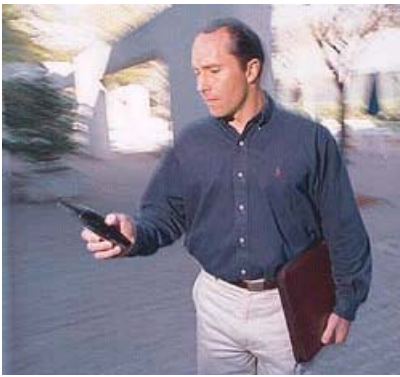# The Future of Mobile Wireless Internet Access

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# Web Phones: The Next Big Thing?



**Neopoint 1000**
About $300, 6 ounces, versatile and slim, connects to a PC and has speech recognition.

**PDQ Smart Phone**
Perhaps from $1000, about 10 ounces, from Qualcomm, combines a phone with a Palm Pilot.

**Thin Phone**
Probably about $200, 4.2 ounces, also from Qualcomm but has a smaller screen.

**Ericsson R380**
Heading for the European market, 5 ounces

**Motorola i1000 Plus**
About $250, 5 ounces, has a phone and pager and handles e-mail.

The new Ericsson R380 phone, which features wireless data functions
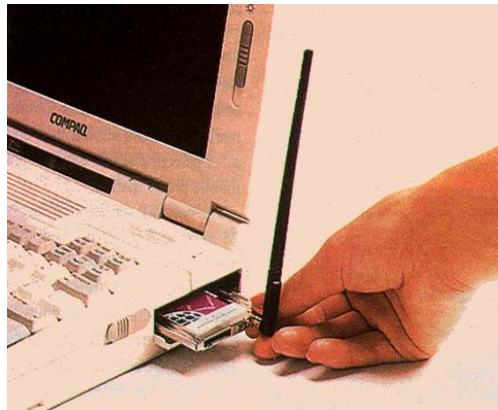
**New York Times, April 15, 1999. Web Phones: The Next Big Thing?**

# AT&T Wireless Services TDMA & Internet Packet Data CDPD Service

The Mitsubishi phone operates as a quad mode TDMA phone for voice services and provides access to Internet and data services over the CDPD network, a packet-based wireless IP network.

# Wireless Data Terminal Evolution

Sierra PCMCIA
CDPD Modem

Nokia 9110

3COM
Palm VII

Nokia
3G vision

# AT&T Wireless Services

AT&T serves over 12 million subscribers with advanced digital TDMA technology and some analog technology, and provides packet data service with CDPD technology

- TDMA
    - European GSM                over 200 million
    - North American TDMA          ~ 40 million
    - Japanese PDC                 ~ 50 million
- CDMA
    - North American CDMA          ~ 50 million

GSM MOU and UWCC TDMA industry groups announced cooperation on January 13, 2000 for common technology development, including EDGE for 3G high-speed data services

# Wireless Standards

| Wireless Technology | GSM/GPRS/EDGE | IS-136 TDMA | IS-95 CDMA | WCDMA |
|---|---|---|---|---|
| Channel Bandwidth | 200 KHz | 30 KHz | 1.25 MHz | 5 MHz |
| Voice bearers 6 to 12 kbps | 8 / 16 | 3 / 6 | 6 to 20 | Up to 100 |
| Peak data rates (kbps) | 9.6 / 144 / 384 | 9.6 | 14.4 to 144 | Up to 384 |
| Frame length (msec) | 20 | 20 | 20 | 10 |
| Frequency reuse | 4 / 12 to 1 / 3 | 7 / 21 to 3 / 9 | 1 | 1 |
| Voice bearers Per MHz / base | 10 to 30 / 20 to 60 | 14 to 33 | 14 to 48 | Up to 60 |
| Micro/Hierarchical cell support | Good | Good | Poor | Fair to Poor |
| Number of subs as of 4Q99 | ~ 200 million | ~ 50 million | ~ 50 million | N.A. |

# Wireless Data Technology

- Dedicated wireless packet data systems
  - Ardis
  - RAM Mobitex
- Wireless data access using cellular systems
  - Early systems - circuit access, CDPD & I-mode
  - GPRS - packet data on GSM
  - Packet data on IS-95 CDMA
- 3rd generation systems
  - EDGE (Enhanced Data rates for GSM Evolution)
  - Packet data on WCDMA
  - HDR (High Data Rates for CDMA2000 - IS-95)
- WAP (Wireless Application Part)
- Bluetooth - connecting nearby devices

