 1805~1880MHz(下載)
手機發射功率	較高(2瓦)	較低(0.25~1瓦)
服務範圍	1~5 miles	0.5 miles
系統容量	大	小
手機電池使用時間	短	長
交遞功能處理複雜度	較簡單	較複雜
基地台架設困難度	較容易	較困難

GPRS

- What is GPRS?
  - GPRS: General Packet Radio Service，最普遍的中文譯名爲「整合封包無線服務」
- Why need GPRS?
  - 透過無線行動通訊傳輸數據資料的需求
  - 現行GSM系統傳輸數據的技術與限制
  - 進階到CDMA或WCDMA的困境

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GPRS

- GPRS的技術背景
  - 在現存的GSM網路架構下，提供數據傳輸(Datacomm)的服務
  - 是利用分封交換(Packet Switched)技術發展出一套在無線通訊上傳輸數據資料的服務
    - Packet Switched v.s. Circuit Switched
  - 它要並不打算增加原有系統容量或加大系統使用頻寬，而是透過重新規劃原有GSM的頻道與時槽(Channel & Timeslot)的分配方法來提高資料在無線介面(Air Interface)的速率
    - GSM現行的頻道分配方法
      - 採FDMA + TDMA 多重接取技術
      - 每一頻帶(Frequency band)200 kHz分成八個時槽(Timeslot)，每個時槽9.6kbps分給一位通話的使用者
      - 使用Circuit switched連結技術

GPRS

- GPRS則要允許一位使用者可以同時使用2~8個時槽，並使用Packet switched連接

- GPRS的四種編碼方式，亦同時代表四種錯誤保護能力(Error Protection) ，以及每個時槽的傳輸速率
  - CS-1 (9.05K bps) 保護最周延
  - CS-2 (13.4Kbps)
  - CS-3 (15.6Kbps)
  - CS-4 (21.4Kbps) 沒有保護

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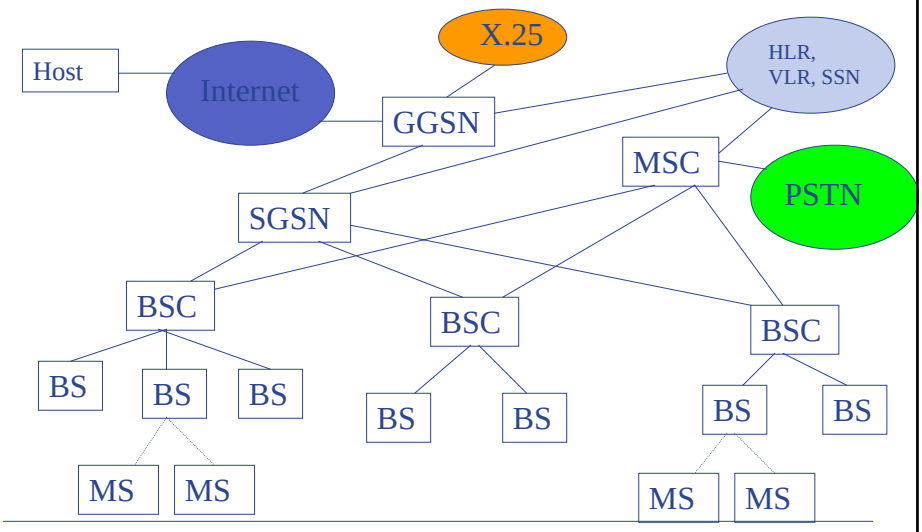
GPRS

- 故GPRS號稱最高傳輸速率可達171.2Kbps (21.4K*8)
- HSCSD Service (High-Speed Circuit-Switched Data Service) 也是定義了無線通訊傳輸數據資料的技術，但是將以電路交換的技術達到連通。傳輸速率可達57.6Kbps
- 無論HSCSD或GPRS，用戶端的行動終端設備必須有能夠支援多個時槽同時收發的功能及GPRS標準

GPRS



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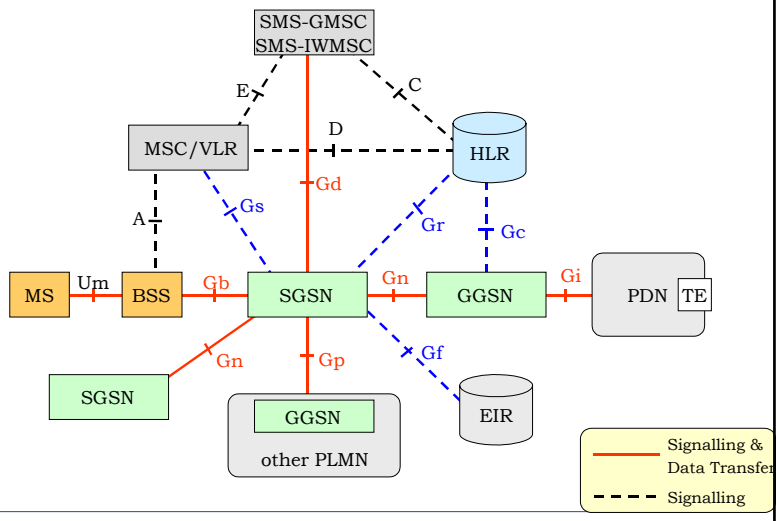
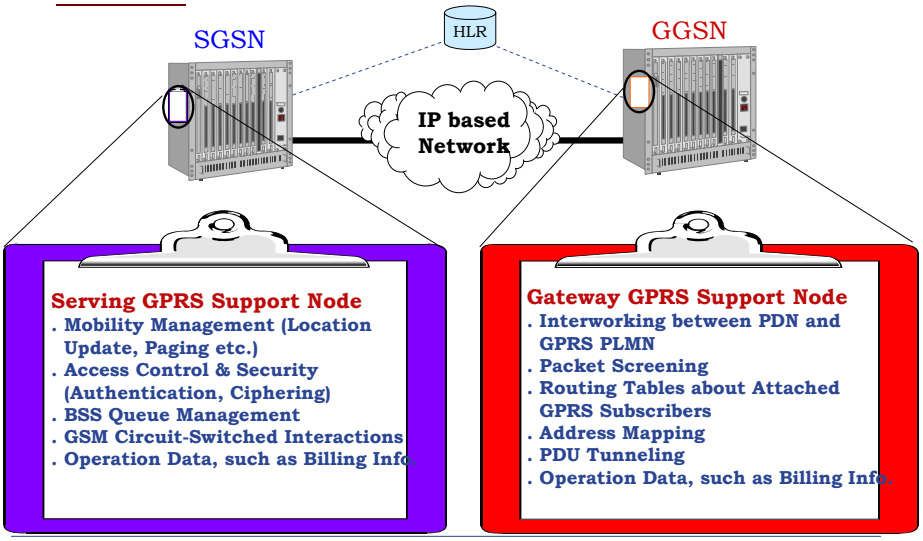
GPRS



