



# Third Generation (3G) Wireless: Where is it Going?

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# The Creation of IMT-2000

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- ❖ A decision was made at WARC-92 to identify a global spectrum in a common frequency band around 2000 MHz
- ❖ Spectrum would have both terrestrial and satellite components
- ❖ Originally known as FPLMTS (Future Public Land Mobile Telecommunications Systems)

*Source: ITU Website, <http://www.itu.int/itu/news/199505/radio.htm>*



# Key Features of IMT-2000

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- ❖ Emphasizing worldwide commonality in design
- ❖ Compatibility of services within fixed networks and within IMT-2000
- ❖ High quality
- ❖ Use of small pocket-terminal worldwide

*Source: Working Document of Security Principles for FPLMTS, 1994*



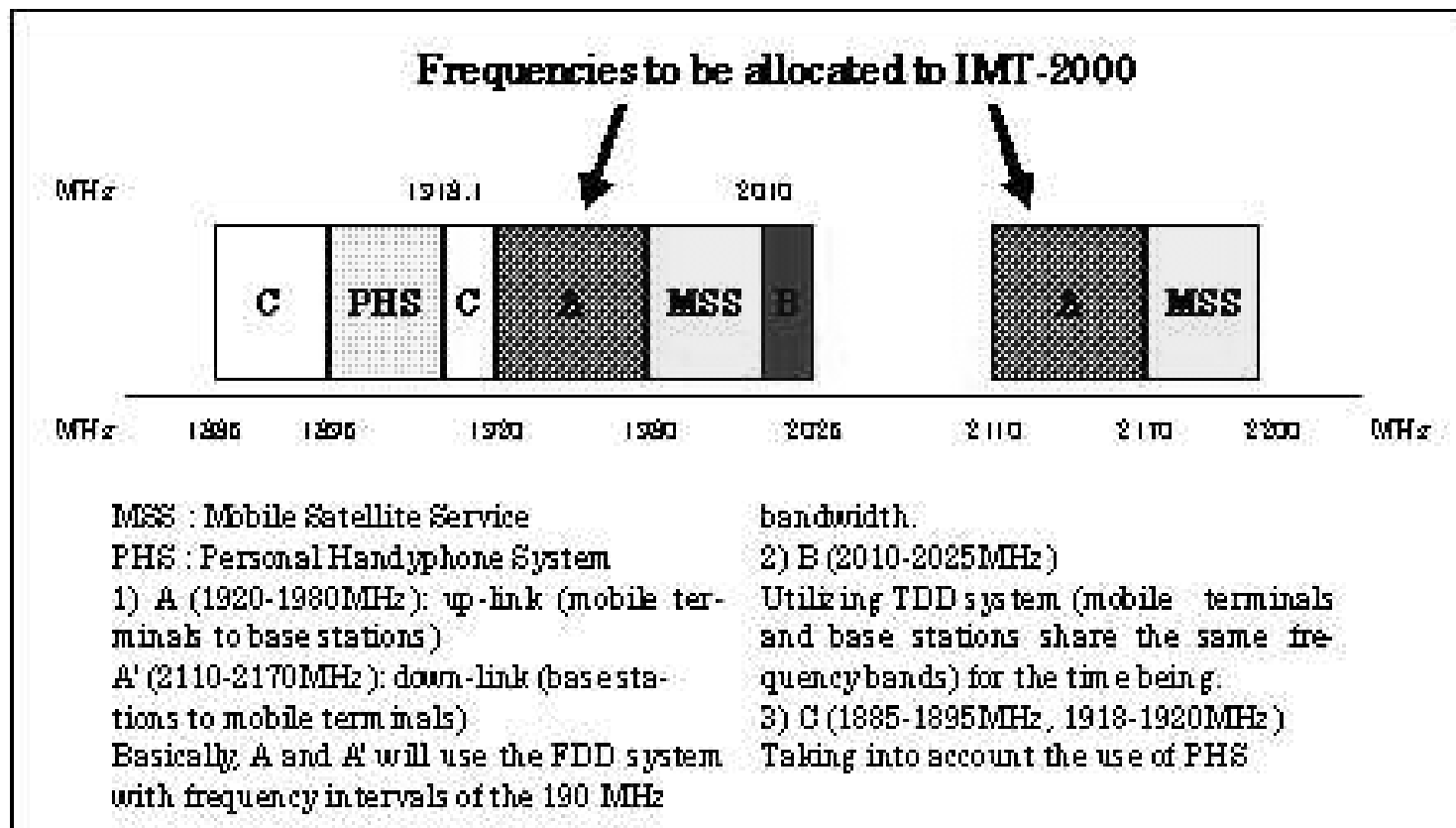
# The Evolution of the Standard

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- ❖ Originally, IMT-2000 was to embrace a single worldwide wireless standard.
- ❖ Unable to unite 2G systems under one 3G technology
- ❖ IMT-2000 will now be seen as a “family of standards” to ensure both current investments and global compatibility