# Macrocellular Wireless Data Evolution
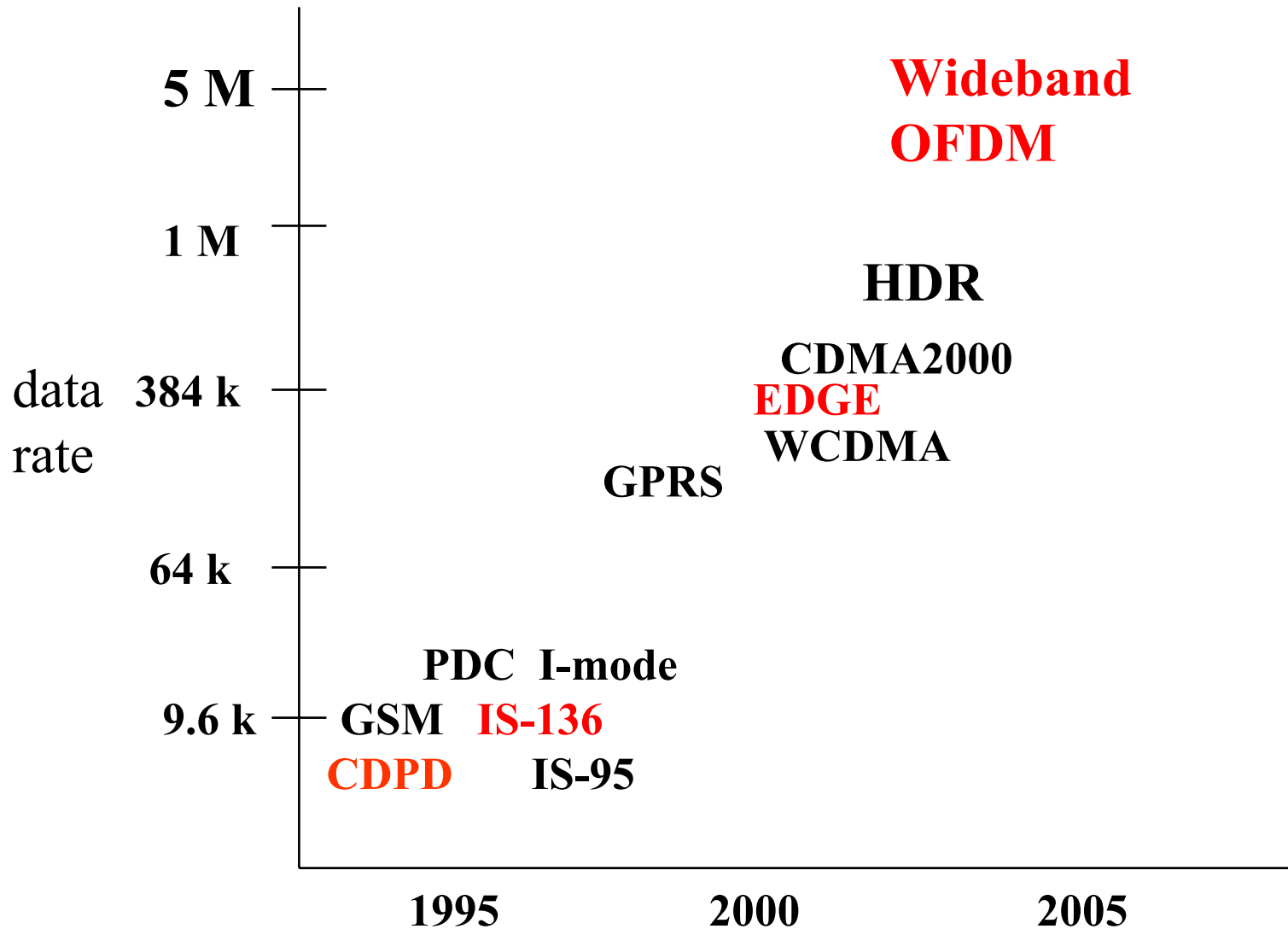
# Dedicated Wireless Packet Data Systems
## -  used for e-mail & short messages

## ARDIS

- Created by IBM & Motorola in 80's
- 25 KHz channels
- FM modulation
- 4800 bps (2-level)
- 19.2 kbps (4-level)
- National US network operated by American Mobile

## RAM

- Created by Ericsson in 80's
- 12.5 KHz channels
- GMSK modulation
- 8 kbps
- National US network operated by BellSouth

# Early Data Services on Cellular Systems

- **Voice-band modems over analog cellular**
  - **end-to-end**
  - **with a cellular inter-working function**
- **9.6 kbps circuit & FAX access over GSM, IS-136, PDC & IS-95 using a single time-slot or code and an interworking functions to standard modems**
- **CDPD - Cellular Digital Packet Data**
- **I-Mode - 9.6 kbps packet data over PDC - Japanese Personal Digital Communications (cellular)**

# CDPD - Cellular Digital Packet Data

- Proposed by IBM in 1991
- 30 KHz channels (compatible with AMPS)
- Shared base stations with cellular & an overlay network
- GMSK modulation at 19.2 kbps
- Supports TCP/IP connectivity
- Multi-mode CDPD/AMPS & CDPD/TDMA handsets & PCMCIA cards
- Service provided by AT&T, Bell Atlantic & others

# I-Mode Packet Data Service

- NTT DoCoMo introduced packet data using PDC time-slots in 1997 with 9.6 kbps peak rates
- NTT DoCoMo introduced I-Mode service in early 1999
- Dual-mode PDC voice and packet data handsets
- Micro-browser and IP based
- 1000's of content providers
  - weather
  - stocks
  - sports
  - horoscopes
  - short message service,….
- Over 5 million subscribers in 1st year of service

# GSM Evolution

- Circuit data - 9.6 kbps
- HSCD - 32 kbps circuit data
- GPRS - 144 kbps packet data
- 1/3 & 1/1 reuse frequency hopping
- EDGE - peak data rates of 384 kbps
- VoIP over EDGE