GPRS



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GPRS

- GGSN:
  - **Gateway GPRS Support Node**
  - **Gateway** of GSM network to packet switching networks
  - **Router**
  - **Protocols transform** between GSM network and packet switching network
- SGSN:
  - **Serving GPRS Support Node**
  - **Packet transfer** between GGSN and Mobile host

IS-95

- EIA/TIA IS-95是由Qualcomm所發展出來的數位蜂巢式行動電話系統，並於1996年起在美國營運，採分碼多重擷取(Code Division Multiple Access, CDMA)技術。
- CDMA的直接序列展頻(Direct Sequence Spread Spectrum, DSSS)技術，將欲傳送的資料訊號(Information Signal)與一個虛有雜訊序列(Pseudo-Noise Sequence)訊號混合，虛有雜訊序列是一個較高速、較寬頻帶的數位訊號，該訊號表示一個獨特的正交碼(Orthogonal Code)。混合後的訊號看起來像是一個雜訊，實際上透過該虛有雜訊序列的正交特性可以粹取出原有的資料訊號。
- 因此，CDMA可將許多使用者的訊號重生於一共用頻率/時槽通道上，這些訊號可以用不同的編碼展開及區分。

IS-95

- CDMA的語音編碼可爲8kbps或13kbps，當其使用語音編碼速率爲9kbps時，IS-95的容量約爲AMPS的9倍。
- 最成功的IS-95系統爲南韓所發展。
- IS-95系統是
  - 以一個行動交換中心(MSC)爲核心；
  - MSC以768 E1幹線連接12個基地台控制器(BSC)；
  - 每個BSC可控制一至多個基地收發台(BTS)，整個系統最多可容納512個BTS；
  - 每個BTS具有820個無線通路；
  - IS-95的漫遊標準亦採用IS-41的規範。

IS-95

- 在CDMA的技術中，每一個用戶擁有一個唯一的虛擬亂碼，壓縮過的語音資料經過這組頻率高的虛擬亂碼調幅調變後，在傳送給接收端。由於每個使用者使用的亂碼均是兩兩相互正交，因此所有的使用者都可以在相同的頻譜中傳送資料而不互相干擾。
- 當聲音訊號被轉成數位訊號時，就有許多種方法可以將這些訊號包裝在一起，TDMA就是一種以時間爲區隔將許多數位訊號資料交錯地放在同一頻道上。CDMA則是使用展頻(Spread Spectrum)技術來分割訊號，已使得在同一頻道內可以塡入十倍的資料量，同時此一技術可使同一頻率在同一時間內被許多接續(Connection)所利用。

Comparison among IS-95, GSM, and AMPS

- 系統容量較高：
  - IS-95的系統容量至少是目前任何一種接取技術的兩倍以上。
  - CDMA的系統容量比TDMA更接近理想的理論值。
- 系統容量較具彈性：
  - CDMA的系統不像TDMA或FDMA的系統容量有一固定值，在某些緊急情況下，只要系統再多釋出一組虛擬亂碼，就可以多讓一個使用者使用該系統服務。
  - 當然，由於背景雜訊的增加，會稍微影響其他用戶的通話品質。
- 與原使用者共用頻譜：
  - CDMA技術透過使用互質頻譜(Co-Primary Spectrum)的概念，合元使用者共用已配置的頻譜，FCC(美國聯邦通信署，Federal Communication Commission)不須在配置新的頻譜給PCN的業者
  - 不似GSM或AMPS系統，當頻譜不敷使用時，政府必須在釋放出新的頻譜。DCS-1800就是在GSM-900頻譜不足時，所新增出來的頻譜。

Comparison among IS-95, GSM, and AMPS

- 低複雜度的通道再指定方式：
  - CDMA的技術中不需要像TDMA一般要有快速且即時的通道再指定(Channel Assignment)，CDMA通道數的多寡的最大限制因素是背景雜訊(Background Noise)的接受度。
  - 所謂的背景雜訊是只當系統新加入一個用戶的資料訊號時，對其他用戶而言相當於是一些小的背景雜訊。
  - 由於這些背景雜訊須在訊號開始傳送時才被加總，因此可使用非連續傳送，亦即當語音訊號存在時才傳送，已減低背景雜訊。
- 軟性交遞(Soft Handoff)功能：
  - Soft Handoff是CDMA技術當中一項相當重要的特性。
  - CDMA系統的手機可同時從數個基地台接收訊號，連續第將這些訊號反展頻，因此當使用者從一個基地台進到另一個基地台管轄範圍時，行動台無須在不同的載波間作切換，因此通訊可持續，不像FDMA或TDMA的技術一般，再進行交遞時，會有短暫的訊號中斷。
- 可調性功率控制：
  - 所謂可調性功率控制是指行動台會隨其所處的位置調整發射功率，以降低所造成的背景雜訊強度。相較於FDMA或TDMA之行動台所發射功率是固定的。

Issues of Resource Management in Mobile Communications

- Location Management
- Channel Assignment
- Handoff (Handover) Management
- Channel Borrowing Algorithms
- Dynamic Channel Allocation Algorithm
- Bandwidth Allocation (Scheduling) Algorithm

Location Management

- Location Registration
  - Authentication
    - Security
  - Database Updates
    - Dynamic Updates
    - Delay Constraints
- Call Delivery
  - Database Query
    - Centralized Database Architecture
    - Distributed Database Architecture
  - Terminal Paging
    - Distance-based Delay Constraint
    - time-based Delay Constraint

