King Fahd University of Petroleum & Minerals
Computer Engineering Dept

COE 543 – Mobile and Wireless Networks

Term 111

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Lecture Contents

1. Introduction to Mobile and Wireless Networks
   a. Examples of 1st G
   b. Examples of 2nd G
   c. Examples of PCS networks
   d. Examples of mobile data services and WLANs
   e. Introduction into 3rd G

Wireless Applications

- Voice-Oriented Networks – extensions to the PSTN
  - Local networks – low power/mobility, excellent voice quality, etc
    - E.g. cordless telephony, PCS, Wireless PBX
  - Wide area networks – high power/mobility
    - E.g. cellular telephony
- Data-Oriented Networks
  - Broadband
  - Ad-Hoc
    - E.g. WLANs, WPANs, etc.
  - Wide area mobile networks – connectivity for mobile user
    - E.g. GSM/GPRS

History of Voice-Oriented Wireless Networks

Year	Event
Early 1970s	Exploration of 1st generation mobile radio at Bell Labs
Late 1970s	1st G cordless telephone
1982	Exploration for 2nd G digital cordless CT-2
1982	Deployment of 1st G NMT
1983	Deployment of U.S. AMPS
1983	Exploration of 2nd G GSM
1985	Exploration of wireless PBX and DECT
1988	Initiation for GSM development
1988	Exploration of IS-54 digital cellular
1988	Exploration of the QUALCOMM CDMA technology
1991	Deployment of GSM
1993	Deployment of PHS/PHP and DCS-1800
1993	Initiation for IS-95 standard for CDMA
1995	PCS band auction by FCC
1995	PACS finalized
1998	3G standardization started

source: chapter one of (1)

History of Data-Oriented Wireless Networks

Year	Event
1979	Diffused infrared (IBM Rueschlikon Labs – Switzerland)
1980	Spread spectrum using SAW devices (HP Labs – California)
Early 1980s	Wireless modem (Data Radio)
1983	ARDIS (Motorola/IBM)
1985	SM band for commercial spread spectrum applications
1986	Mobitex (Swedish Telecom and Ericsson)
1990	IEEE 802.11 for Wireless LAN standards
1990	Announcement of wireless LAN products
1991	RAM mobile (Mobitex)
1992	Formation of WINForum
1992	ETSI and HIPERLAN in Europe
1993	Release of 2.4, 5.2, and 17.1-17.3 GHz bands in EU
1993	CDPD (IBM and 9 operating companies)
1994	PCS licensed and unlicensed bands for PCS
1996	Wireless ATM forum started
1997	U-NII bands released, IEEE 802.11 completed, GPRS started
1998	IEEE 802.11b and Bluetooth announcement
1999	IEEE 802.11a/HIPERLAN-2 started

source: chapter one of (1)

First Generation Wireless Standards

Standard	Forward Band (MHz)	Reverse Band (MHz)	Channel Spacing (KHz)	Region	Comments
AMPS	824-849	869-894	30	USA	Also in Australia, southeast Asia, Africa
TACS	890-915	935-960	25	EU	Later, bands allocated to GSM
E-TACS	872-905	917-950	25	UK	
NMT 450	453-457.5	463-467.5	25	EU	
NMT 900	890-915	935-960	12.5	EU	Frequency overlapping; also in Africa
NTT	925-940	870-885	25/6.25	Japan	Nationwide
NTT	915-918.5	860-863.5	6.25	Japan	regional

source: chapter one of (1)

First Generation Wireless Standards

- AMPS: Advanced Mobile Phone System
- TACS: Total Access Communication System
- E-TACS: Enhanced TACS
- NTT: Nippon Telephone and Telegraph

Second Generation Wireless Standards

Standard	GSM	IS-54	IS-95	JDC
Region	Europe/Asia	US	US/Asia	Japan
Access Method	TDMA/FDD	TDMA/FDD	CDMA/FDD	TDMA/FDD
Modulation Scheme	GMSK	π/4-DQPSK	SQPSK/QPSK	π/4-DQPSK
Channel Spacing (KHz)	200	30	1250	25
Bearer channel/carrier	8	3	variable	3
Channel bit rate (kb/s)	270.833	48.6	1228.8	42
Speech rate (kb/s)	13	8	1-8	8
Frame Duration (ms)	4.615	40	20	20

Moe Rahnema, "Overview Of The GSM System and Protocol Architecture," IEEE Communications Magazine, April 1993, pp. 92-100.