# GPRS Airlink

- **General Packet Radio Service (GPRS)**
- **Same GMSK modulation as GSM**
- **4 channel coding modes**
- **Packet-mode**
- **Flexible time slot allocation (1-8)**
- **Radio resources shared dynamically between speech and data services**
- **Independent uplink and downlink resource allocation (Uplink State Flag polls uplink)**

# EDGE

- **Extends GPRS packet data with adaptive modulation/coding**

- **8-PSK/GMSK at 271 ksps in 200 KHz RF channels supports 9.02 to 69.2 kbps per time slot**

- **Supports peak rates over 384 kbps**

- **Requires linear amplifiers with < 3 dB peak to average power ratio using linearized GMSK pulses**

- **Initial deployment with 2x 1 MHz using 1/3 reuse with EDGE Compact as a complementary data service**

# Adaptive Modulation & Link Performance of EDGE
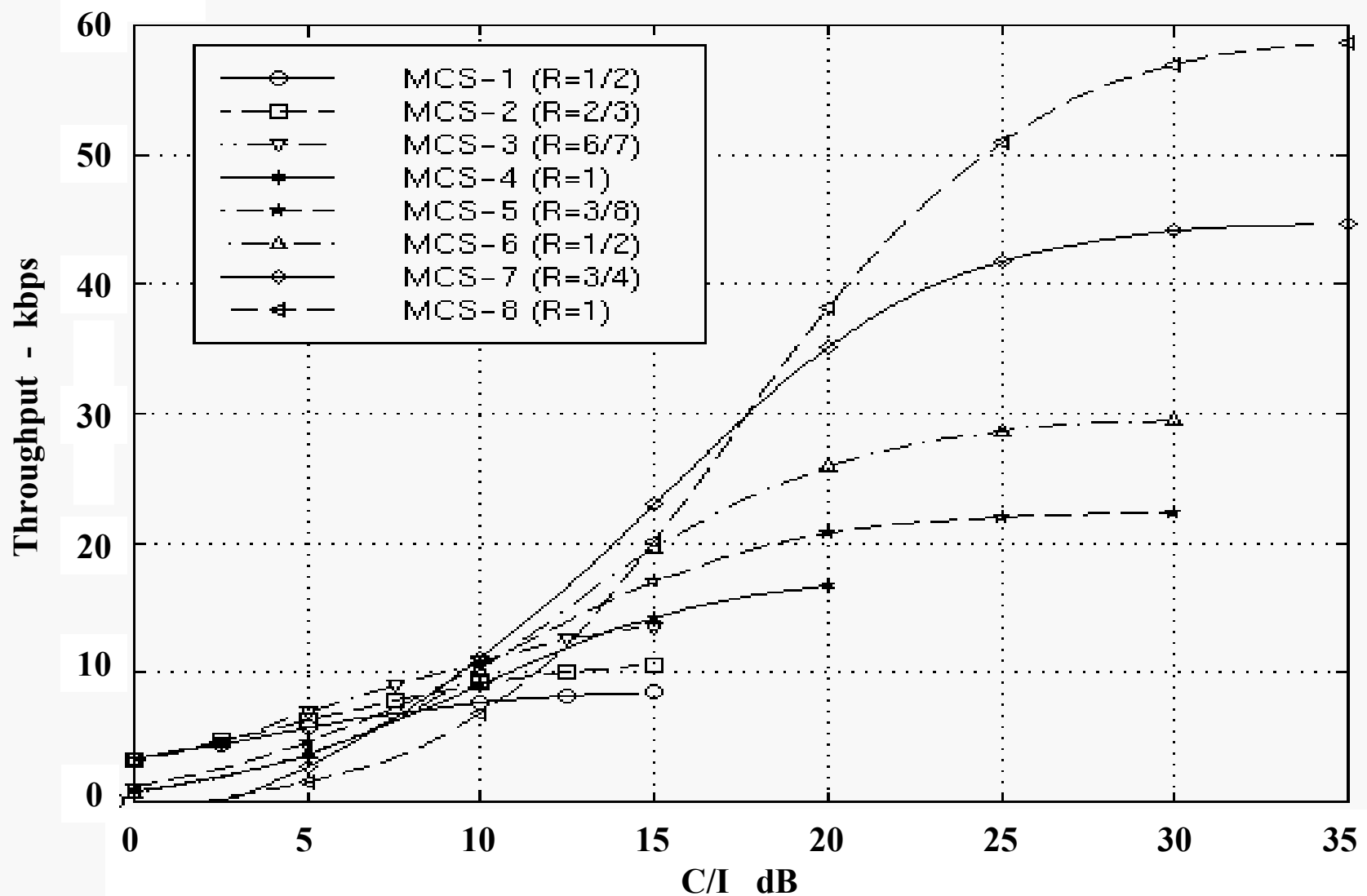
# EDGE Development

- **R'1999 supports best effort packet data**
  - **trials in 2001**
  - **commercialization in 2002**
- **R'2000 supports Voice over IP over EDGE**
  - **commercialization in 2003**
- **Key features**
  - **IP centric**
  - **dual-mode IS-136 & EDGE terminals**
  - **launching R'99 with EDGE Compact in 1 MHz x2 of spectrum**
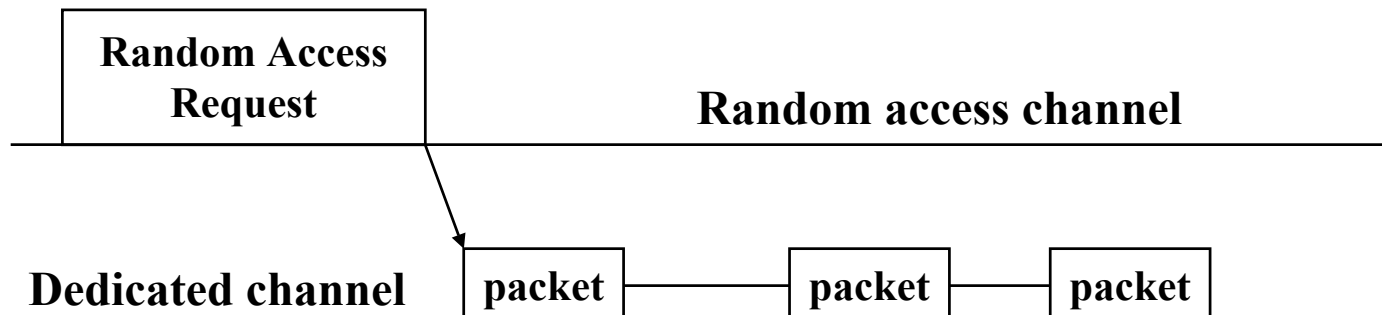  - **launching R'2000 with ~ 2 MHz x2 of spectrum**

# WCDMA Packet Access

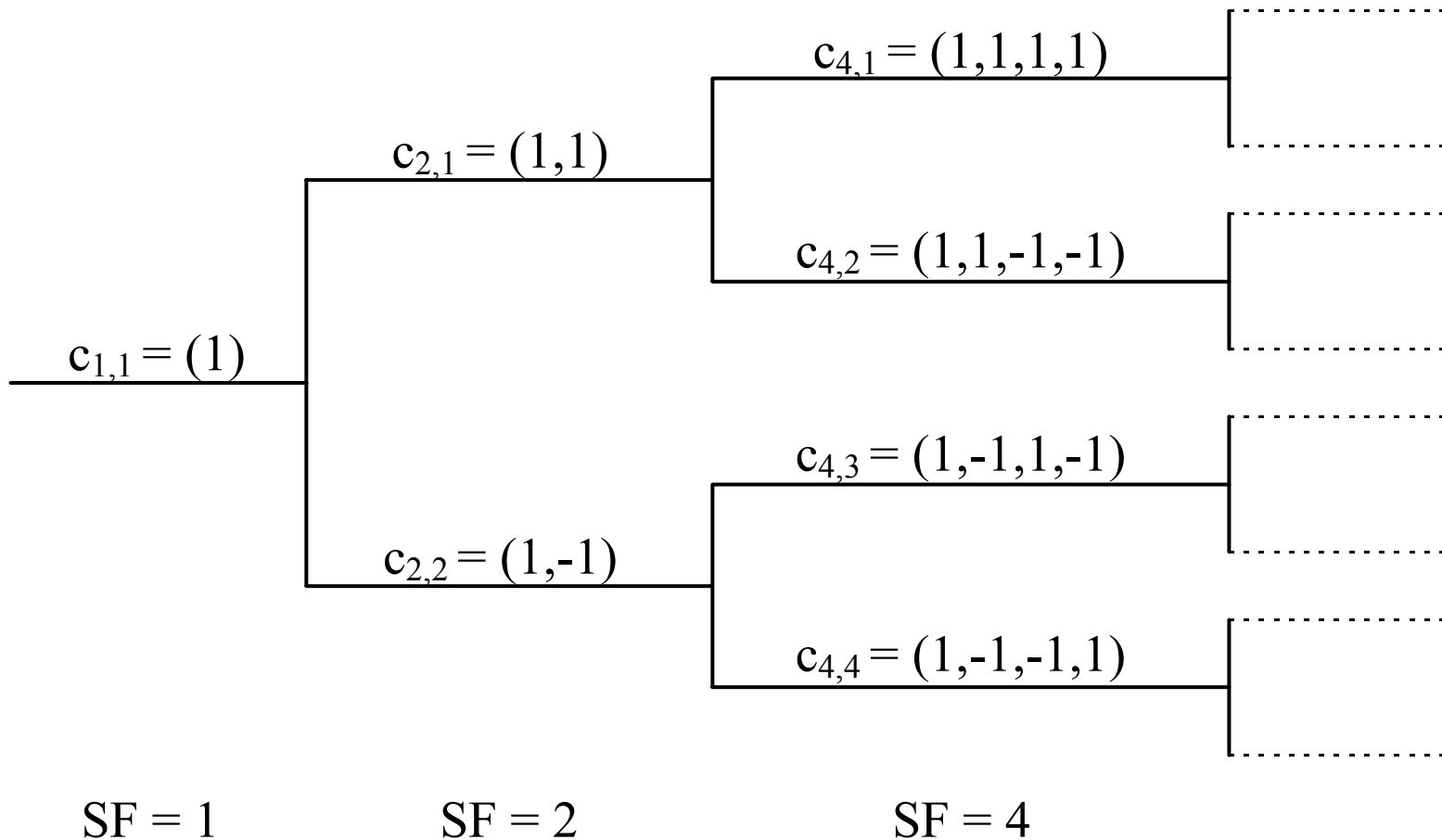**Dual mode scheme with adaptive mode selection based on packet-traffic characteristics**