*Source: Personal Communications Newsletter, January 12, 1998*

# IMT-2000 Frequencies



Source: <http://www.mpt.go.jp/pressrelease/english/telecomm/news8-9-3.html>



# Key Players in the Debate

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- ❖ **CDMA:** U.S. and Asia focused, fueled by Qualcomm, Lucent, and Motorola<sup>1</sup>
- ❖ **GSM:** Europe focused, fueled by Ericsson, Nokia, Nortel, Alcatel<sup>2</sup>
- ❖ **IS-136:** proposed high speed data (HSD) interface<sup>3</sup>
- ❖ As Asian subscriptions increase, CDMA could overtake GSM as most popular cellular technology<sup>4</sup>

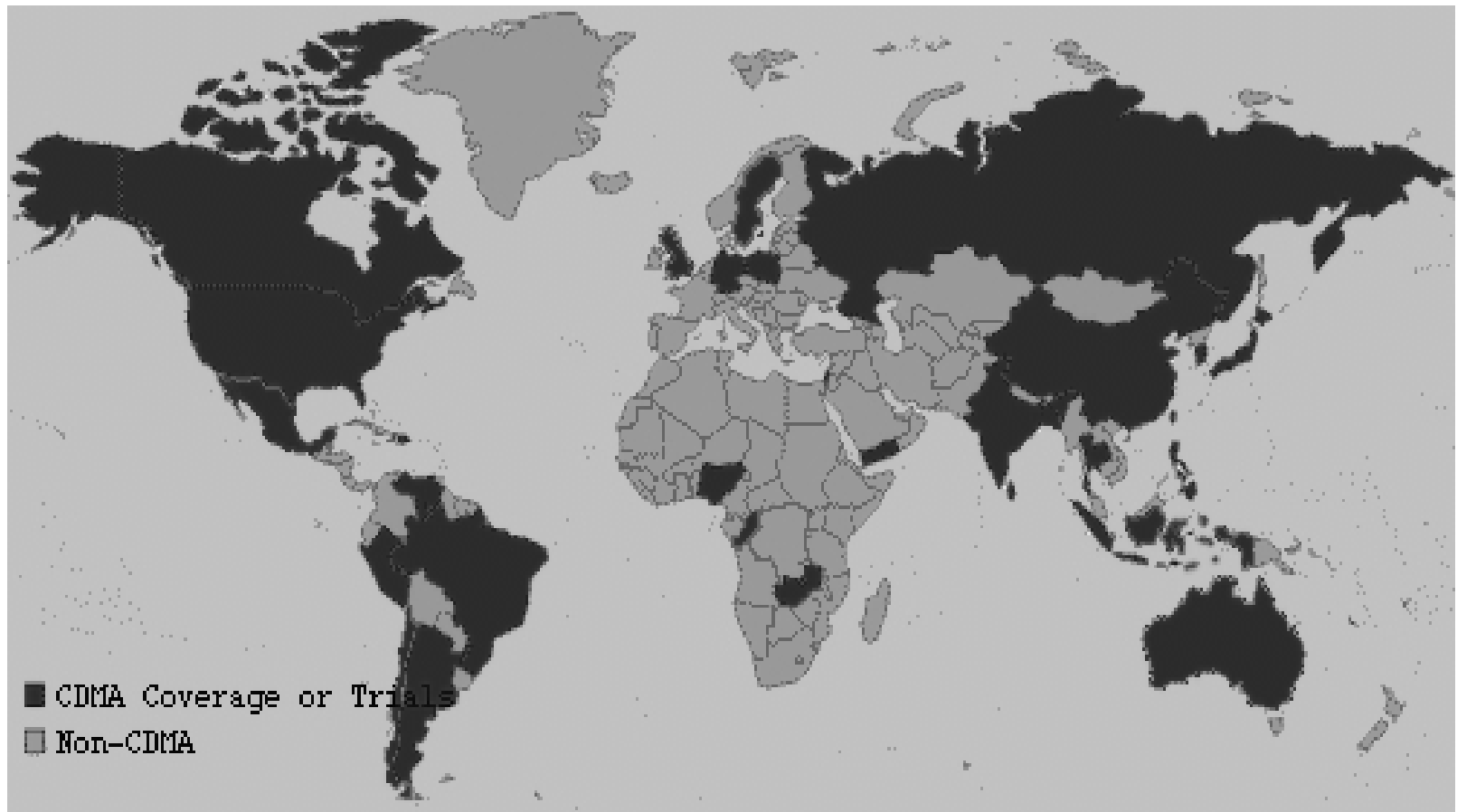
Sources: 1, AOL Website, July 16, 1998, <http://www.aol.com>

2, *Online Telecommunications Magazine*, June 1998

3, Ojanperä, "Development of 3G Radio Technologies"

4, CDG Website, June 1998, <http://www.cdg.org>

# 3G Technologies Around the World





# The Evolution of European Wireless Systems

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- ❖ Systems developed by the High Speed Data Group (HSD) of the Global TDMA Forum (GTF) within the Universal Wireless Communications Consortium (UWCC).
- ❖ The EDGE (Enhanced Data for GSM/Global Evolution) system would enhance GSM system through higher level modulations
- ❖ The Double EDGE system would provide two carrier spacings, 200 kHz and 1.6 MHz, to allow for the IS-136 air interface
- ❖ Provides less expensive equipment in a more timely fashion and so provides economies of scale

*Source: Ojanperä, T., "Development of 3G Radio Technologies," Nokia Research Center*