Second Generation Wireless Standards (2)

- GSM: pan-European digital cellular
  - Channel bit rate of 270 kb/s – higher than the rest
  - GPRS – based on GSM technology
- IS-54: North American interim standard
  - Later became IS-136
  - Uses the same band and carrier spacing as AMPS (gradual deployment)
- JDC: Japanese Digital Cellular
- IS-95: Based on CDMA technology
- Voice coding ~ 10 kb/s for all systems

Personal Communication Services (PCS)

- Intended for residential applications
- Support smaller cell sizes ➔ lower power levels
- Zonal coverage
- Low (~ 10 m) height antennas
- Higher quality of voice service – better grade of service (99% availability)
- Mostly use TDD
- Less efficient modulation techniques
- Non-coherent (simple) transmit/receive systems

Donald Cox, "Wireless Personal Communications: What Is It?," IEEE Personal Communications Magazine, April 1995, pp. 20-35

2nd Generation PCS

System Aspect	PCS	Cellular
Cell Size	5-500 m	0.5-30 km
Coverage	Zonal	Comprehensive
Antenna Height	< 15 m	> 15 m
Vehicle Speed	< 5 km/h	< 200 km/h
Handset Complexity	Low	Moderate
Basestation Complexity	Low	High
Spectrum Access	Shared	Exclusive
Average Handset Power	5-10 mW	100-600 mW
Speech Coding	32 kb/s ADPCM	7-13 kb/s vocoder
Duplexing	TDD	FDD
Detection	Non-coherent	Coherent

2nd Generation PCS Standards

System	CT-2 and CT-2+	DECT	PHS	PACS
Region	Europe/Canada	Europe	Japan	US
Access Method	TDMA/TDD	TDMA/TDD	TDMA/TDD	TDMA/FDD
Carrier Spacing (kHz)	100	1728	300	300
Bearer Channel/carrier	1	12	4	8 per pair
Channel bit rate (kb/s)	72	1152	384	384
Modulation	GFSK	GFSK	π/4-DQPSK	π/4-DQPSK
Speech coding (kb/s)	32	32	32	32
Frame Duration (ms)	2	10	5	2.5

Mobile Data Services

- Provide moderate data rates (10s of kb/s) and wide coverage area access to packet-switched data networks
- CDPD utilizes the AMPS bands –
- ARDIS, CDPD, and Mobitex designed (before the internet proliferation) optimized for coverage and availability and not bit rate
- GPRS and Metricom (relatively newer) support higher bit rates
- Employ data sense multiple access (DSMA) and ALOHA-like protocols

Mobile Data Services (2)

System	ARDIS	Mobitex	CDPD	GPRS
Frequency Band (MHz)	800 bands 45 kHz separation	935-940 896-961	869-894 824-849	890-915 935-960
Channel bit rate (kb/s)	19.2	8.0	19.2	200
RF Channel spacing (kHz)	25	12.5	30	200
Channel Access/Multiuser Access	FDMA/DSMA	FDMA/Dynamic S-ALOHA	FDMA/DSMA	FDMA/TDMA
Modulation	4-FSK	GMSK	GMSK	GMSK

Older technologies – lower bit rates

Fairly new technology

Mobile Data Services (3) - References

- R.R. Quick and K. Balachandran, “Overview of the Cellular Digital Packet Data (CDPD) System,” Proceedings of the PIMRC’93, Yokohama, Janapan (1993), pp. 338-343.
- A. DeSimone, S. Nanda, "Wireless Data: Systems, Standards, Services," *ACM Wireless Networks*, V. 1, N. 3, (October 1995), pp. 241-253.
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- M. Khan, J. Kilpatrick, "MOBITEX and Mobile Data Standards," *IEEE Communications Magazine*, (March 1995), pp. 96-101.