Channel Assignment Management

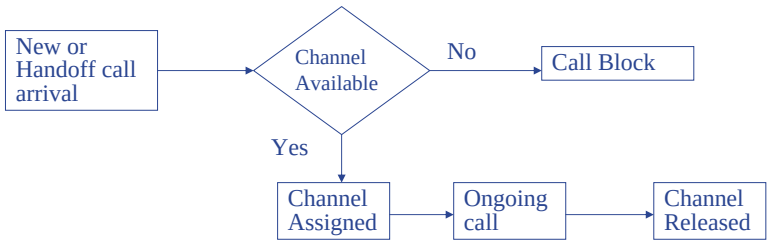
- Modeling the Cellular Network
  - Cellular Graph
  - Co-Channel Distance
- Co-Channel Interference
  - Co-Channel Interference Only
  - Co-Channel Interference and Adjacent Channel Interference
- Channel Assignment Strategy
  - Fixed Channel Allocation (FCA)
    - Channel Borrowing Schemes
  - Dynamic Channel Allocation (DCA)
    - Centralized DCA Schemes
    - Distributed DCA Schemes
  - Hybrid Channel Allocation (HCA)

Handoff Management

- Handoff Strategies
  - MCHO(Mobile Controlled Handoff)
    - TDMA: DECT, PACS
  - NCHO(Network Controlled Handoff)
    - FDMA: CT-2 Plus, AMPS
  - MAHO(Mobile Assisted Handoff)
    - TDMA: GSM
- Consider Factors
  - Call Block
  - Force Terminal

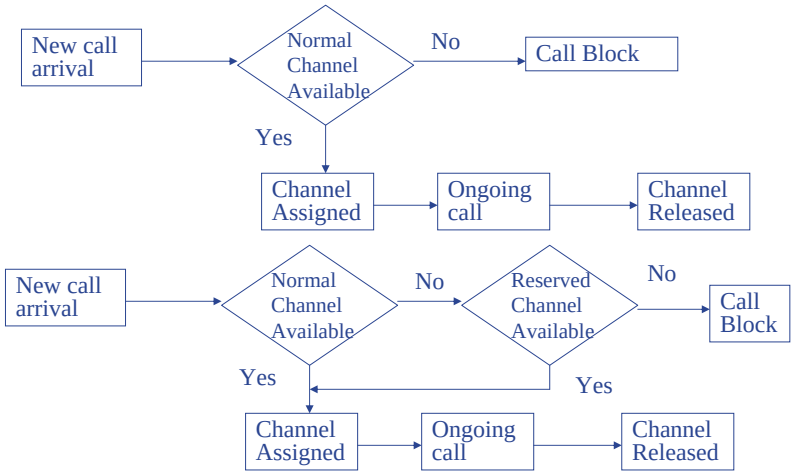
Handoff Management

- Channel assignment strategies for Handoff
  - Non-Prioritized Scheme: Non-channel Reserved for Handoff Call
  - Reserved Channel Scheme: Channel-Reserved for Handoff Call
  - Queuing Priority Scheme:Handoff Call request and queuing
- Non-Prioritized Scheme Algorithm:



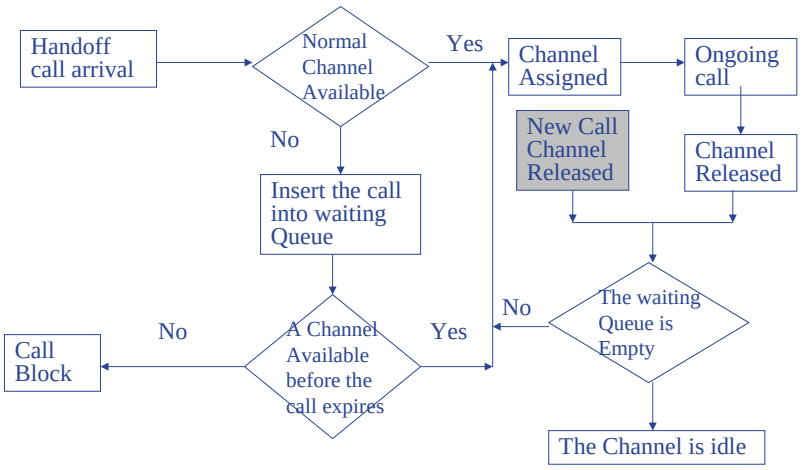
Handoff Management

- Reserved Channel Scheme Algorithm



Handoff Management

- Queuing Priority Scheme Algorithm



Handoff Management

- Queuing Priority Scheme 之 Choose algorithm from Queue:
  - Multiple Queues for New Call and Handoff Call
  - Single Queue to New Call and Handoff Call
  - Priority:
    - FIFO
    - Signal of MS
    - Direction of MS
    - Predicated Drop time of MS

Handoff Management

- Handoff of CDMA
  - Hard Handoff
    - Break before make
    - MS一次只從一個BS取得通訊資源(channel)
  - Soft Handoff
    - Make before break
    - MS同時與一個以上的BS取得通訊資源(channel)
  - Idle Handoff
    - MS在未通訊的情形下由一個BS轉換到另一個BS且執行Handoff

Channel Borrowing Algorithms

- Simple Channel Borrowing Scheme
  - Borrow from Richset (SBR):
    - 從鄰近可用通道最多的Cell借用，但不鎖住該通道
  - Basic Algorithm (BA):
    - 會鎖住該通道
  - Basic Algorithm with Reassignment (BAR):
    - 當自己的Cell已有可用通道時，可跳回自己可用通道
  - Borrow First Available (FBA):
    - 已內設一組借用順序，通道不足愈向外界用時，需依照該順序逐一找到第一個可借用之通道，並選擇第一個可借用通道來借用

Channel Borrowing Algorithms

- Hybrid Channel Borrowing Scheme
  - Simple Hybrid Channel Borrowing Strategy (SHCB)
    - Cell的通道分成標準通道與可借用通道兩集合
  - Borrowing with Channel Ordering (BCO)
    - Cell內的通道都被設定了優先權，優先權愈高的愈優先指定給本地的呼叫。反之，優先權愈低的愈優先外借
  - Sharing with Bias (SHB)
    - 依成見分享，將細胞依成見分成數個集合(領域)，指向同領域的鄰近細胞借用通道
  - Channel Assignment with Borrowing and Reassignment (CARB)
    - 將借用來的通道與自己已釋放的通道一起考量分配
  - Ordered Channel Assignment Schema with Rearrangement (ODCA)
    - 結合CARB與BCO的通道分派模式