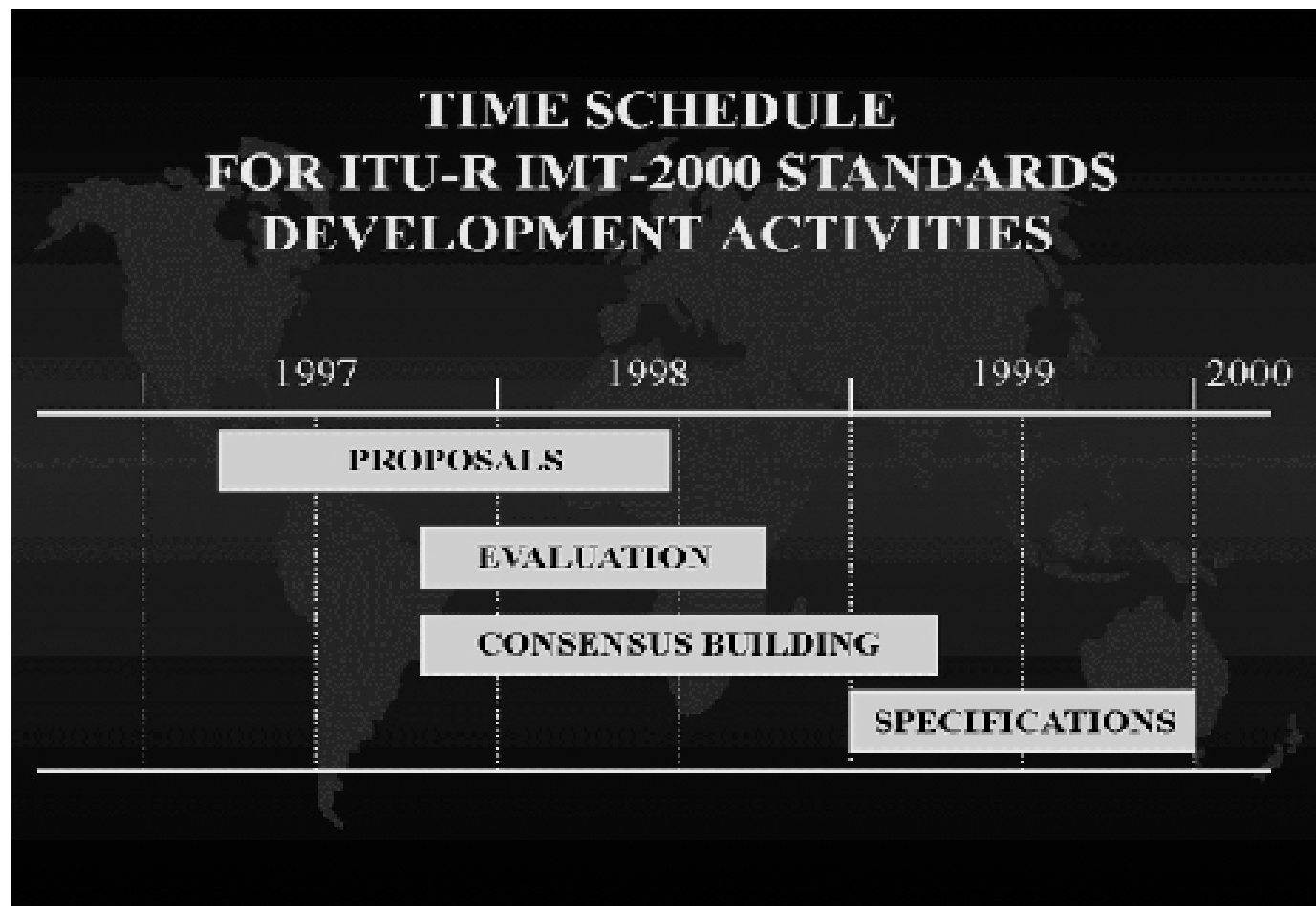
# Current Status of IMT-2000

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- ❖ 10 terrestrial and 5 satellite proposals were received at ITU--June, 1998
- ❖ Proposals will be evaluated by groups representing various countries--July 1998
- ❖ Accepted proposals will be announced--Fall, 1998

Source: *Wireless Week*, July 6, 1998

# ITU Timetable for 3G Policy





# IMT-2000 Proposals: Terrestrial (of 10 submitted)

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- ❖ **DECT, ETSI Project**  
(Digital Enhanced Cordless Communications)
- ❖ **UWC-136, USA TIA TR45.3**  
(Universal Wireless Communications)
- ❖ **WIMS/W-CDMA, USA TIA TR46.1**  
(Wireless Multimedia & Messaging Services/  
Wideband CDMA)

Source: ITU Website, <http://www.itu.int/imt/2-radio-dev/rtt/index.html>



# IMT-2000 Proposals: Terrestrial (of 10 submitted)

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- ❖ **TD-SCDMA, China ATT**  
(Time-Division Synchronous CDMA)
- ❖ **W-CDMA, Japan ARIB**  
(Wideband CDMA)
- ❖ **CDMA II, S. Korea TTA**  
(Asynchronous DS-SS-CDMA)

