King Fahd University of Petroleum & Minerals
Computer Engineering Dept

COE 543 – Mobile and Wireless Networks

Term 022

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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

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
- NNT: 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/FD	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 serive (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	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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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 200		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

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

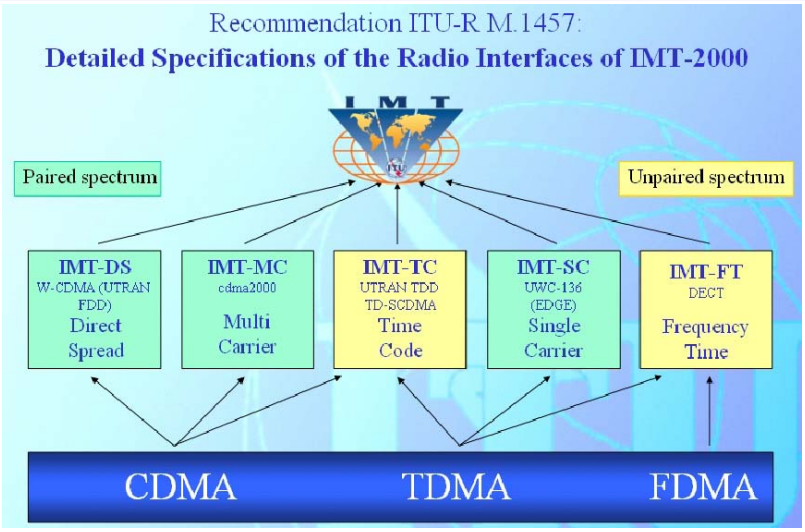
- Improve voice services
- Provide packet data services – IP-based traffic and real-time video
- Provide seamless incorporation into 2G and satellite networks
- Support 144 kb/s for outdoor applications
- Support 2 Mb/s for indoor applications
- Symmetrical and asymmetrical data transmission
- Simultaneous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

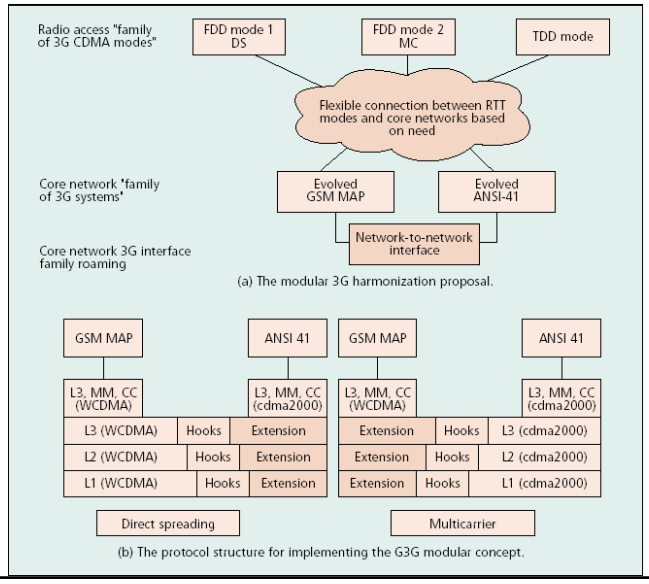


 Source: ITU-IMT-2000project.pdf

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)

The Air-interface Specification for 3GPP's Proposals



(a) The modular 3G harmonization proposal.

(b) The protocol structure for implementing the G3G modular concept.

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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.ericsson.com/technology/IMT-2000.shtml

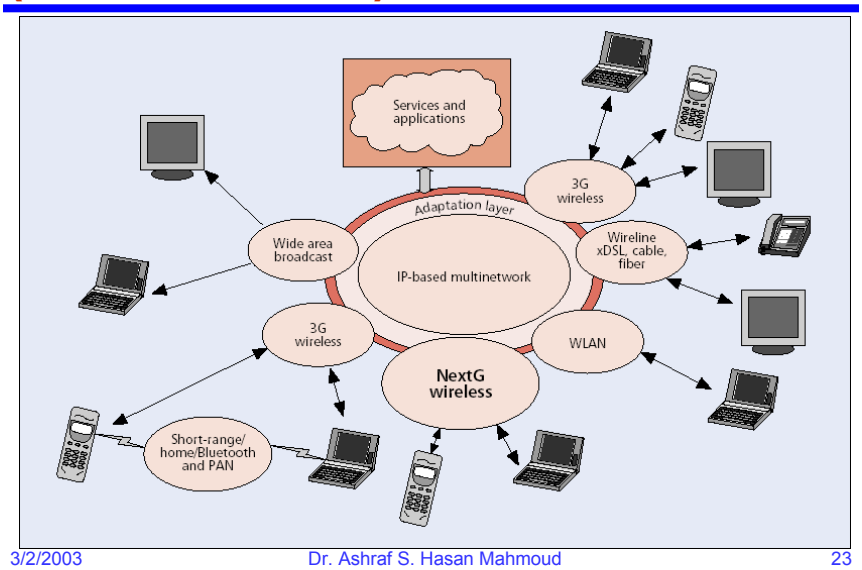
Beyond 3G – Enabling Concepts/Technologies

- 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
- Intellegent 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

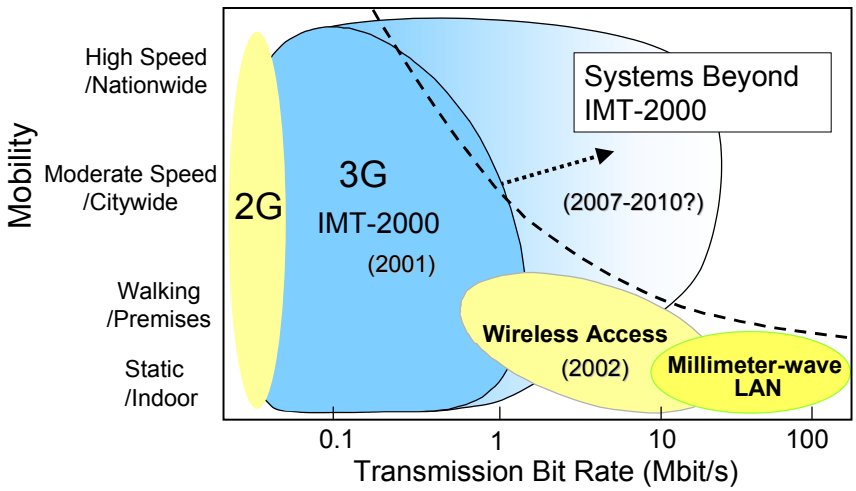
concepts

Technologies

Beyond 3G – Ultraconnectivity (Multi-networks)



Beyond 3G – Pushing the Envelope



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- 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

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