# The Fourth Generation for Wireless Systems: Trends and Future Perspectives

*Prof. Giovanni Emanuele Corazza*
gecorazza@deis.unibo.it

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## Outline

➢ Part I: Trends in information society

➢ Part II: Wireless systems evolution

➢ Part III: The sixth framework programme (FP6)

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# Part I

# Information society trends

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## Industrial society

1. Standardization
2. Synchronization
3. Centralization
4. Specialization
5. Maximization of E = P/H

| TLC: Radio – TV broadcasting |
|---|

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## Post-industrial society

1. Individualization
2. Space/time de-structuring
3. Distribution
4. Continuous and flexible education
5. Work/education/entertainment

### TLC:

➢ Cellular telephony (1G+2G)
➢ Internet
➢ IMT-2000 (3G)
➢ Broadband wireless (4G)

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## The centrality of the human being

➢ Information society?
  • Competence and know-how are not enough!
  • Knowledge transformation, innovation, generation
➢ Thinking
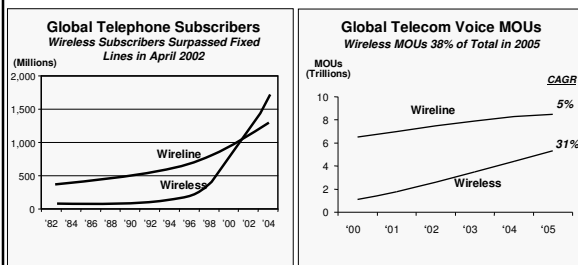  • Critical
  • Creative
  • Constructive

# Part II

# Wireless systems evolution

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## The dimensions in the wireless world

➤ Market: status and forecast
➤ Services and applications
➤ Air interface standards
➤ Geographic coverage and mobility
➤ Backbone network and protocols
➤ Convergence and interworking
➤ Transmission data rate (bandwidth)
➤ Terminals

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## Wireless Leading Global Telecom Growth

**Global Telephone Subscribers**
*Wireless Subscribers Surpassed Fixed Lines in April 2002*

(Millions)



**Global Telecom Voice MOUs**
*Wireless MOUs 38% of Total in 2005*

MOUs
(Trillions)

*CAGR*

Wireline — *5%*

Wireless — *31%*

**Wireless Becoming Primary Phone in Emerging Markets and Replacing Wireline Demand in Developed Markets**

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## The Wireless Path: 1G->2G->3G
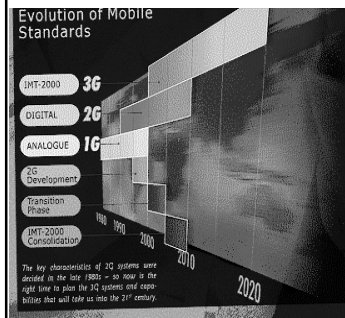


1G: Analogue voice (NMT, TACS, AMPS, PCH etc…)

2G: Digital voice, low-rate data applications (GSM, IS-54, IS-95….)

3G: IMT-2000 Global Standard for wireless multimedia

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## 3G: IMT-2000 Objectives set by ITU

➤ Global Service Capability
➤ Terrestrial & Satellite Components
➤ Standardized radio interfaces
➤ Flexible/Seamless Service Provision
➤ Wider Range of Services (emphasis on data)
➤ Fixed/Mobile and Public/Private
➤ Improved Operational Efficiencies

➤ … follow lessons learned from GSM !