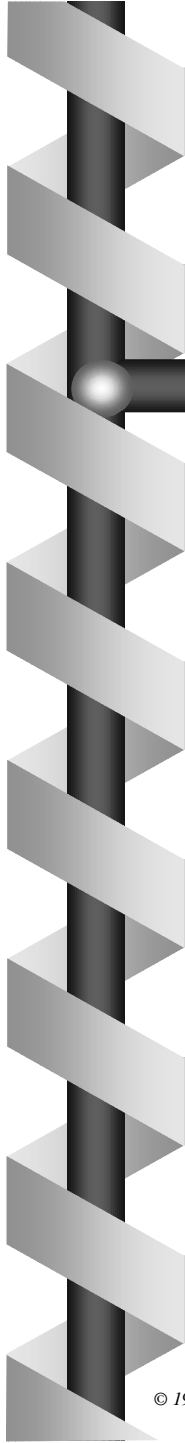
Source: ITU Website, <http://www.itu.int/imt/2-radio-dev/rtt/index.html>



# IMT-2000 Proposals: Terrestrial (of 10 submitted)

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- ❖ **UTRA: W-CDMA, ETSI SMG2**  
(UMTS Terrestrial Radio Access: Wideband CDMA)
- ❖ **NA: W-CDMA, USA T1P1-ATIS**  
(North American: Wideband CDMA)
- ❖ **cdma2000, USA TIA TR45.5**  
(Wideband CDMA: IS-95)
- ❖ **CDMA I, S. Korea TTA**  
(Multiband Synchronous DS-CDMA)

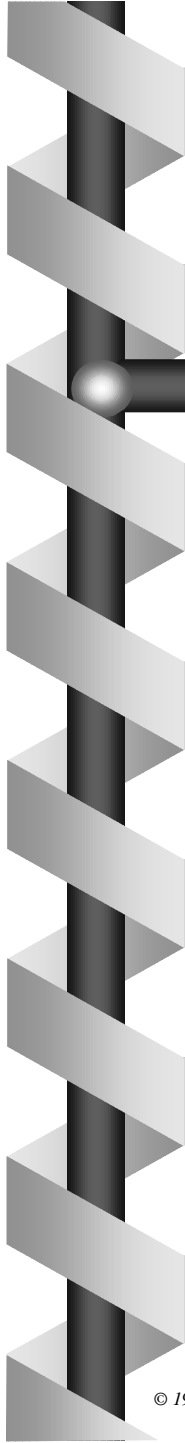


# IMT-2000 Proposals: Satellite (of 5 submitted)

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- ❖ **SAT-CDMA, S. Korea Telecommunication Technologies Association (TTA)**  
(49 LEO sats in 7 planes at 2000 km)
- ❖ **SW-CDMA, European Space Administration (ESA)**  
(Satellite Wideband CDMA)
- ❖ **SW-CTDMA, ESA**  
(Satellite Wideband hybrid CDMA/TDMA)

Source: ITU Website, <http://www.itu.int/imt/2-radio-dev/rtt/index.html>



# IMT-2000 Proposals: Satellite (of 5 submitted)

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- ❖ **ICO RTT, ICO Global Communications (Inmarsat affiliate based in UK)**  
(10 MEO sats in 2 planes at 10390 km)
- ❖ **Horizons, Inmarsat (International Marine Satellites)**  
(Horizons satellite system)

*Source: ITU Website, <http://www.itu.int/imt/2-radio-dev/rtt/index.html>*



# DECT (Digital Enhanced Cordless Communications)

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- ❖ **Authored by the European Telecommunications Standards Institute**
- ❖ **Interworking to connectionless networks:** Ethernet, Token Ring LANs, TCP/IP, MANs
- ❖ **Generic data link service**
- ❖ **Multimedia messaging service**
- ❖ **Channel setup:** < 50 ms
- ❖ **Error rates better than  $10^{-9}$**
- ❖ **Throughput rate of up to 552 kbit/s**  
(2-level modulation, higher with 4- and 8-level)





# UWC-136 (Universal Wireless Communications)

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- ❖ **Authored by the Universal Wireless Communications Consortium)**
- ❖ **Spectrum efficiency:**  
at least 0.45 Mbits/s/Mhz/cell
- ❖ **Fits into existing IS-136 RF frequency plan**
- ❖ **Microcell and macrocell performance comparable:**  
pedestrian (3 km/h): up to 384 kbit/s  
low speed vehicular (<100 km/h): up to 384 kbit/s  
high speed vehicular (100-500 km/h): up to 144 kbit/s

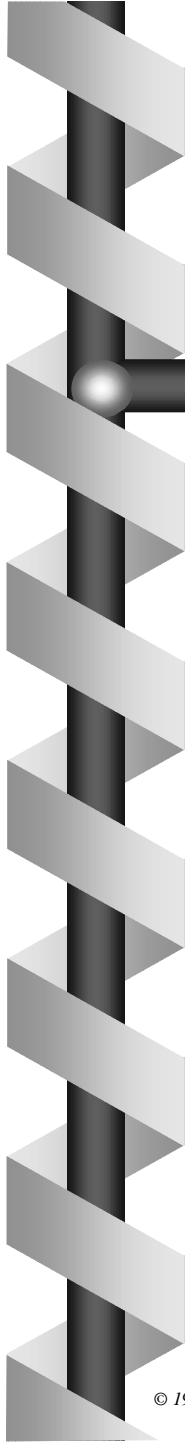
Source: <http://www.itu.int/imt/2-radio-dev/rtt/usa/tia/uwc-136.pdf>



