4G

Mohammad Abualreesh

Mohammad.Abualreesh@hut.fi

Outline

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- Definition, motivation, new… in 4G
- 3G vs. 4G
- Challenges & Needs
- 4G networks (Models, features, air interface)
- Industry Initiatives
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Evolution

Figure 1 shows the evolution of wireless technologies.

- ***First Generation (1G):*** 1G wireless mobile communication systems, was introduced in the early 1980s. 1G wireless was analog and supported the first generation of analog cell phones. They include a signaling protocol known as SS7 (Signaling System 7).

- ***Second Generation (2G):*** 2G systems, fielded in the late 1980s, were intended primarily for voice transmission and was all about digital PCS.

Evolution

- ***Third Generation (3G):*** 3G in wireless will be a deliberate migration to faster, data-centric wireless networks. The immediate goal is to raise transmission speeds from 125kbps to 2M bit/sec.

- ***Fourth Generation (4G):*** In reality, as of first half of 2002, 4G is a conceptual framework for or a discussion point to address future needs of a universal high speed wireless network that will interface with wireline backbone network seamlessly.

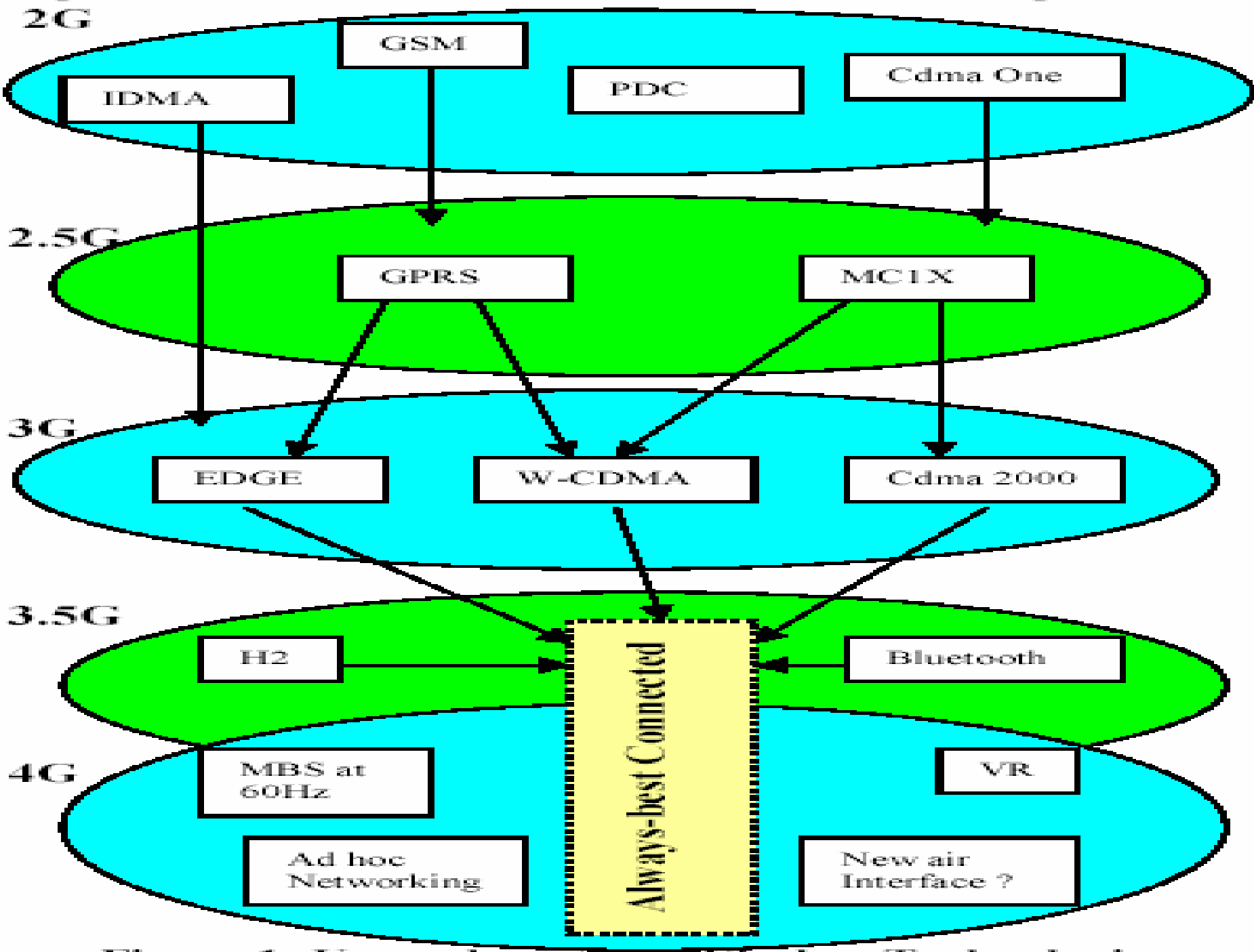


Figure 1: Upgrade path of Wireless Technologies

Lessons from 3G

- Customer demand was extremely uncertain
  - Exploring and trialing next generation applications should be done upfront BEFORE the definition of the requirements for the system and the air interface
  - We need to start this activity NOW (2002 time of writing this Motorola document) to get the 4G requirements by 2005!