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## 3G IMT 2000 scenarios



**Satellite    Macro-Cell    Micro-Cell    Pico-Cell**
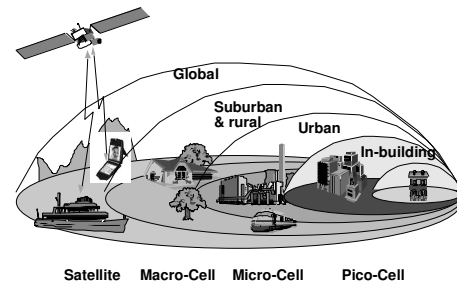
## RTT Proposals for IMT-2000

> Terrestrial component
- DECT (ETSI)
- UWC-136 (USA TIA TR 45.3)
- WIMS (USA TIA TR 46.1)
- TD-SCDMA (China CATT)
- W-CDMA (Japan ARIB)
- CDMA II (Korea TTA)
- UTRA (ETSI)
- NA W-CDMA (USA T1P1)
- cdma2000 (USA TIA TR 45.5)
- CDMA I (Korea TTA)

• Satellite component
- SAT-CDMA (Korea TTA)
- SW-CDMA (ESA)
- SW-CTDMA (ESA)
- ICO (Ico Glob. Comm.)
- Horizons (Inmarsat)
- Iridium (Iridium Inc.)

## Present Status for IMT-2000 Terrestrial RTTs

> IMT-DS Direct Spread (UTRA FDD W-CDMA)
> IMT-MC Multi Carrier (cdma2000, HDR)
> IMT-TC Time Code (UTRA TDD T-CDMA and TD-SCDMA)
> IMT-SC Single Carrier (UWC-136/EDGE)
> IMT-FT Frequency Time (DECT)

"*The comprehensive set of [...] radio interfaces incorporates the required flexibility...*"

## Consequences induced by IMT-2000 multimodality

COMPLEXITY:
> Terminal manufacturers (HW and SW)
> Base station manufacturers (HW and SW)
> Operators
> Service providers
> Regulators

IS GLOBAL ROAMING AN ACHIEVABLE TARGET IN THE SHORT TERM?

Largest common denominator: SPREAD SPECTRUM!