# **WIMS/W-CDMA** (Wireless Multimedia and Messaging Services/Wideband CDMA)

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- ❖ **Principal author: Golden Bridge Technology**
- ❖ **Data rates** of 8 kbps, 16 kbps, 32 kbps, 64 kbps, 144 kbps, 384 kbps, T1/E1
- ❖ **Multimedia operating system**
- ❖ **Exploits software radio technology** providing backward compatibility
- ❖ **Usable in all environments:** WLL, indoor, pedestrian, vehicular
- ❖ **Duplex method: FDD**
- ❖ **Multiple access method: DS-CDMA**



# TD-SCDMA (Time-Division Synchronous CDMA)

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- ❖ **Authored by China's Academy of Telecommunications Technology**
- ❖ **Utilizes new technologies:** synchronous CDMA, smart antennas, software radio
- ❖ **Similar to IS-95 system**
- ❖ **Each RF channel equals:**  
8 TDMA time slots=16 CDMA code channels
- ❖ **Code channel identification:**  
by specific Walsh code XOR a common pseudo random (PN) spreading code

Source: <http://www.itu.int/imt/2-radio-dev/rtt/chn>

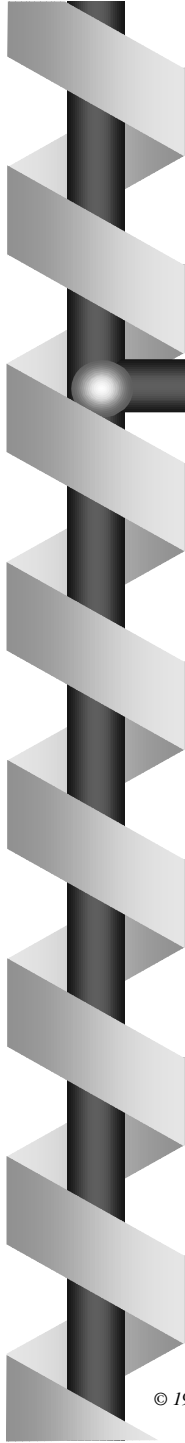


# W-CDMA (Wideband CDMA)

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- ❖ **Authored by Japan's Association of Radio Industries and Businesses (ARIB)**

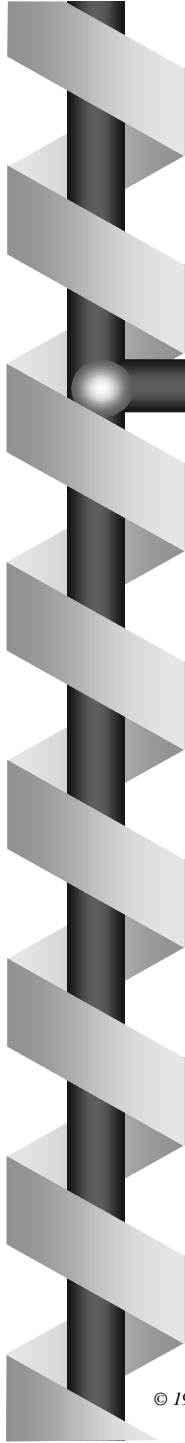
*Source: ITU Website, <http://www.itu.int/imt/2-radio-dev/rtt/index.html>*



# CDMA II (Asynchronous DS-CDMA)

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- ❖ **Authored by S. Korea's Telecommunication Technologies Association**
- ❖ **Adopted inter-cell asynchronous mode**
- ❖ **Multi-bandwidth spreading technique** supports multimedia services
- ❖ **High-data-rate capabilities provided** by wide-band spreading and multi-code schemes
- ❖ **Multiple access method: DS-CDMA**
- ❖ **Duplexing method: FDD**
- ❖ **Chip rate:** 1.024/4.096/8.192/16.384 Mcps



# NA: W-CDMA (North American: Wideband CDMA)

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- ❖ **Principal author: Ericsson**
- ❖ **GSM DCS-1900 variant**
- ❖ **4.096 Mcps spread spectrum overlap on GSM**
- ❖ **Duplex scheme: FDD/TDD**
- ❖ **Multiple access scheme: DS-CDMA**
- ❖ **Support for:** inter-frequency handover, future technologies (adaptive antennas, transmitter diversity), high-data-rate transmission (384 kbps with wide-area coverage, 2 Mbps with local coverage)

Source: [http://www.itu.int/imt/2-radio-dev/rtt/usa/t1p1/wcdma\\_na.pdf](http://www.itu.int/imt/2-radio-dev/rtt/usa/t1p1/wcdma_na.pdf)



# CDMA I (Multiband Synchronous DS-CDMA)

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- ❖ **Authored by S. Korea's Telecommunication Technologies Association**
- ❖ **Proposed multiband system of 0.9216/3.6864/14.7456 Mcps**
- ❖ **Base station coordination:** synchronous between stations with optional asynchronous mode
- ❖ **Discontinuous transmission possible** with pilot channel aided coherent scheme
- ❖ **Enhances power efficiency in reverse link:** BPSK data/OCQPSK (orthogonal complex QPSK) for low rate and QPSK/OCQPSK for high rate services

Source: [http://www.itu.int/imt/2-radio-dev/rtt/kor/tta1/tta\\_rtt1.pdf](http://www.itu.int/imt/2-radio-dev/rtt/kor/tta1/tta_rtt1.pdf)