**Small infrequent packets appended to random access request**

| Random Access Request | Small packet | Random access channel |
|---|---|---|
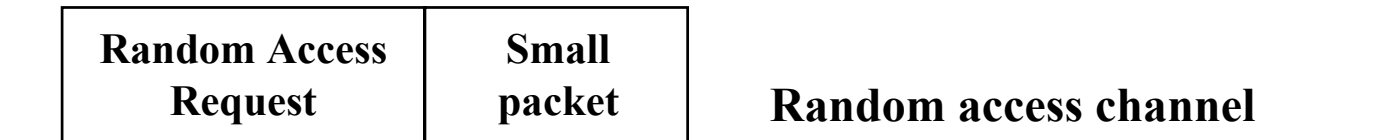
**Large or frequent packets transmitted on dedicated channel to maintain closed loop power control and assign dedicated code**

| Random Access Request | Random access channel |
|---|---|

**Dedicated channel** | packet | packet | packet |

# Orthogonal Variable Spreading Factor (OVSF) codes.

$c_{4,1} = (1,1,1,1)$

$c_{2,1} = (1,1)$

$c_{4,2} = (1,1,-1,-1)$

$c_{1,1} = (1)$

$c_{4,3} = (1,-1,1,-1)$

$c_{2,2} = (1,-1)$

$c_{4,4} = (1,-1,-1,1)$

SF = 1             SF = 2             SF = 4

# CDMA2000 Wireless Data

- 1.25 MHz carriers
- up to 384 kbps
- integrated voice & data airlink
- multicode operation

# IS-95 CDMA HDR

- Based on separate carriers for voice and data
- Asymmetrical
- 1.25 MHz channels
- 1.22 MHz chip rates
- No soft-handoff
- No power control on downlink
- uplink power control, similar to CDMA2000 & max of about 150 kbps
- synchronized base stations
- modulation/coding/spreading adaptation
- reuse of 1

# IS-95 CDMA HDR (cont'd)

- **32 kbps to 2.4 Mbps rates**
- **Typical peak rates of 250 to 500 kbps**
- **Spectral efficiency of 400 to 600 kbps/base/MHz**
- **Uplink request downlink mode 600 times per second**
- **2-branch RX proposed for terminal**
- **TDMA with intelligent scheduling on downlink**
- **IP networking to the base station**
- **IP based mobility management**
- **voice or packet data access (not simultaneous - possible in the future with multi-carrier CDMA terminals)**

# 4G Wireless

- IP packet data centric
- A "wireless cable modem"
  - Asymmetric access
  - WOFDM downlinks (peak rates of 5 to 10 Mbps)
  - 3G (EDGE) uplinks
- High-speed service to advanced handsets, laptops, PDAs, body-computers with heads-up displays, dash-board computers,….
- Complements 2G/3G Wireless
- Targets spectrum from 500 MHz to 3 GHz
- Flexible bandwidth - 200 KHz to 5 MHz
- Full macro-cell coverage
- Very high spectrum efficiency for downlink & uplink

# OFDM/Multi-carrier Applications

- **Military HF modems**
- **Voice-band modems**
- **Digital Broadcasting**
- **ADSL**
- **WLANs (IEEE 802.11 & HiperLAN II)**
- **WDM fiber optics**
- **Cable modems**

# OFDM Characteristics

- High peak-to-average power levels
- Preservation of orthogonality in severe multi-path
- Efficient FFT based receiver structures
- Enables efficient TX and RX diversity
- Adaptive antenna arrays without joint equalization
- Support for adaptive modulation by subcarrier
- Frequency diversity
- Robust against narrow-band interference
- Efficient for simulcasting
- Variable/dynamic bandwidth
- Used for highest speed applications
- Supports dynamic packet access