Dynamic Channel Allocation Algorithms

- Dynamic Channel Allocation (DCA)
  - Centralized DCA Schemes
  - Distributed DCA Scheme
    - Cell-Based Distributed DCA Schemes
    - Signal Strength Measurement-based Distributed DCA Scheme
- 考量因素
  - 未來對鄰近細胞產生阻塞機率
  - 候選通道的頻率使用方式
  - 重新使用的間隔
  - 目前流量條件下的通道分發佔有情形
  - 系統平均的阻塞率
  - 用Radio到個別用戶的通道量測

Dynamic Channel Allocation Algorithms

- Centralized DCA Schemes
  - First Available (FA)
  - Locally Optimized Dynamic Assignment (LODA)
  - Selection with Maximum Usage on the Reuse Ring (RING)
  - Mean Square (MSQ), Nearest Neighbor (NN), Nearest Neighbor plus One (NN+1)
  - 1-Clique
  - Schemes with Channel Rearrangement

Dynamic Channel Allocation Algorithms

- Distributed DCA Scheme
  - Cell-Based Distributed DCA Schemes
    - Local Packing Dynamic Distributed Channel Assignment (LP-DDCA)
    - Adjacent Channel Interference Constraint (ACI Constraint)
    - LP-DDCA with ACI Constraint
    - Moving Direction

Dynamic Channel Allocation Algorithms

- Distributed DCA Scheme
  - Signal Strength Measurement-based Distributed DCA Scheme
    - Sequential Channel Search (SCS)
    - Dynamic Channel Selection (DCS)
    - Minimum Signal-to-Noise Interference Ratio (MSIR)
    - Channel Segregation
    - One-Dimensional Cellular Systems
    - Minimum Interference (MI)
    - MINMAX

3G

- IMT-2000
  - Year 2000 Ready
  - Operate at 2000 MHz
  - Provide 2000K bps Data Rate
- 3G Data Rate 要求
  - Vehicular -- 144 Kbps
  - Pedestrian --- 384 Kbps
  - Indoor --- 2Mbps
- Three Important 3G Technologies Standards
  - W-CDMA (Wideband CDMA) (歐日系統)
    - GSM/GPRS/EDGE → W-CDMA
  - cdma2000 (北美系統/韓國系統)
  - TD-SCDMA (Time Division Synchronize CDMA) (大陸系統)

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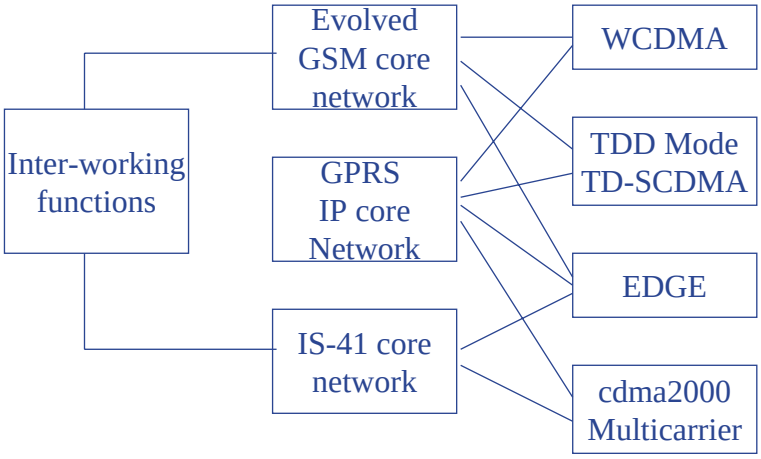
IMT 2000

- ITU (International Telecommunication Union)
- IMT-2000
  - Year 2000 Ready
  - Operate at 2000 MHz
  - Provide 2000K bps Data Rate
- 3G Data Rate Requirement
  - Vehicular -- 144 Kbps
  - Pedestrian --- 384 Kbps
  - Indoor --- 2Mbps

Core Networks



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3G in some regions

- Europe:
  - WCDMA (using FDD)
- Japan:
  - WCDMA (both TDD and FDD)
- Korea:
  - WCDMA
  - CDMA2000
- North America:
  - CDMA2000
- China:
  - TD-SCDMA
- **How about Taiwan ??**

3G Technology Development

- Two groups:
  - Third Generation Partnership Project (3GPP)
    - 3GPP works on UMTS which is based on WCDMA
  - Third Generation Partnership Project2 (3GPP2)
    - 3GPP2 works on CDMA2000

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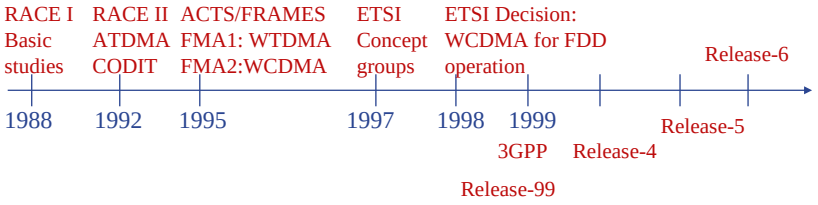
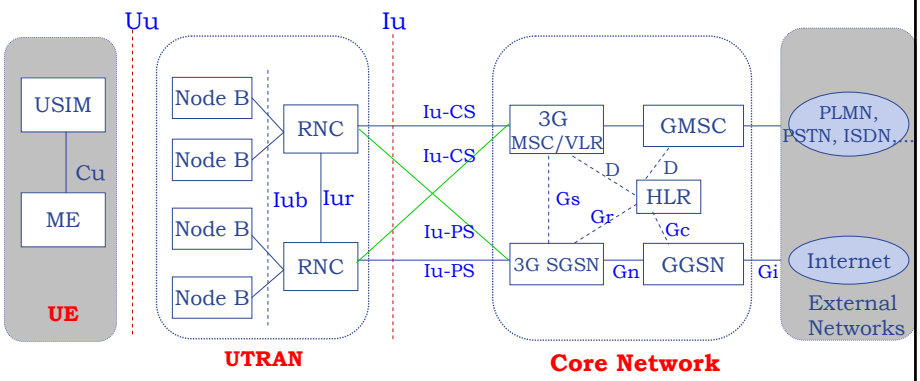
Three parts of WCDMA

- User Equipment
  - Mobile equipment (ME)
  - UMTS subscriber identity module (USIM)
- UTRAN: UMTS Terrestrial Radio Access Networks
  - Node B
  - Radio Network Controller
- Core Network
  - MSC/VLR，HLR，SGSN，GGSN