Wireless LAN Standards

- WLANs provide high bit rates (> 1 Mb/s)
- Local area coverage (< 100 m)
- Operate mostly in the unlicensed bands (e.g. ISM)
- IEEE 802.11 and HIPERLAN-1 ➔ 2G
- Rest – OFDM-based ➔ next generation

Wireless LAN Standards (2)

Parameters	IEEE 802.11	IEEE 802.11b	IEEE 802.11a	HIPER-LAN/2	HIPER-LAN/1
Frequency Band (MHz)	2.4 GHz	2.4 GHz	5 GHz	5 GHz	5 GHz
Data rate	1, 2 Mb/s	1, 2, 5.5, 11 Mb/s	6, 9, 12, 18, 24, 36, 54 Mb/s		23.5 Mb/s
Access Method	Distributed control, CSMA/CA, PCF, or RTS/CTS			Central control; reservation based	Active contention resolution – priority signaling
Modulation	DSSS:FHSS	DSSS:CCK	OFDM	OFDM	GMSK

Products available

Wireless LAN Standards (3)

Standard	Modulation Method	Frequencies	Data Rates Supported (Mbit/s)
802.11 legacy	FHSS, DSSS, infrared	2.4 GHz, IR	1, 2
802.11b	DSSS, HR-DSSS	2.4 GHz	1, 2, 5.5, 11
"802.11b+" non-standard	DSSS, HR-DSSS (PBCC)	2.4 GHz	1, 2, 5.5, 11, 22, 33, 44
802.11a	OFDM	5.2, 5.8 GHz	6, 9, 12, 18, 24, 36, 48, 54
802.11g	DSSS, HR-DSSS, OFDM	2.4 GHz	1, 2, 5.5, 11; 6, 9, 12, 18, 24, 36, 48, 54
802.11n*	advanced techniques: e.g. MIMO, etc.	2.4, 5 GHz	~ 248

*Drafts exist – to be completed June 2009.
Source: http://en.wikipedia.org/wiki/IEEE_802.11
Very nice summary of all 802.11 technologies

IMT-2000

- The primary standard for 3G networks is referred to as International Mobile Telecommunication beyond the year 2000 (IMT-2000)
- Goals:
  - Higher data rates – multimedia applications
  - Higher spectral efficiency
- ITU-R received many candidate proposals for radio transmission technologies (RRT)

IMT-2000 Requirements

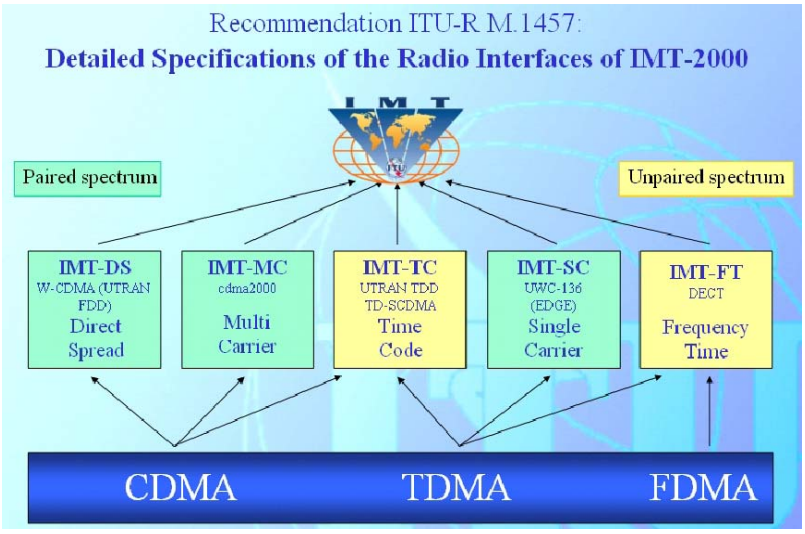
- Improve voice services
- Provide packet data services – IP-based traffic and real-time video
- Provide seamless incorporation into 2G and satellite networks
- Support 144 kb/s for outdoor applications
- Support 2 Mb/s for indoor applications
- Symmetrical and asymmetrical data transmission
- Simultaneous services for multimedia applications
- Global roaming between different operational environments
- Etc.

IMT-2000 Technologies

- IMT-2000 Technologies:
  1. IMT-DS (direct spread): W-CDMA
  2. IMT-MC (multicarrier): cdma2000 aka IS-2000:
     - Deployed in phases (cdma2000 1x, 1x EV-DO, 1x EV-DV, 3x, etc.)
     - Packet core network (PCN) – key component
  3. IMT-TC (time-code): UTRA (TDD) and TD-SCDMA (FDD)
  4. IMT-FT (frequency-time): DECT
     - system for cordless business communication
  5. IMT-SC (single carrier): TDMA
     - UWC-136 (D-AMPS) or EDGE)

UTRA: UMTS Terrestrial Radio Access
TD-SCDMA: Time-Division Synchronous CDMA
UWC-136: Universal Wireless Communication
EDGE: Enhanced Data rates for GSM Evolution
GSM MAP: GSM Mobile Application Part