# **UTRA (UMTS Terrestrial Radio Access: Wideband CDMA)**

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- ❖ **Represents ETSI Special Mobile Group's attempt to ensure backward compatibility for GSM**
- ❖ **Product of the harmonization of ARIB & UTMS**
- ❖ **Duplex method: FDD and TDD**
- ❖ **Will operate in indoor, pedestrian, vehicular, and mixed-cell environments**
- ❖ **Will most likely adopt Turbo codes for high-rate services**

*Source: <http://www.itu.int/imt/2-radio-dev/rtt/etsi/utra.pdf>*





# UTRA Key Technical Characteristics

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- ❖ **Carrier spacing:** flexible in the range 4.4-5.2 MHz (200 kHz carrier raster)
- ❖ **Chip rate:** 4.096/8.192/16.384 Mcps
- ❖ **Frame length:** 10 ms
- ❖ **Spreading modulation:** balanced QPSK (forward link), dual channel QPSK (reverse link)
- ❖ **Coherent detection:** time multiplexed pilot
- ❖ **Physical control channel:** time multiplexed (forward link), I&Q multiplexed (reverse link)



# UTRA Key Technical Characteristics

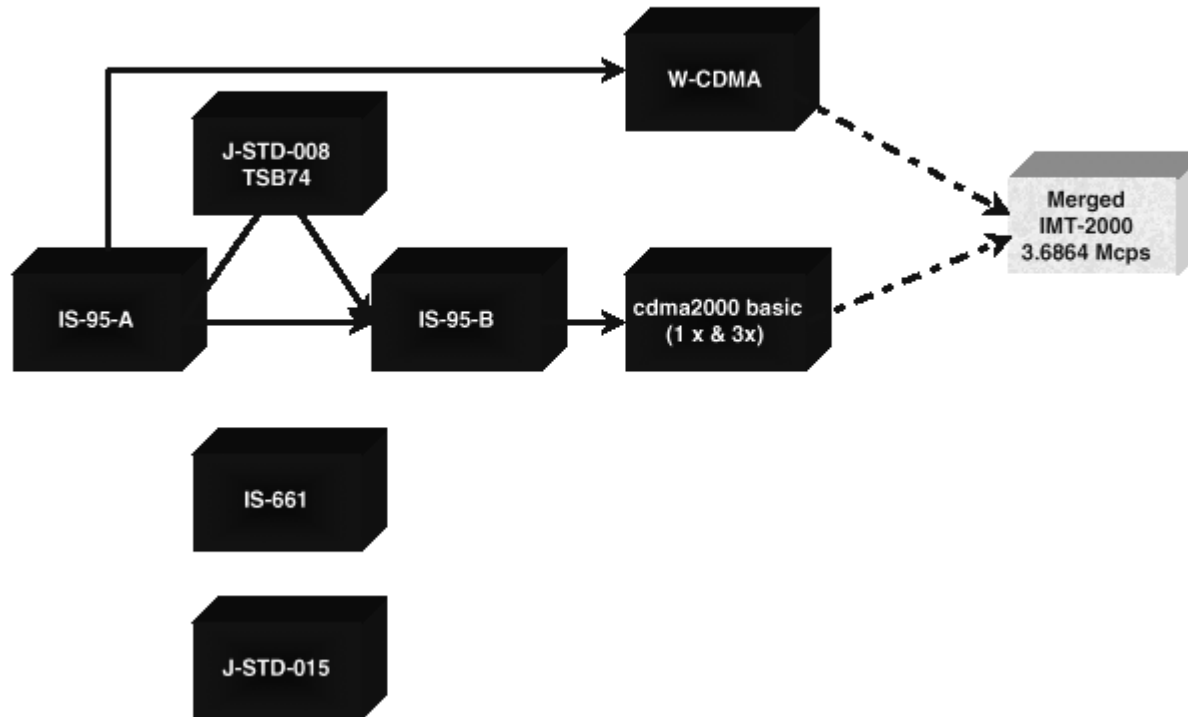
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- ❖ **Power control:** open and closed loop (1.6 kHz)
- ❖ **Multi-rate/variable-rate scheme:** variable spreading factor and multi-code
- ❖ **Channel coding scheme:** convolutional coding (rate 1/2-1/3), optional outer Reed-Solomon coding (rate 4/5)
- ❖ **Inter-base station synchronization:** FDD mode: no accurate synchronization needed, TDD mode: synchronization needed

*Source: Ojanperä, T., "Development of 3G Radio Technologies," Nokia Research Center*

# cdma2000 (Wideband CDMA: IS-95): one U.S. View of IMT-2000

## CDMA Standards



Source: Tiedemann, E., *The Evolution of CDMA*, 8th Virginia Tech Symposium on Wireless Personal Communications



# The Pros and Cons of CDMA

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## Advantages include:<sup>1</sup>

- ❖ Voice activities cycles
- ❖ No hard handoff
- ❖ No guard time in CDMA
- ❖ Less fading
- ❖ Capacity advantage
- ❖ No frequency mgmt. or assignment needed
- ❖ Soft capacity
- ❖ Coexistence

## Drawbacks include:

- ❖ Rake receiver needed in each portable receiver
- ❖ Island cells occur if time sync is off between base stations
- ❖ Not suitable for microcell and in-building systems