3GPP UMTS System



Release 99 Network Architecture



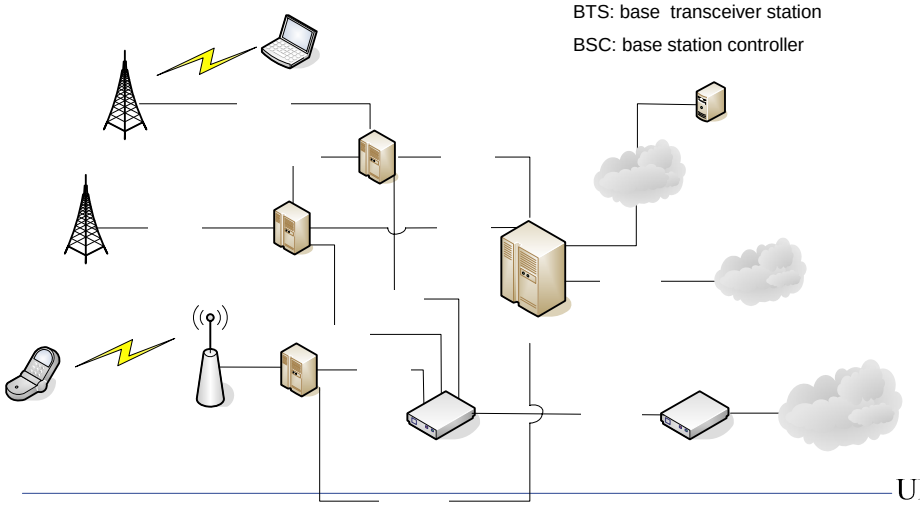
System Architecture of 3GPP Release 99

Release 99 Network Architecture

UE: user equipment

BTS: base transceiver station

BSC: base station controller



UE

Uu

Iub
(ATM)

Release 99 Network Elements

- Node B: In 3GPP, the base station is known as node B.
- RNC: radio network controller
- HLR: Home Location Register
- MSC/VLR: Mobile Services Switching Center/Visitor Location Register
- SGSN: Serving GPRS Support Node
- GGSN: Gateway GPRS Support Node
- UE: user equipment
- BTS: base transceiver station
- BSC: base station controller

RNC

Iu-ps
(ATM)

Iu-ps
(ATM)

Gb

SGSN

A-interface

Release 99 Network Interfaces

- Cu: USIM ←→ ME
- Uu: UE ←→ Node B
- Iub: Node B ←→ RNC
- Iur: RNC ←→ RNC
- Iu: UTRAN ←→ CS

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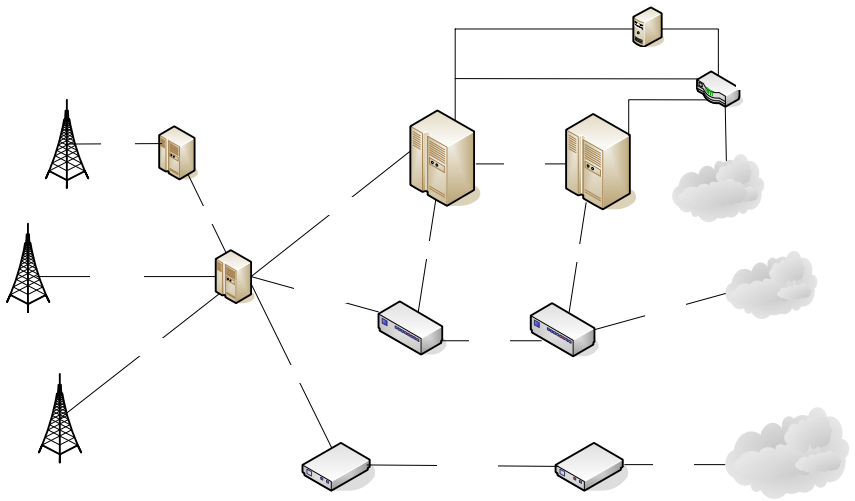
Release 4 Network Architecture



Release 4 Different from Rel.99

- The main difference between the Release 1999 architecture and the Release 4 architecture is that the core network becomes a distributed network.
- Rather than having traditional circuit-switched MSCs, a distributed switch architecture is introduced, which is also referred to as IP Multimedia Services (IMS).

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Release 4 Different from Rel.99

- In Release 4, High Speed Downlink Packet Access (HSDPA) is introduced.
- HSDPA enables a more robust data offering in the downlink. The uplink remains the same as in Release 1999.

Release 4 Different from Rel.99

- The Mobile Switching Center (MSC) is divided into:
  - MSC server
    - Contains all the mobility management and call-control logic.
  - Media gateway
    - Contains the switching matrix.

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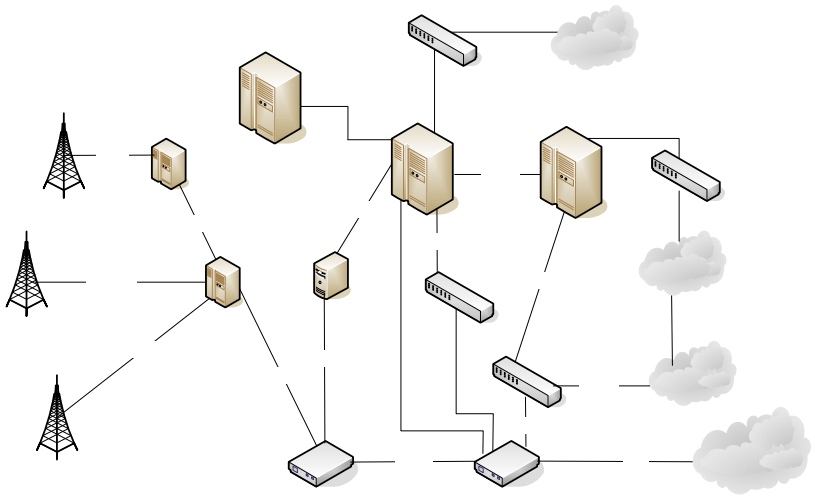
Release 5 Network Architecture



CSCF

R-SG

RNC

CSCF

Iub

Release 5 Different from Rel.4

- The next step in the UMTS evolution is introduction of an all-IP multimedia network architecture.
- Specifically, both voice and data are handled largely in the same manner all the way from the user terminal to the ultimate destination.
  - This architecture can be considered the ultimate convergence of voice and data.