## Current 3G problems

> High price for spectrum licences
> Multiple air interface standards
> Manufacturers slow to invest in terminals
> Poor availability of compatible infrastuctures and terminals
> Patchy service coverage: frequent revert to 2G
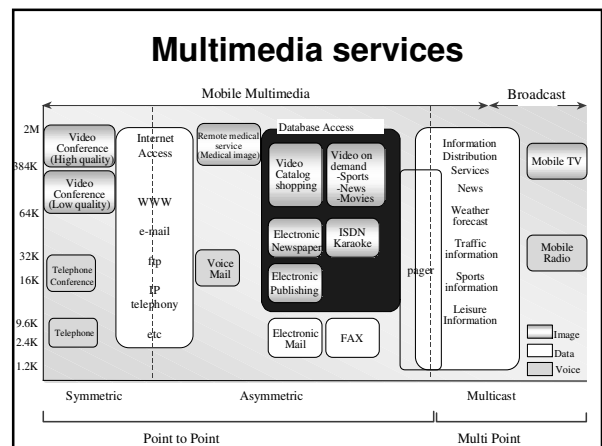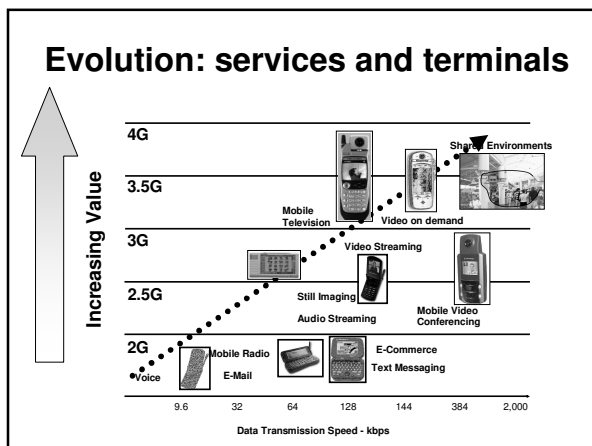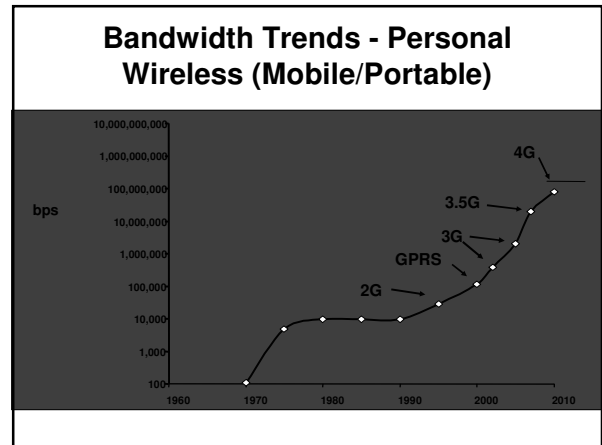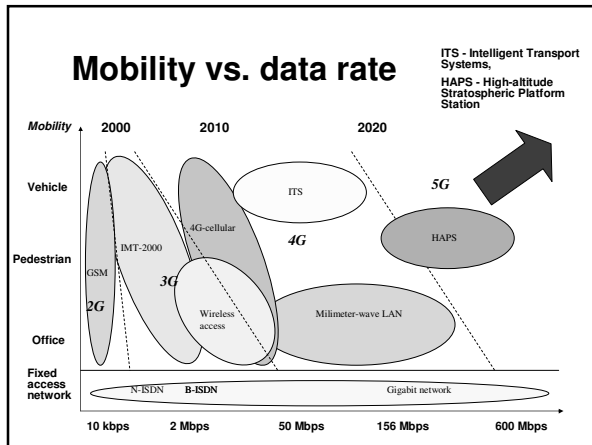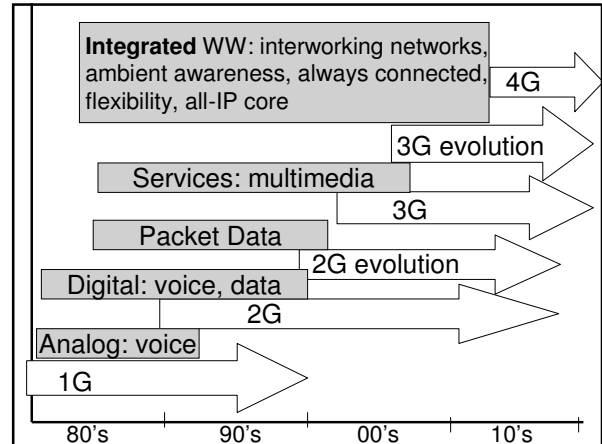> Delayed 3G roll-out: 2005