*Source: 1, Oregon State Univ. Website, <http://www.ece.orst.edu/~rodrigfr/cdma/tutorial.html>*



# J-STD-008 AND TSB74 Key Pioneering Characteristics

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- ❖ Multiple rates (Rate Set 1 and 2)
  - Rate Set 2: 1800, 3600, 7200, 14400 bps
- ❖ Multiple bands (cellular and PCS)
- ❖ Faster Forward link power control
  - Erasure indicator bit

*Source: Tiedemann, E., The Evolution of CDMA, 8th Virginia Tech Symposium on Wireless Personal Communications*



# IS-95-B Key Characteristics

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- ❖ **Higher rate operation**
  - Up to 76.8 kbps (Rate Set 1) and 115.2 kbps (Rate Set 2)
- ❖ **Supplemental channels**
- ❖ **Independent soft handoff of fundamental and supplemental channels**
- ❖ **Searching on another frequency for hard handoff**
- ❖ **Soft channel assignment, access handoff, and access probe handoff**
- ❖ **Enhanced soft handoff reporting based upon total  $E_c/I_0$**

*Source: Tiedemann, E., The Evolution of CDMA, 8th Virginia Tech Symposium on Wireless Personal Communications*



# cdma2000

## Key Characteristics

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- ❖ **Different RF channel bandwidths ( $N \times 1.2288$  MHz where  $N = 1, 3, 5, 9, 12$ )**
  - 1.2288, 3.6864, 7.3728, 11.0592, and 14.7456 Mcps
- ❖ **Multi- carrier operation for overlays of existing systems**
- ❖ **Fast forward link power control**
- ❖ **Forward link transmit diversity**
- ❖ **Turbo coding**
- ❖ **Auxiliary pilots**

*Source: Tiedemann, E., The Evolution of CDMA, 8th Virginia Tech Symposium on Wireless Personal Communications*



# cdma2000

## Key Characteristics

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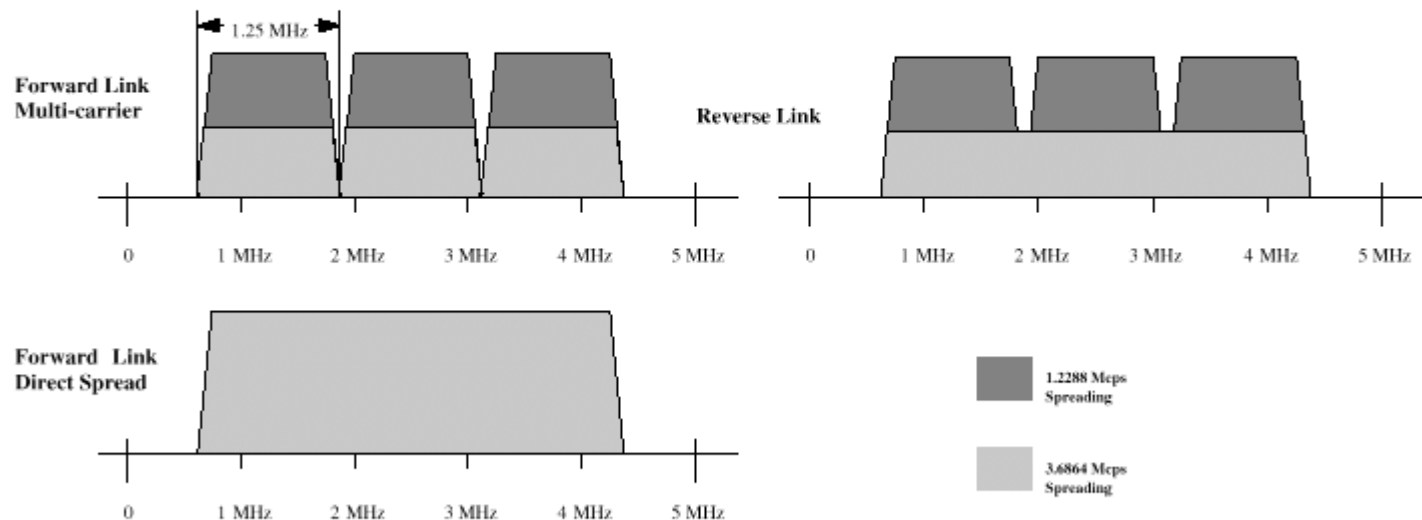
- ❖ **Coherent reverse link**
  - BPSK- like modulation
  - Continuous transmission
  - Peak to average reduction
- ❖ **Enhanced channel structure**
- ❖ **Mixed frame lengths**
- ❖ **Advanced Medium Access Control (MAC)**
  - Supports efficient packet operation
  - Supports different quality of service (QoS)

*Source: Tiedemann, E., The Evolution of CDMA, 8th Virginia Tech Symposium on Wireless Personal Communications*