# Smart Antennas

Switched Multibeam Antenna
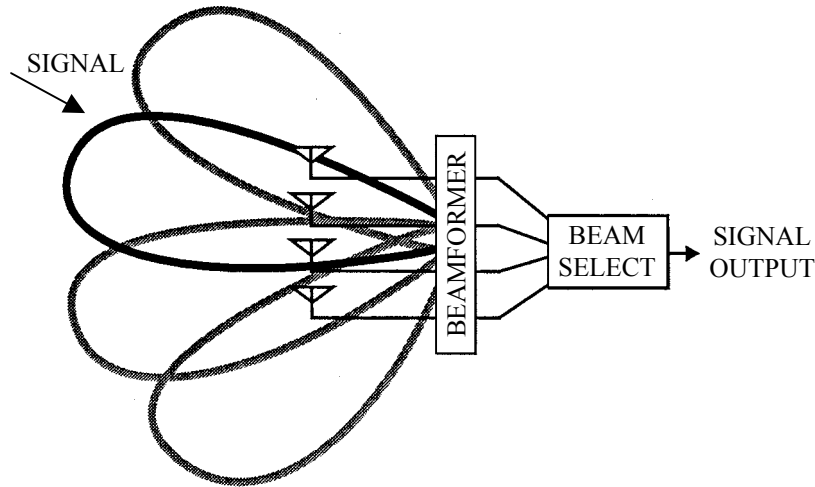
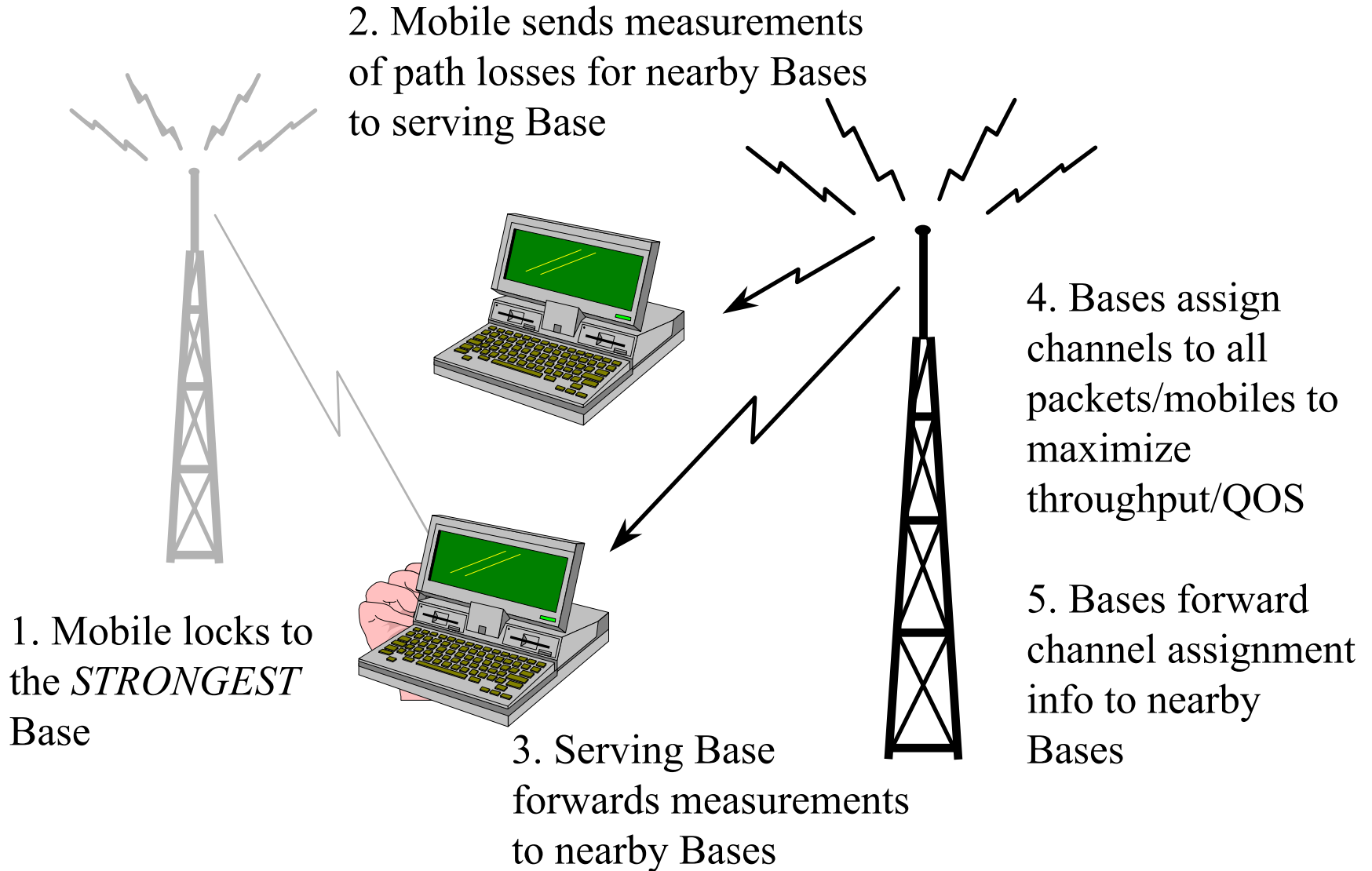Adaptive Antenna Array
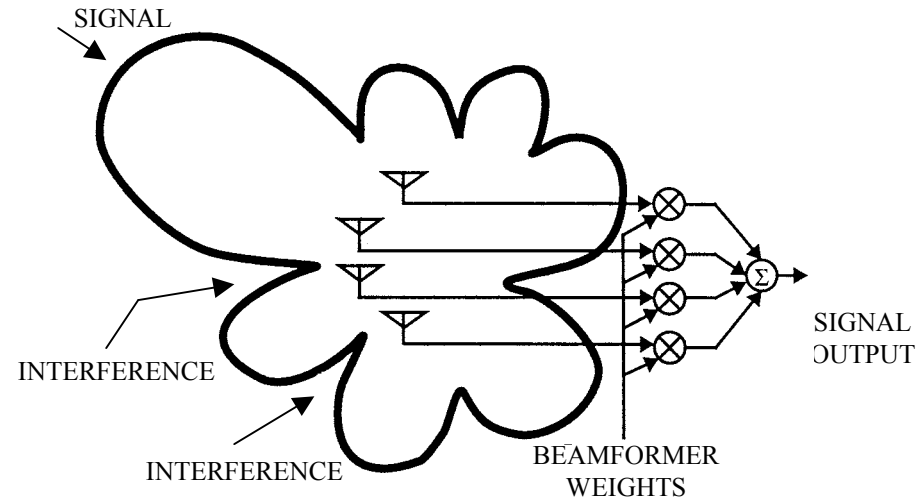