Cx

HSS/HLR

Gr

Iu

C

SGSN

Release 5 Different from Rel.4

- In Release 5, not only is the core enhanced, but the uplink data rate also is improved through the introduction of High Speed Uplink Packet Access (HSUPA).

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New Elements of Release 5

- CSCF: Call State Control Function
- MRF: Multimedia Resource Function
- MGCF: Media Gateway Control Function
- T-SGW: Transport Signaling Gateway
- R-SGW: Roaming Signaling Gateway

CDMA2000

- CDMA2000 is a wireless platform that is part of the IMT-2000 specification and is an extension of the CDMAOne wireless platforms using the IS-95A/B and J-STD-008 standards.
- CDMA2000 is geared toward the transport and treatment of 3G wireless services supporting multimedia applications for fixed as well as mobile situations.

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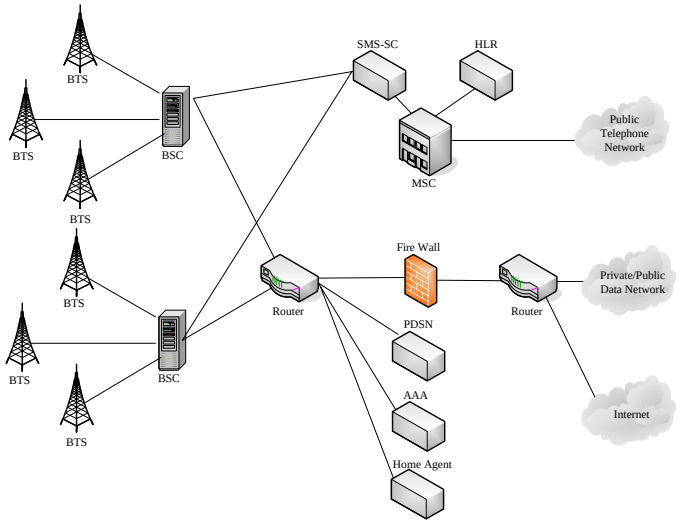
CDMA2000

- CDMA2000 can be and has been deployed in an existing IS-95 channel or system and will exhibit the numerous enhancements:
  - 1.25 MHz channel support
  - 144 kbps packet-data rates
  - 2× increase in voice capacity
  - 2× increase in standby time
  - Improved handoff

CDMA2000 Network Architecture



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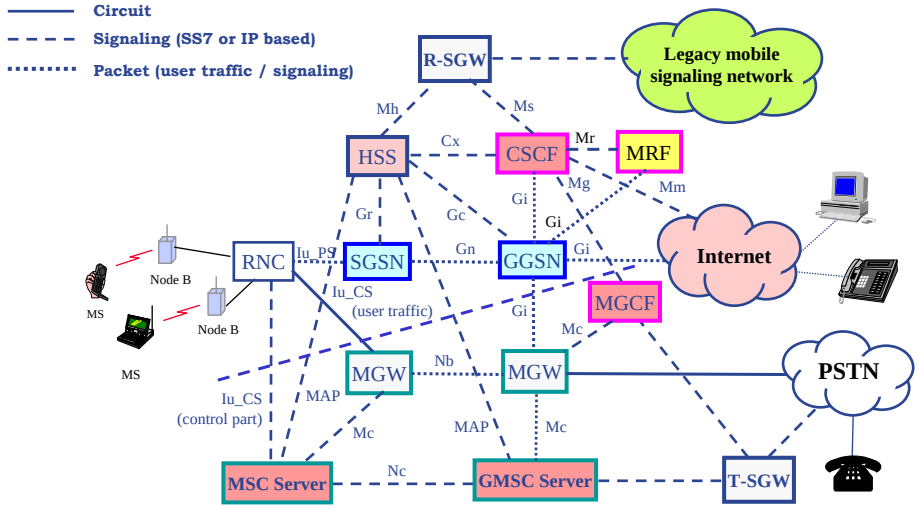
All IP Network Architecture



What is WiMAX ?

- **Worldwide Interoperability for Microwave Access**
- **Wireless MAN (WMAN)**
- **IEEE 802.16**
  - 802.16d(去年更名爲802.16-2004)
  - 802.16e
- **Last Mile access**
  - -Fast local connection to network
  - -其發展預期可改善傳統無線網路的缺失，將在寬頻網最後一哩（ **Last Mile** ）中與 **xDSL**和**Cable**競爭的無線技術

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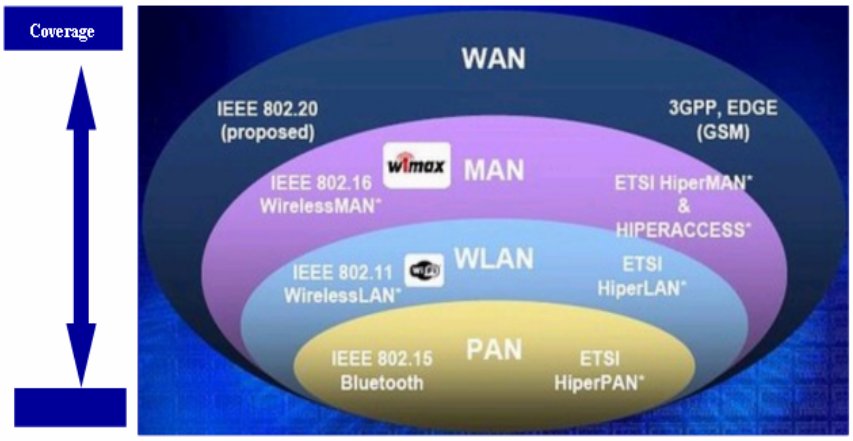
WiMAX

- 英特爾（Intel）主導
- WiMAX以IEEE 802.16爲基礎，期望成爲WMAN（無線都會網路）的主流規格
- WiMAX的傳距遠（最大至30英哩，約48公里），傳速高（每個WiMAX基地台最快134Mbps），每個末端連網裝置可獲得300Kbps～2Mbps的連網頻寬