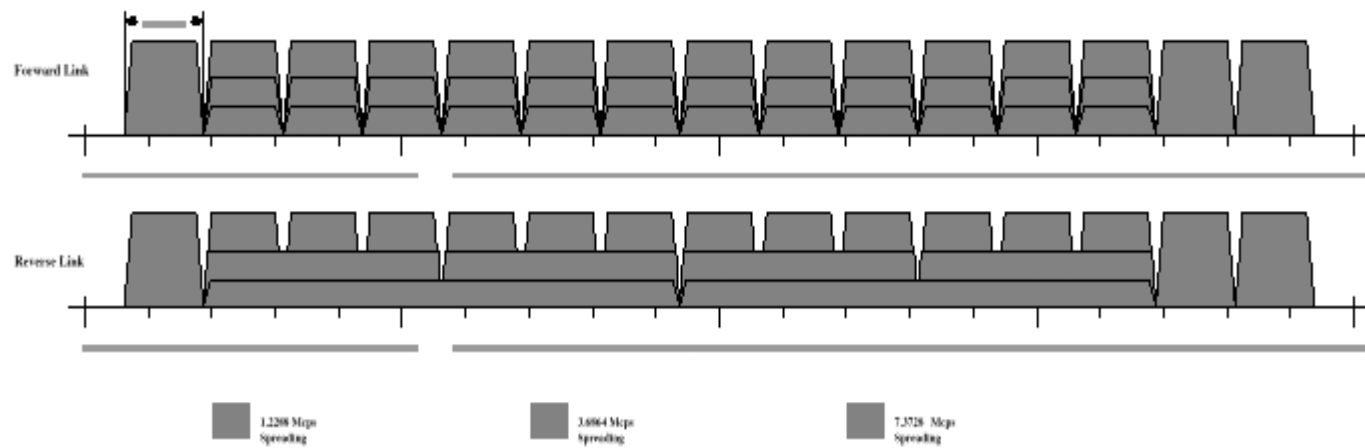


# Forward Link Spreading

- **Multi-Carrier (MC):** demultiplexes modulation symbols into N separate 1.25 MHz carriers resulting in a chip rate of 1.2288 Mcps per carrier
- **Direct Spread (DS):** spreads the modulation symbols to N x 1.2288 Mcps resulting in one N X 1.25 MHz carrier



# Example Multi-Carrier Deployment in 20MHz

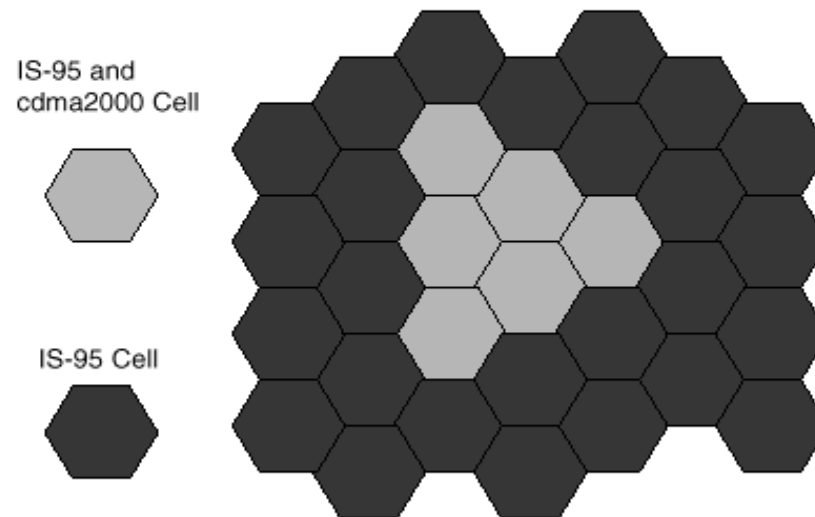


Notes: Can also support five 3.6864 Mcps carriers in 20 MHz

Source: Tiedemann, E., *The Evolution of CDMA*, 8th Virginia Tech Symposium on Wireless Personal Communications

# cdma2000 Deployments

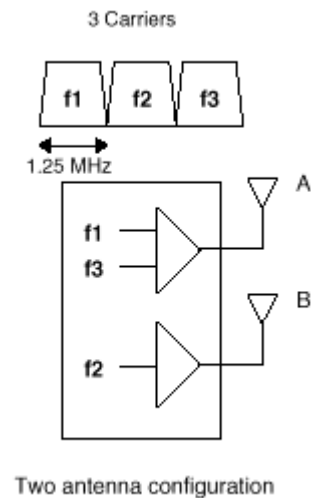
Mix cdma2000 cells (either 1.2288 or 3.6864 Mcps) with existing IS-95 cells to provide higher capacity, higher rates, and new services



Source: Tiedemann, E., *The Evolution of CDMA*, 8th Virginia Tech Symposium on Wireless Personal Communications

# Forward Link Transmit Diversity

- ❖ Multi-carrier (MCTD)
  - Different carriers are radiated by different antennas
- ❖ Orthogonal transmit diversity (OTD)
  - Split forward link channel into two streams that are transmitted over each antenna
  - Orthogonal forward link permits signals to be orthogonal between antennas
- ❖ Time-switched transmit diversity (TSTD)
  - Quickly switch transmissions on a forward channel between antennas
  - Orthogonal forward link permits signals to be orthogonal between antennas





# Third Generation Questions

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## ❖ **Markets**

--Is there a market?

--If so, what market?

--Is this a technology push or a market pull?

## ❖ **Technology**

--What performance gains do we really get over IS-95 or GSM, particularly for voice?

## ❖ **Standards**

--Are we going to have one or two CDMA systems, or can W-CDMA (now UTRA) and cdma2000 converge?



# Acknowledgements

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