IMT-2000 Technologies



Source: ITU-IMT-2000project.pdf

The Air-interface Specification for 3GPP's Proposals

Parameters	3GPP2 (cdma2000)	3GPP (W-CDMA)
Multiple access technique and duplexing scheme	Multiple access: DS-CDMA (UL); MC-CDMA(DL) Duplexing: FDD	Multiple access: DS-CDMA Duplexing: FDD
Chip rate	N x 1.2288 Mchip/s (N = 1, 3, 6, 9, 12)	3.84 Mchips/s
Pilot structure	Code-divided continuous dedicated pilot (UL) Code-divided continuous common pilot (DL) Code-divided continuous common or dedicated auxiliary pilot (DL)	Dedicated pilots (UL) Common and/or dedicated pilots (DL)
Frame length	5, 10, 20, 40, 80 ms	10 ms with 15 slots
Modulation and detection	Data modulation: UL-BPSK, DL-QPSK Spreading modulation: UL-HPSK, DL-QPSK Detection: pilot-aided coherent detection	Data modulation: UL-dual channel QPSK; DL-QPSK Spreading modulation: QPSK Detection: pilot-aided coherent detection
Channelization code	Walsh codes (UL) Walsh codes or quasi-orthogonal codes (DL)	Orthogonal variable spreading factor codes
Scrambling code	Long code (with a period of $2^{42} - 1$ chips for N = 1) Short PN code (with a period of 2^{15} chips for N = 1). (N is the spreading rate number)	UL-short code (256 chips from the family of S(2) codes or long code (38,400 chips, Gold-code-based) DL: Gold-code-based
Access Scheme	RsMa — flexible random access scheme allowing three modes of access: –Basic access –Power controlled access –Reserved access Designated access scheme — access scheme initiated by the base station message	Acquisition-indication-based random access mechanism with power ramping on preamble followed by message
Inter-base-station operation	Synchronous	Asynchronous Synchronous (optional)

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- M. Zeng, A. Annamalai, Vijay K. Bhargava, "Harmonization of Global Third-Generation Mobile Systems," IEEE Communication Magazine, December 2000, pp. 95-104
- http://www.itu.int/osg/spu/imt-2000/technology.html
- http://www.ericsson.com/technology/IMT-2000.shtml

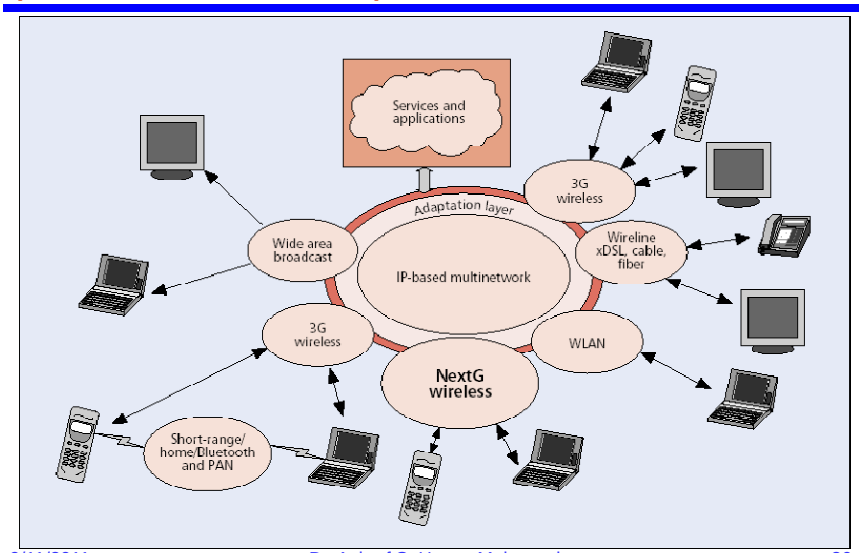
Beyond 3G – Enabling Concepts/Technologies

- Ubiquitous services and paradigm change
  - Ultraconnectivity
  - Flexible networks
- Smart spectrum and dynamic spectrum assignment
- Smart resources
  - Adaptive resource management
  - Dynamic layers and fast adaptation
  - Software radios and smart radios
  - Advanced adaptive waveforms (modulation and coding) and physical layer
  - Quality of service (QoS), adaptive networks, and universal access nodes
- Advances in DSP hardware - Software Radio
- Intelligent Antennas (v.s. Smart Antennas):
  - Narrow beam technologies: switched vs. steered
  - Adaptive processing – combining
  - Space-time coding (BLAST)
- MIMO
- TTLNA: superconductor power amplifier with low noise figure
- Multi-user Detection: non-linear detection method