## Re-thinking 3G

> Do we need 3G?
> WLANs for hot spots
- Integration with cellular
> Multicast/broadcast services rise in popularity: is 3G the best way to deliver?
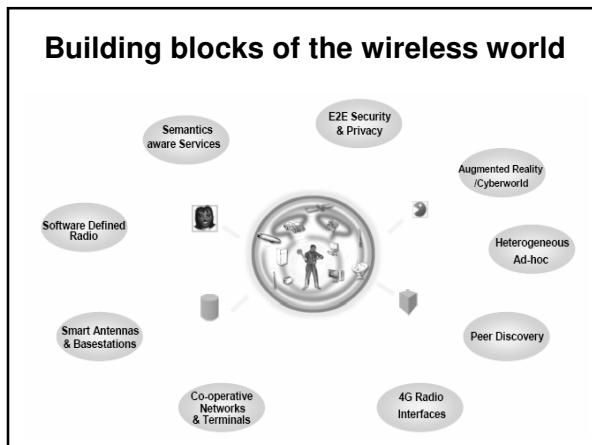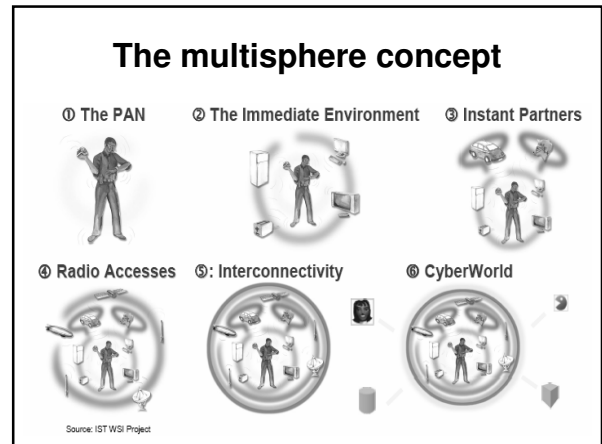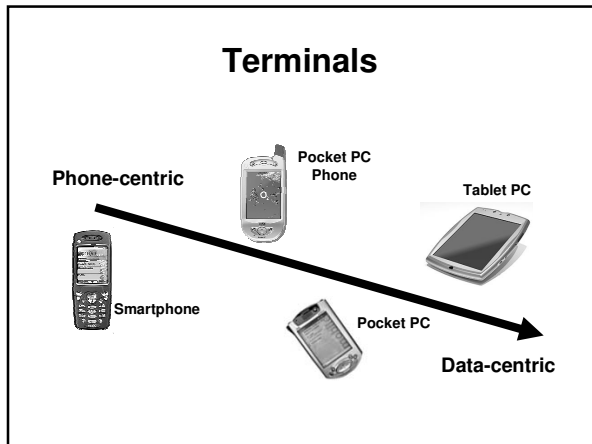> 3G was driven by technology *push* – user *pull* for services needed

## The path to 4G

> Fast and reliable broadband radios
> Scalable system capacity for mass-market services
> Integration of multiple radios into a single all-IP network
> New networking modes: multicast, multihop, peer-to-peer, ad-hoc
> Truly "useful" mobile information services
> Intelligent agents for user-friendliness

## Cellular Evolution: 4G

| 1 G | 2 G / 2.5G | 3 G | 4 G |
|---|---|---|---|
| ➢analog<br>➢ narrow band<br>➢ national roaming<br>➢ FDD only | ➢ digital<br>➢ narrow band<br>➢ international roaming<br>➢ FDD only<br>➢ GPRS<br>➢ EDGE | ➢ digital air channel<br>➢ broadband up to 2 Mbps<br>➢ international roaming<br>➢ FDD/TDD<br>➢ ATM/IP based networks | ➢ digital air channel<br>➢ broadband multipath<br>➢ radio channel with data rates 10, 20 and 155 Mbps<br>➢ Integration of different systems (Cellular, WiFi, PAN)<br>➢ Software Radio<br>➢ all IP based broad band cellular network |
| AMPS<br>TACS<br>NMT<br>C-net | GSM<br>TDMA<br>CDMA<br>PDC | IMT 2000<br>UTRA (FDD/TDD)<br>cdma 2000<br>HS-TDMA | Multiple Air Interfaces within one seamless network |

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**Integrated** WW: interworking networks, ambient awareness, always connected, flexibility, all-IP core

4G

3G evolution

Services: multimedia

3G

Packet Data

2G evolution

Digital: voice, data

2G

Analog: voice

1G

80's    90's    00's    10's

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## Mobility vs. data rate

ITS - Intelligent Transport Systems,

HAPS - High-altitude Stratospheric Platform Station



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## Bandwidth Trends - Personal Wireless (Mobile/Portable)



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## Evolution: services and terminals



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## Multimedia services



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## Terminals

**Phone-centric**

**Smartphone**

**Pocket PC Phone**

**Tablet PC**

**Pocket PC**

**Data-centric**

## The multisphere concept

① The PAN    ② The Immediate Environment    ③ Instant Partners

④ Radio Accesses    ⑤: Interconnectivity    ⑥ CyberWorld

Source: IST WSI Project

## Building blocks of the wireless world

Semantics aware Services

E2E Security & Privacy

Augmented Reality /Cyberworld

Software Defined Radio

Heterogeneous Ad-hoc

Smart Antennas & Basestations

Peer Discovery

Co-operative Networks & Terminals

4G Radio Interfaces

## User Vision of Future Services

➢ Fully converged services
  • Personal communications, information systems, broadcast media and entertainment will have merged into a seamless pool of content available conveniently, securely and in a manner reflecting the user's personal preferences