Lessons from 3G

- The 3G story (for the financial community, the regulatory bodies, the end-users…) and research was centered around a new, more capable, air interface. There was significant over-expectations.
  - The 4G story should be centered around the user experience
  - The 4G research should be centered around architecture and system aspects that would support an effective, open, flexible integration of multiple technologies
- Standards for 3G where elaborated in « vertical monolithic » standard bodies.
  - 4G requirements, global architecture and protocols should be coordinated at the highest level possible in a "global 4G" standard body. Specific element of the standard and or regional variations should be fully developed in multiple, ad-hoc, effective "horizontal" standard bodies.

Definition, motivation, new… in 4G

What is 4G

- 4G can be imagined as an integrated wireless system that enables seamless roaming between technologies.
- A user can be operating in cellular technology network and get handed over to a satellite-based network and back to a fixed wireless network, depending upon the network coverage and preference of charging.

Reasons to Have 4G

- Support interactive multimedia services: teleconferencing, wireless Internet, etc.
- Wider bandwidths, higher bit rates.
- Global mobility and service portability.
- Low cost.
- Scalability of mobile networks.

Major trend

- One of the major trends toward 4G is the great heterogeneity of the deployed networks. Given both investors' requirements for capital expenditure intensity and the technological divergence of private and public networks, the issues of service portability and interoperability have become of primary importance.

Global roaming

4G wireless networks support global roaming across multiple wireless and mobile networks.