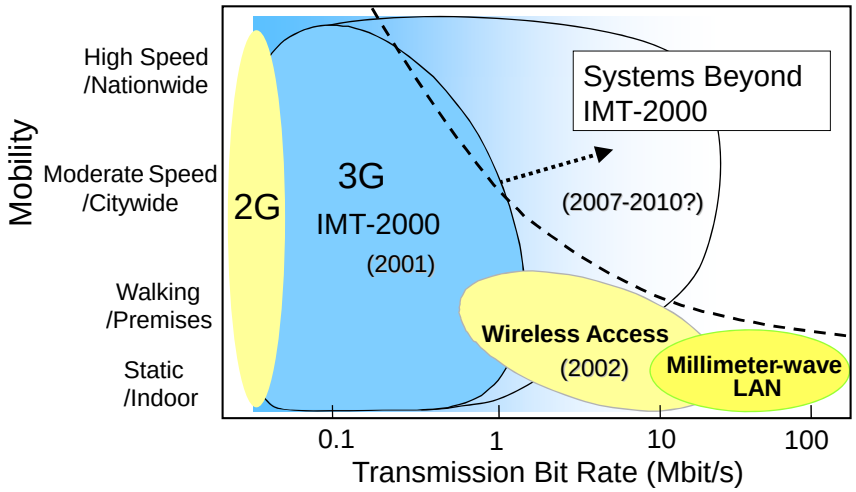
concepts

Technologies

Beyond 3G – Ultraconnectivity (Multi-networks)



Beyond 3G – Pushing the Envelope



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- Robert Berezdivin, Robert Breinig, and Randy Topp, Raytheon, "Next-Generation Wireless Communications Concepts and Technologies," IEEE Communications Magazine, March 2002, pp. 108-116
- Q. Bi, G. I. Zysman, and H. Menkes, "Wireless Mobile Communications at the Start of the 21st Century," *IEEE Commun. Mag.*, Jan. 2001, pp. 110–16

Metrics

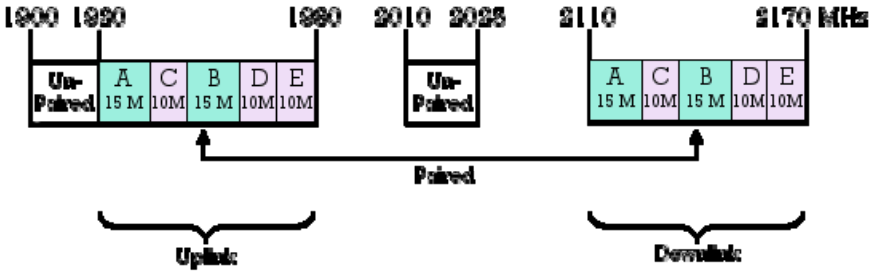
- Capacity:
  - Number of users (voice – data)
    - Data could be circuit switched or packet switched
- Efficiency
  - Bits/sec/Hz
  - Erlang/m2/Hz → voice only at a give GOS
  - Internet traffic ?

References

1) Kaveh Pahlavan, Prashant Krishnamurthy, Principles of Wireless Networks – A unified Approach, Prentice Hall, 2002 – Chapter 1

3G (UMTS) Spectrum - Europe

- Paired bands utilized FDD-CDMA, while unpaired bands utilize TDD-CDMA



Source: http://www.three-g.net/3g_spectrum.html

Example: 3G Spectrum Cost at UK

License Name	Frequencies	Winner	Final Amount Bid
License A (reserved for a new entrant to the industry)	2x15 MHz paired spectrum plus 5 MHz unpaired spectrum	Hutchison 3G	£4,384,700,000
License B	2x15 MHz paired spectrum	Vodafone	£5,964,000,000
License C	2x10 MHz paired spectrum plus 5 MHz unpaired spectrum	BT	£4,030,100,000
License D	2x10 MHz paired spectrum plus 5 MHz unpaired spectrum	One2One	£4,003,600,000
License E	2x10 MHz paired spectrum plus 5 MHz unpaired spectrum	Orange	£4,095,000,000

Source: http://www.three-g.net/3g_spectrum.html