➢ Context aware computing
  • Devices will interact with users in a multi-sensory manner, encompassing not only touch and speech, but also environmental data pertinent to the application

➢ Mobile agents
  • Intelligent Mobile Agents will exist throughout the networks and in user devices, acting continually to simplify tasks and ensure transparency to the user
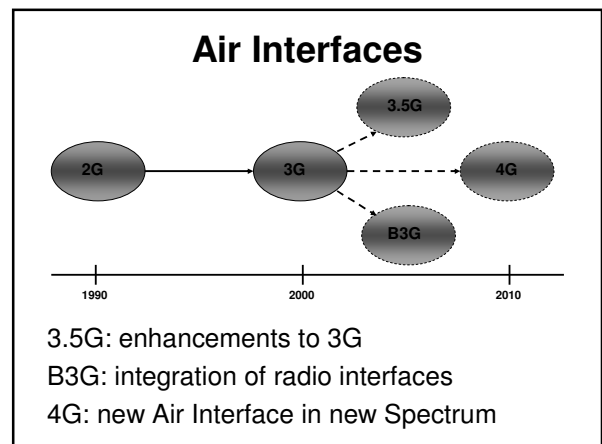
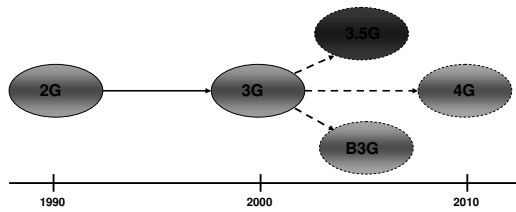## Key Requirements for Future Services

User Expectations
➢ Seamless, intuitive, predictable, reliable service
➢ Continuous stream of innovative applications
➢ Service costs decreasing with time even as scope and quality increase
➢ Wide variety of low cost terminals

Operator Requirements
➢ Technologies that make high-BW applications useful for people on the move
➢ Globally harmonized spectrum
➢ Open, standardized systems

## Air Interfaces

3.5G

2G    3G    4G

B3G

1990    2000    2010

3.5G: enhancements to 3G

B3G: integration of radio interfaces

4G: new Air Interface in new Spectrum

## 3.5G: traditional approach



➤Backwards compatible with legacy radio network
➤Objectives: capacity increase, better performance, lower cost
➤Technologies/standards are monolithic/specific to known business models
➤Examples: HSDPA, MIMO

## B3G: open approach
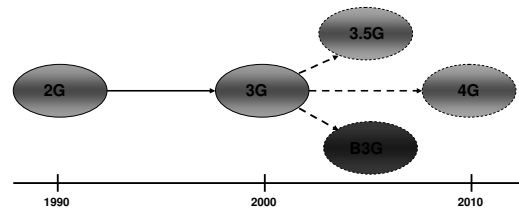


➤Simplicity of adding air interfaces to an always best connected network
➤Objectives: new functionality, applications, content
➤Technologies/standards are neutral with respect to business models
➤Examples: WLAN, DVB-T