Organization of Management

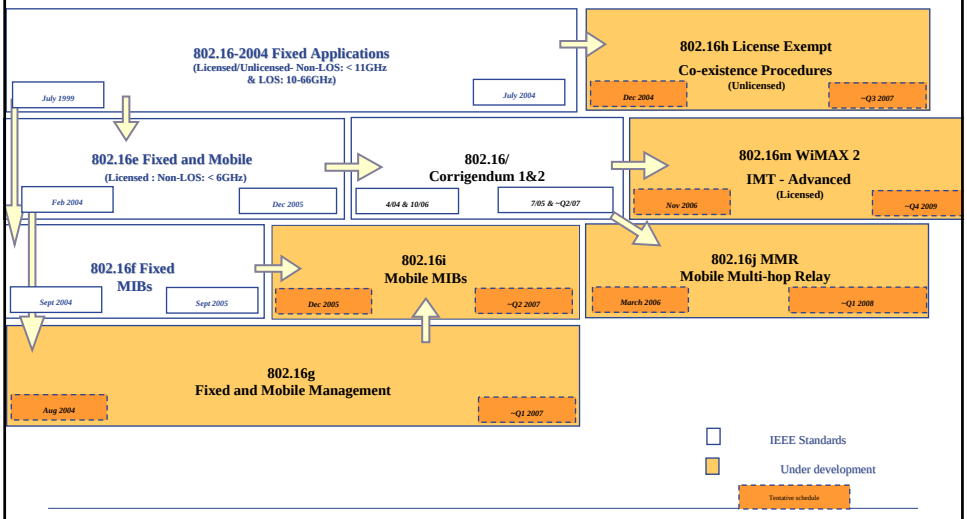
- IEEE802.16工作組 是標準的制定者
- WiMAX Forum是IEEE802.16技術的推廣者

Comparisons of Wireless communication



資料來源：國家實驗研究院科技政策研究與資訊中心(2005/06)

WiMax Standards Evolution



IEEE WiMAX Standards (1/2)

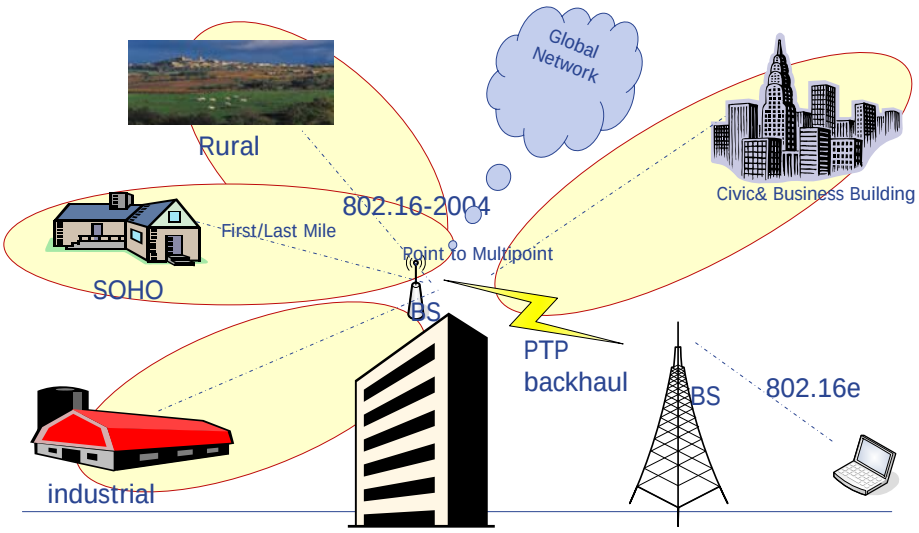
項目	內容	狀態
802.16	• 只限於點對點傳輸 (Point-to-Point) • 須在可目視 (Line-of-Sight) 環境 • 有固定頻帶寬帶限制	• 2001年11月通過
802.16a	• 支援多點傳輸 (Point-to-Multipoint) • 可在非目視環境 (Non-Line of Sight) • 可隨環境調整傳輸所需頻寬 (但範圍需在 1.25-20MHz)	• 2003年1月通過
802.16c	• 802.16 的測試標準	• 2003年1月發表初版
802.16-2004	• 融合 802.16, 802.16a 與 802.16c 並修訂補強之 • 爲 WiMAX 選定用於遊牧式 (nomadic)與固定式 (fixed) 應用	• 2004年6月通過 • 2005年9月通過D5修正版定案
802.16/conf04	• 準備測試計劃以檢驗 802.16-2004 的一致性 • 針對 OFDM256 與 ETSI 進行共同研究 • 與 WiMAX Forum之相關活動部分重疊	• 2006年9月標準發表
802.16e	• 爲 WiMAX 選定用於可攜式 (portable)與移動式 (mobile) 應用 • 增加交遞 (Handover) 等程序	• 2005年12月通過 • 2006年2月標準發表

IEEE WiMAX Standards (2/2)

項目	內容	狀態
802.16f	• 定義管理資訊基底 (MIB) • 支援 802.16-2004 無線網路管理	• 2005年12月標準發表
802.16g	• 定義管理面相關流程與服務 (如系統管理、 資源管理、交遞管理、互通性測試等等) • 用於 WiMAX 網路管理之用	• 2007年4月對D9進行 Sponsor Ballot
802.16h	• 改善 WiMAX Radio Access 機制供免執照頻寬 (Unlicensed Band) 運轉之用	• 2007年4月對D2c進行 TG Review
802.16i	• 802.16f 管理資訊基底 (MIB) 的修訂與補充 • 支援 802.16e 無線網路管理	• 2007年8月對D4進行 Letter Ballot
802.16j	• Multi-hop relay for WiMAX • Compatible to 802.16e MS	• 2007年8月對D1進行 Letter Ballot • 預定2008年3月發表
802.16k	• Bridging extension for 802.1D to WiMAX	• 2007年3月標準發表
802.16m	• Next generation of WiMAX2 • 將投入 ITU 競爭 4G 標準	• 2007年3月完成初版 Requirement

IEEE 802.16 Published Standards and Drafts: http://www.ieee802.org/16/published.html