Smart Antennas significantly improve wireless system performance

• Interference suppression ⇒ Quality and capacity improvement  (2x capacity is practical)

• Multipath diversity ⇒ Improve reliability

• Higher antenna gain ⇒ Range extension and lower cost (50 to 100% greater coverage possible)

# Network Based Dynamic Packet Assignment



2. Mobile sends measurements of path losses for nearby Bases to serving Base

4. Bases assign channels to all packets/mobiles to maximize throughput/QOS

1. Mobile locks to the *STRONGEST* Base

5. Bases forward channel assignment info to nearby Bases

3. Serving Base forwards measurements to nearby Bases

# Wireless Application Protocol (WAP)

- **Mobile computing architecture supporting virtually all wireless network technologies**

- **Provides an inter-working function between a wireless client and a fixed server to mitigate low bandwidth and unreliable wireless access issues**

- **Uses Handheld Device Markup Language (HDML) and Wireless Markup Language (WML)**

- **Orientation to low-speed access**

# WAP Architecture
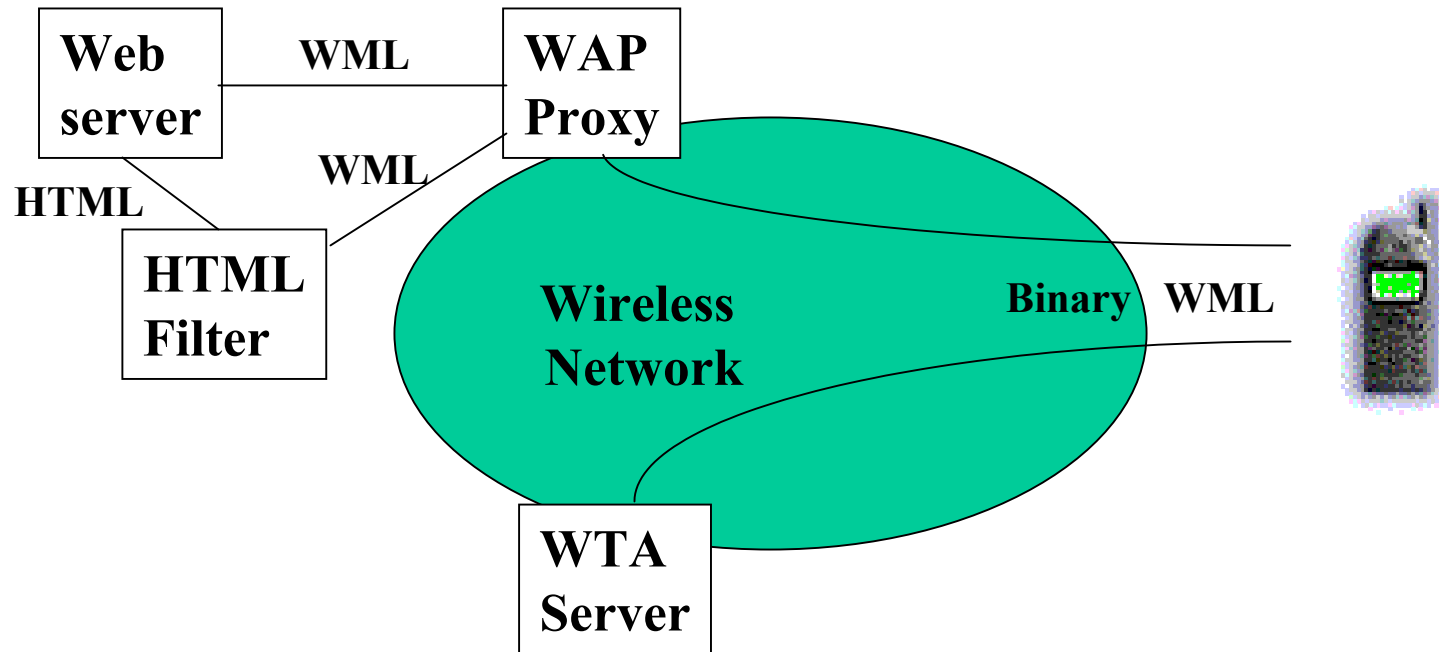


WAP - Wireless Application Protocol
WTA - Wireless Telephony Application
WML - Wireless Markup Language
HTML - HyperText Markup Language