## Broadband wireless technologies

| Technology | Standard | Usage | Throughput | Range | Frequency |
|---|---|---|---|---|---|
| UWB | 802.15.3a | WPAN | 110-480 Mbps | Up to 30 feet | 7.5 Ghz |
| Wi-Fi* | 802.11a | WLAN | Up to 54 Mbps | Up to 300 feet | 5 Ghz |
| Wi-Fi | 802.11b | WLAN | Up to 11 Mbps | Up to 300 feet | 2.4 Ghz |
| Wi-Fi | 802.11g | WLAN | Up to 54 Mbps | Up to 300 feet | 2.4 Ghz |
| WiMAX | 802.16d | WMAN | Up to 75 Mbps (20 Mhz BW) | Typical 4-6 miles | Sub 11 Ghz |
| WiMAX | 802.16e | Mobile WMAN | Up to 30 Mbps (10 Mhz BW) | Typical 1-3 miles | 2-6 Ghz |
| WCDMA/UMTS | 3G | WWAN | Up to 2 Mbps (Up to 10 Mbps with HSDPA technology) | Typical 1-5 miles | 1800, 1900, 2100 Mhz |
| CDMA2000 1 x EV-DO | 3G | WWAN | Up to 2.4 Mbps (typical 300-600 Kbps) | Typical 1-5 miles | 400, 800, 900, 1700, 1800, 1900, 2100 Mhz |
| Edge | 2.5G | WWAN | Up to 348 Kbps | Typical 1-5 miles | 1900 Mhz |

## 4G: revolutionary approach
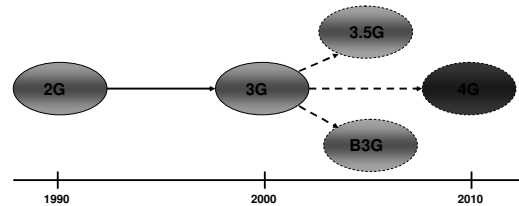


➤Higher bit rates than 3G and full mobility
➤Higher spectral efficiency and lower cost per bit than 3G
➤Air interface optimized for IP traffic
➤Examples: OFDM, MIMO

## Technical issues

➤ High data rates
 • OFDM
 • MC-CDMA
 • Synchronization & estimation
 • Distortion (linear, non-linear)
➤ Coding
 • Iterative decodable codes (Turbo, LDPC)
➤ Smart antenna systems
➤ MIMO (Multi Input Multi Output) devices
➤ Reconfigurable terminals (SW and HW)
➤ Cognitive radio

## Re-configurable Technology

### *What does Reconfiguration mean?*

"Reconfiguration refers to the software re-definition and/or adaptation of every element within each layer of the communication chain."
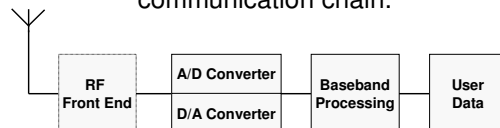
## Re-configurable Technology

**Benefits**

- Users
  - Select network depending on service reqs and cost
  - Connect to any network – worldwide roaming
  - Access to new services
- Operators
  - Respond to variations in traffic demand (load balancing)
  - Incorporate service enhancements and improvements
  - Correction of software bugs and upgrade of terminals
  - Rapid development of new personalised services
- Manufacturers
  - Single platform for all markets
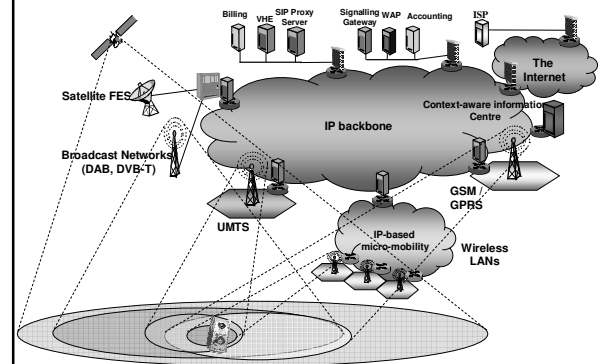  - Increased flexible and efficient production