Fixed WMAN+Mobile WMAN



WiMAX, Wi-Fi .11 & .16 PHY比較

	Wi-Fi (802.11)	WiMAX (802.16)
BB (base band)		
Modulation	.11/.11b: BPSK, QPSK .11a/g: BPSK, QPSK, 16-QAM, 64-QAM	BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM
Channel access	.11/.11b: DSSS .11a/g: OFDM	LOS: SC NLOS: SCa, OFDM, OFDMA .16e: OFDMA
Duplexing	Done by MAC	TDD or FDD with support of MAC
Space utilization	.11n: MIMO-OFDM	N/A
RF (radio frequency)		
Channel bandwidth	20 or 22 MHz	LOS: 25 or 28 MHz NLOS: 1.25~28 MHz
Frequency band	.11/b/g: 2.4GHz (83MHz wide) .11a: 5.2GHz (260MHz wide)	LOS: 10~66 GHz NLOS: 2~11 GHz License-exempt: 5~6 GHz 16e: 2~11 GHz
Power	.11/11b/g: 100mW .11a: 1W	63.5dbm (2238.72W) ~ 64dbm (2511.89W)
Ideal PHY's		
Max. distance	90m	9.6KM
Max. bitrate	54 Mbps	75Mbps
Max. velocity of MT	30 km/hr	.16e: 70 km/hr

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WiMAX, Wi-Fi .11 & .16 MAC比較

	Wi-Fi(802.11)	WiMAX(802.16)
Medium Access Method	CSMA/CA	TDMA
	Contention & polling	Polling (contention during initial ranging and request)
Contention resolution	By CSMA/CA and RTS/CTS	Binary exponential backoff
Connection	Pure connection of AP with MT	Connection of BS & SS, and bandwidth allocation
Reliable delivery	By ACK	By ARQ
Security	11: authentication and WEP 11i: WAP & WAP2	By cryptographic suite & PKM
QoS	Provided by .11e using HCCA & EDCA	Defined spec and types of service flows
Scheduling	Defined in HCCA of .11e	4 service type: UGS, rtPS, nrtPS, BE
Bandwidth allocation	Defined in HCCA of .11e	Defined request/grant flow
Multicast (receiver)	designated by the sending SS	using the same CID
Ranging	Supported by .11k	Specified procedure

LTE

- LTE: Long Term Evoluation
- 爲3GPP所制定的標準，使用「正交頻分復用」（OFDM）的射頻接收技術，以及2x2和4x4 MIMO的分集天線技術規格。同時支援FDD（頻分雙工）和TDD（時分雙工）。LTE是GSM超越3G與HSDPA階段邁向4G的進階版本
- LTE與WiMAX，以及3GPP2的超行動寬頻（Ultra Mobile Broadband，UMB）技術常一起被稱爲4G，過去的3G技術是指同一無線網路提供語音和數據通訊，但到了4G時代則變成爲全數據網路，LTE估計最高下載速率100Mbps與上傳50Mbps以上，比WiMax更快。

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LTE

- 較於WiMAX的固定無線網路技術，二者都採用了正交頻分復用（OFDM）的訊號傳輸，也都採用了Viterbi和Turbo加速器
- 但WiMAX是來自IP的技術，而LTE是從GSM／UMTS的移動無線通信技術衍生而來
- 3GPP計畫在LTE的下行鏈路使用OFDMA，上行鏈路採用SC-FDMA（單載波FDMA，也稱爲「DFT擴展OFDM」），可以減少手機耗電
  - SC-FDMA的優點是訊號具有更低的峰均比（PAPR），因爲它採用了固有的單載波結構。由於結合OFDMA/MIMO／HARQ，LTE系統能隨著可用頻譜的不同，採用不同寬度的頻帶，因此LTE的移動能力比WiMAX先進

LTE

- 南韓電子通訊研究院（ETRI）成功以時速120公里的移動速度、在基地台和終端設備樣品之間進行LTE資料傳輸
- 諾基亞（Nokia）完成使用2.6GHz頻段傳輸速率可達173Mbps的LTE技術現場測試
- LTE又以IP爲基礎的核心網路架構，制定了「系統框架演進」（SAE: System Architecture Evolution），以現有 GSM/WCDMA爲核心
- 2008年11月19日美國高通（Qualcomm）首席執行官Paul E.Jacobs宣佈放棄UMB，朝LTE和LTE-Advanced等發展

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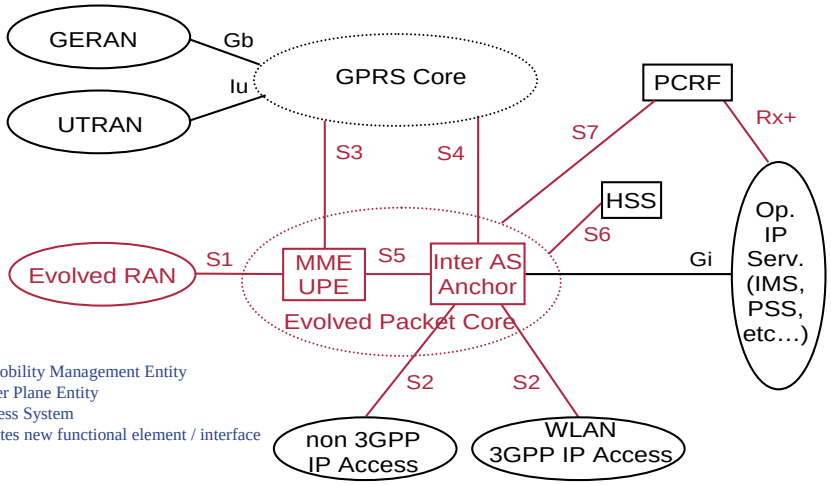
LTE

- LTE採用2x2配置作爲MIMO的基本配置，即BS和EU各兩根天線，未來會考慮4x4配置
- 在每一個 5MHz 的蜂窩（cell）內，至少有200個動態使用者（active user）
- 支援MBSFN (Multicast Broadcast Single Frequency Network)
- 用戶面單向傳輸時延低於5ms，控制面從Sleep Mode到Active Mode遷移時間低於50ms
- 在20MHz頻譜頻寬能夠提供最高下行100Mbps、上行50Mbps的速率

SAE

- SAE: System Architecture Evolution
- Objective:
  - "to develop a framework for an evolution or migration of the 3GPP system to a higher-data-rate, lower-latency, packet-optimized system that supports multiple Radio Access Technologies.
  - The focus of this work is on the PS domain with the assumption that voice services are supported in this domain".

SAE



MME – Mobility Management Entity
UPE – User Plane Entity
AS – Access System
Red indicates new functional element / interface