# Bluetooth

### (named after Harold Bluetooth, Danish King)

- **Goal is low-cost & short range radio link to connect devices locally (ex. handset & laptop)**
- **Supports simultaneous isochronous voice and asynchronous data**
- **Global specification using the 2.4 GHz ISM band**
- **Conceived by Ericsson**
- **Founders are Ericsson, IBM, Intel, Nokia, Toshiba**
- **Over 800 companies have joined as Adopters**
- **Version 1 specification 2Q99**
- **Chipsets available in 2000**

# Bluetooth Networking

Cordless

corporate

Ad Hoc

LAN

Internet

LAN

public

cellular
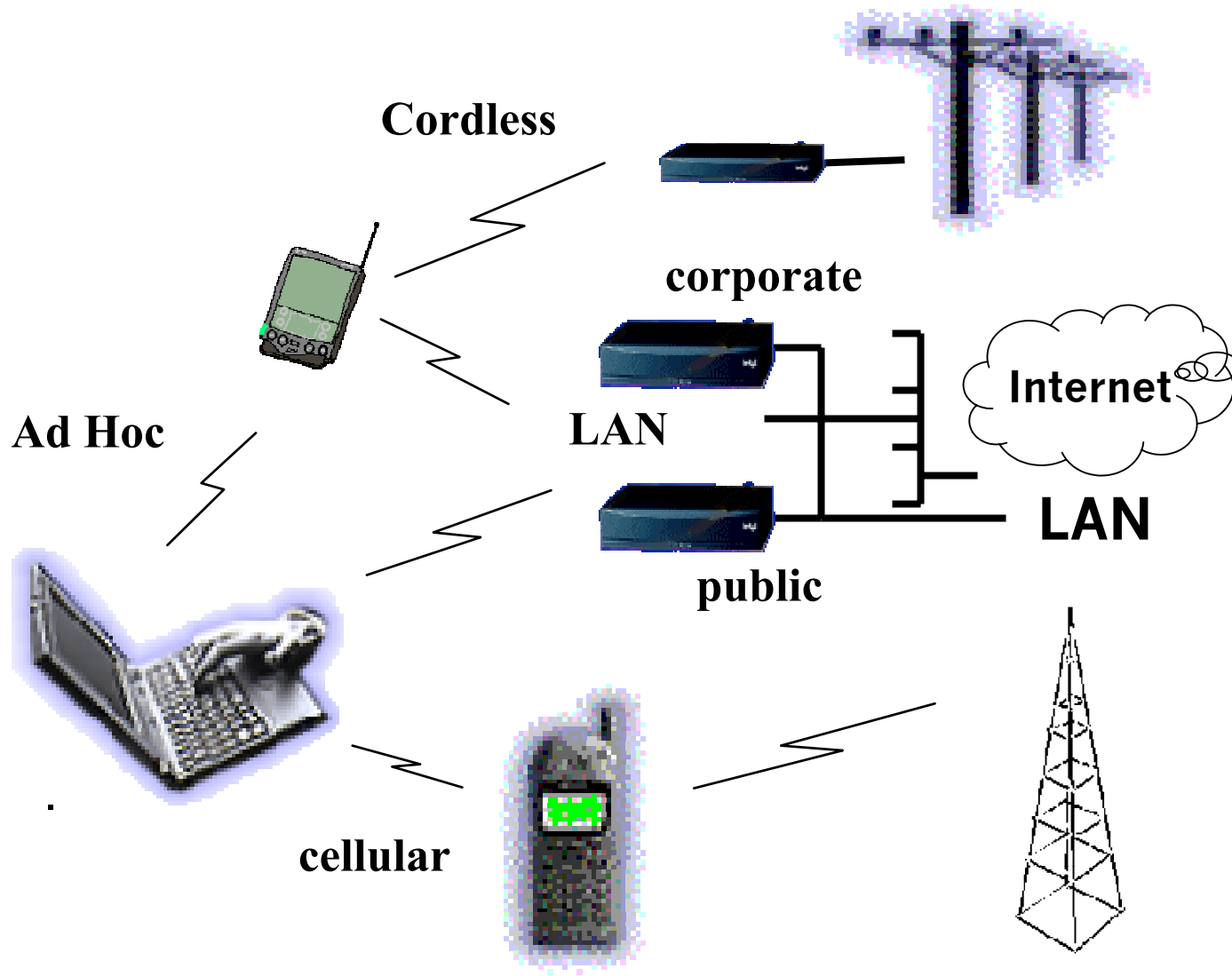
# Bluetooth Air Interface

- **2.4 to 2.48 GHz operation**
- **1600 frequency hops per second**
- **GFSK modulation at 1 Mbps**
- **Discriminator detection**
- **Coding rate 1, 2/3 (Hamming 15,10) and 1/3 (repetition)**
- **0 dBm or up to 20 dBm TX power**
- **0.1% BER max at -70 dBm RX**
- **Packet data and/or circuit voice operation**
- **64 kbps CVSD voice coding**
- **Peak data rates of 721 kbps**

# Wireless Internet Milestones

- 80's - Ardis & RAM dedicated packet data networks
- 90's - CDPD and circuit data over GSM & CDMA
- 1999 - Imode in Japan
- 2000 - many GPRS deployments planned
- 2001- initial WCDMA & EDGE launches
- 2001 - HDR launches
- ? - 4G & WOFDM