## Re-configuration Procedures
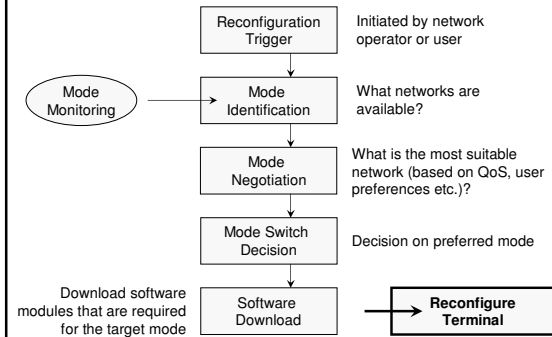


## WW: hierarchical coverage layers
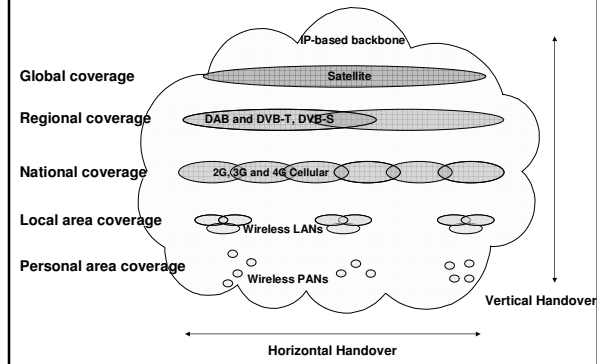


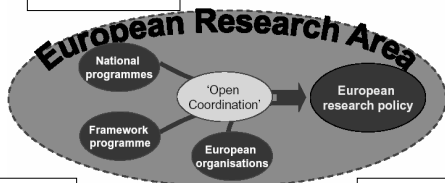## Seamless interworking



## 4G spectrum considerations

- Sufficient spectrum for the new wide-area high data rate access capability must be made available
- Main factors influencing the bandwidth needed for service launch:
  - RF bandwidth of a single carrier (20 MHz is often cited)
  - reuse factor (only reuse of 1 candidates need apply)
  - duplex technique (FDD is generally accepted)
  - number of operators (3 to 6)
  - guardbands (yes, technology dependent)
- Assume only a 2nd carrier per operator is sufficient to meet the predicted long term traffic forecast
- Under conventional allocations schemes, 2 times 120 to 240 MHz of dedicated spectrum plus guardbands would be required

## Part III

## FP6: The sixth framework programme

## The European Research Area

- A blueprint for the future of research in Europe
- Broad support at the highest political, scientific and industrial levels
- Being implemented



European Research Area

National programmes — 'Open Coordination' — European research policy — Framework programme — European organisations

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## Sixth Framework Programme

| I. Focusing and integrating research | Budget (€ million) |
|---|---|
| 1. Life sciences, genomics and biotechnology for health | 2 255 |
| • Advanced genomics and its applications for health | 1 100 |
| • Combatting major diseases | 1 155 |
| 2. Information Society technologies | 3 625 |
| 3. Nanotechnologies and nano-sciences, knowledge-based multifunctional materials and new production processes and devices | 1 300 |
| 4. Aeronautics and space | 1 075 |
| 5. Food quality and safety | 685 |
| 6. Sustainable development, global change and ecosystems | 2 120 |
| • Sustainable energy systems | 810 |
| • Sustainable surface transport | 610 |
| • Global change and ecosystems | 700 |
| 7. Citizens and governance in a knowledge-based society | 225 |
| 8. Specific activities covering a wider field of research | 1 300 |
| Total | 13 345* |

* Including non-nuclear activities of the Joint Research Centre: €760 million

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## The 7 thematic priorities: IST

- **Information Society Technologies**
  - **The 2nd most important economy sector (2 billion €, 2 million persons)**
  - **Applied IST research addressing major societal and economic challenges**: security, societal challenges, 'ambient intelligence', electronic commerce, etc
  - **Communication, computing and software technologies**
  - **Components and microsystems**
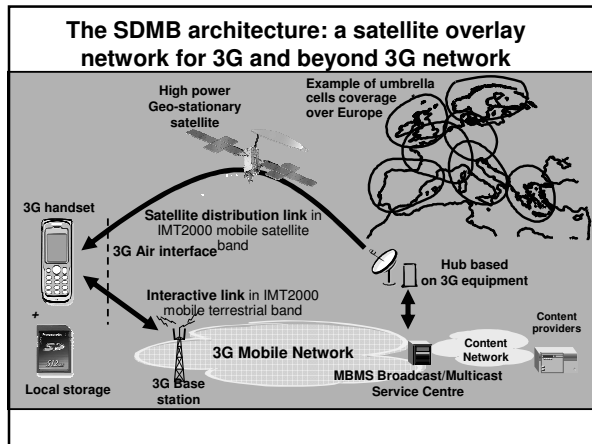  - **Knowledge and interface technologies**

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## Communication and computing infrastructures

- Mobile, wireless, optical and broadband communication infrastructures and computing and software technologies that are reliable, of wide application and can be adapted to meet the growing needs of applications and services:
  - (a) the new generations of wireless and mobile communications systems and networks; satellite communications systems; all-optical technologies; integration and management of communication networks, including interoperable network solutions; capacity-enhancing technologies necessary for the development of systems, infrastructures and services, in particular for audio-visual applications; next Internet generation;
  - (b) software technologies architectures, distributed and embedded systems supporting the development of multifunctional and complex services that involve multiple actors engineering and control of complex and large-scale systems to ensure reliability and robustness.

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**EC/IST MAESTRO**
**Mobile Applications & sErvices based on Satellite & Terrestrial inteRwOrking**

**Integrated Project Presentation**

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## EC IST MAESTRO IP in short

- FP6: Strategic objectives: EC/IST FP6: Mobile and wireless systems beyond 3G
- MAESTRO: **Mobile Applications & sErvices based on Satellite & Terrestrial inteRwOrking**
- Duration: **24 months** with T0 = 01/01/2004
- Budget **10.15 Meuros**, EC funding: 5.2 Meuros
- Co-ordinator: Nicolas.chuberre@Space.alcatel.fr
- Project Web page: **http://ist-maestro.dyndns.org**
- **20 partners** from satellite and terrestrial mobile industry as well as media industry

**The SDMB architecture: a satellite overlay network for 3G and beyond 3G network**



**IST/FP5 MoDiS project Trial: MONACO July/Sept 2004**

- **Proof of S-DMB concept:** W-CDMA efficiency in broadcast mode with hybrid satellite/terrestrial transmission
- **Measurement campaign** for system cost & performances assessment
- **Service demonstration**: streaming, download , alert & Peer2peer
- www.ist-modis.org



**EU-Argentina Co-operation**

- The EU-Argentina Co-operation Agreement on Science and Technology has the purpose to strengthen the bilateral co-operation in this field (O.J. Reference: L 6 of 11/01/2000).
- **For more information see (amongst others):** http://www.delarg.cec.eu.int
- Francisco-Jaime.Viegas@cec.eu.int

**Delegación de la Comisión Europea en la República Argentina**

- **Dirección**
  - **Ayacucho 1537**
  - **C1112AAA Buenos Aires**
  - **Tel: (5411) 4805-3759**
  - **Fax: (5411) 4801-1594**
- **e-mail: delegation-argentina@cec.eu.int**
- **Website: http://www.delarg.cec.eu.int**
- **Servidor Europa: europa.eu.int**
- **Centro de Documentación**
  - **Horario de atención: lunes a jueves 11 a 13 y 14 a 17**
  - **(Solicitar entrevista previa)**
- **Angelos PAGKRATIS, Embajador - Jefe de la Delegación**

**Conclusions and perspectives**

- The path to 4G is not unique
- It may not lead to a single air interface
- Research issues
  - Reconfigurable ad-hoc networking (mixed comms and sensors)
  - Software networks and cognitive radios
  - Ambience and context awareness
  - Management fo complexity
  - Multidisciplinary research, social domain
- 4G requires new thinking!

**Thank you!**