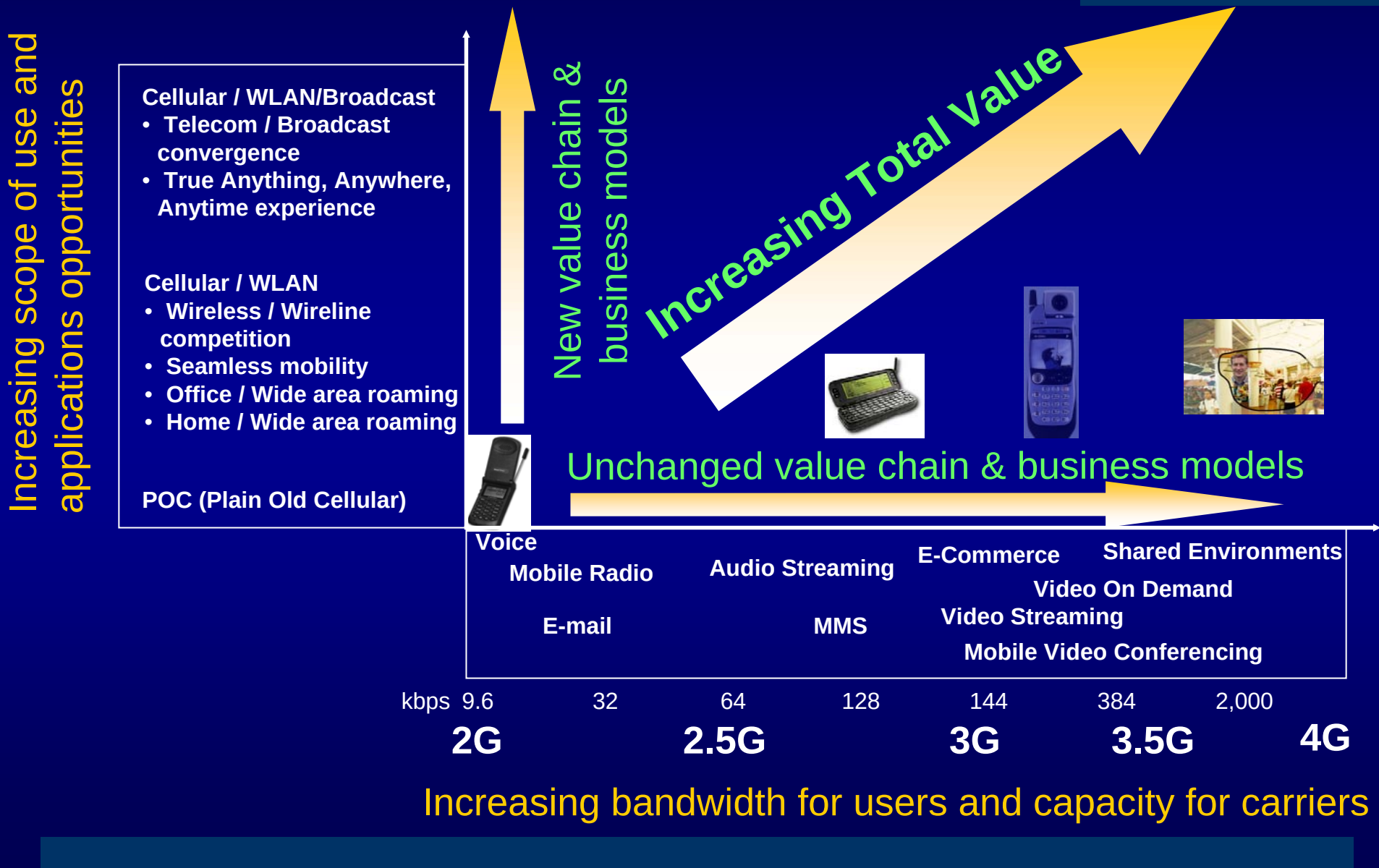
What's New in 4G

- Entirely packet-switched networks.
- All network elements are digital.
- Higher bandwidths to provide multimedia services at lower cost (up to 100Mbps).
- Tight network security.

POTENTIAL APPLICATIONS OF 4G

- ***Virtual Presence*:**
  - 4G system gives mobile users a "virtual presence" -- for example, always-on connections to keep people on event.
- ***Virtual navigation*:**
  - A remote database contains the graphical representation of streets, buildings, and physical characteristics of a large metropolis. Blocks of this database are transmitted in rapid sequence to a vehicle.
- ***Tele-medicine***
  - 4G will support remote health monitoring of patients.
- ***Tele-geoprocessing***
  - Queries dependent on location information of several users, in addition to temporal aspects have many applications.
- ***Crisis-management applications***
- ***Education***

Where is value for next generation?



3G vs. 4G

3G vs. 4G

- 3G
  - Predominantly voice driven - data was always add on
  - Wide area cell-based
  - Back compatible to 2G.
  - 1800-2400 MHz
  - W-CDMA, 1xRTT, Edge Access technology
  - FEC Convolutional rate 1/2, 1/3
- 4G
  - Converged data and voice over IP
  - Hybrid - Integration of Wireless LAN (WiFi, Bluetooth) and wide area
  - Extend 3G capacity by one order of magnitude.
  - Higher frequency bands 2-8 GHz
  - OFDM and MC-CDMA (Multi Carrier CDMA)
  - Concatenated coding scheme

3G vs. 4G

- Circuit and packet switched networks.
- Combination of existing & evolved equipment.
- Data rate (up to 2Mbps).
- Optimized antenna design, multi-band adapters
- A number of air link protocols, including IP 5.0

- Entirely packet switched networks.
- All network elements are digital.
- Higher bandwidth (up to 100Mbps).
- Smarter Antennas, software multiband and wideband radios
- All IP (IP6.0)

Challenges
&
Needs

Challenges in the Migration to 4G Mobile Systems

	Key challenges	Proposed solutions
Mobile station		
Multimode user terminals	To design a single user terminal that can operate in different wireless networks, and overcome the design problems such as limitations in device size, cost, power consumption, and backward compatibilities to systems.	A software radio approach can be used: the user terminal adapts itself to the wireless interfaces of the networks [1].
Wireless system discovery	To discover available wireless systems by processing the signals sent from different wireless systems (with different access protocols and incompatible with each other).	User- or system-initiated discoveries, with automatic download of software modules for different wireless systems [2].
Wireless system selection	Every wireless system has its unique characteristic and role. The proliferation of wireless technologies complicates the selection of the most suitable technology for a particular service at a particular time and place.	The wireless system can be selected according to the best possible fit of user QoS requirements, available network resources, or user preferences [3, 4].

Challenges in the Migration to 4G Mobile Systems

System		
Terminal mobility	To locate and update the locations of the terminals in various systems. Also, to perform horizontal and vertical handoff as required with minimum handover latency and packet loss.	Signaling schemes and fast handoff mechanisms are proposed in [5].
Network infrastructure and QoS support	To integrate the existing non-IP-based and IP-based systems, and to provide QoS guarantee for end-to-end services that involves different systems.	A clear and comprehensive QoS scheme for UMTS system has been proposed [6]. This scheme also supports interworking with other common QoS technologies.
Security	The heterogeneity of wireless networks complicates the security issue. Dynamic reconfigurable, adaptive, and lightweight security mechanisms should be developed.	Modifications in existing security schemes may be applicable to heterogeneous systems. Security handoff support for application sessions is also proposed [4].
Fault tolerance and survivability	To minimize the failures and their potential impacts in any level of tree-like topology in wireless networks.	Fault-tolerant architectures for heterogeneous networks and failure recovery protocols are proposed in [7].

Challenges in the Migration to 4G Mobile Systems

Service		
Multi-operators and billing system	To collect, manage, and store the customers' accounting information from multiple service providers. Also, to bill the customers with simple but detailed information.	Various billing and accounting frameworks are proposed in [8, 9].
Personal mobility	To provide seamless personal mobility to users without modifying the existing servers in heterogeneous systems.	Personal mobility frameworks are proposed. Most of them use mobile agents, but some do not [10, 11].

Table 1. *A summary of key challenges and their proposed solutions.*

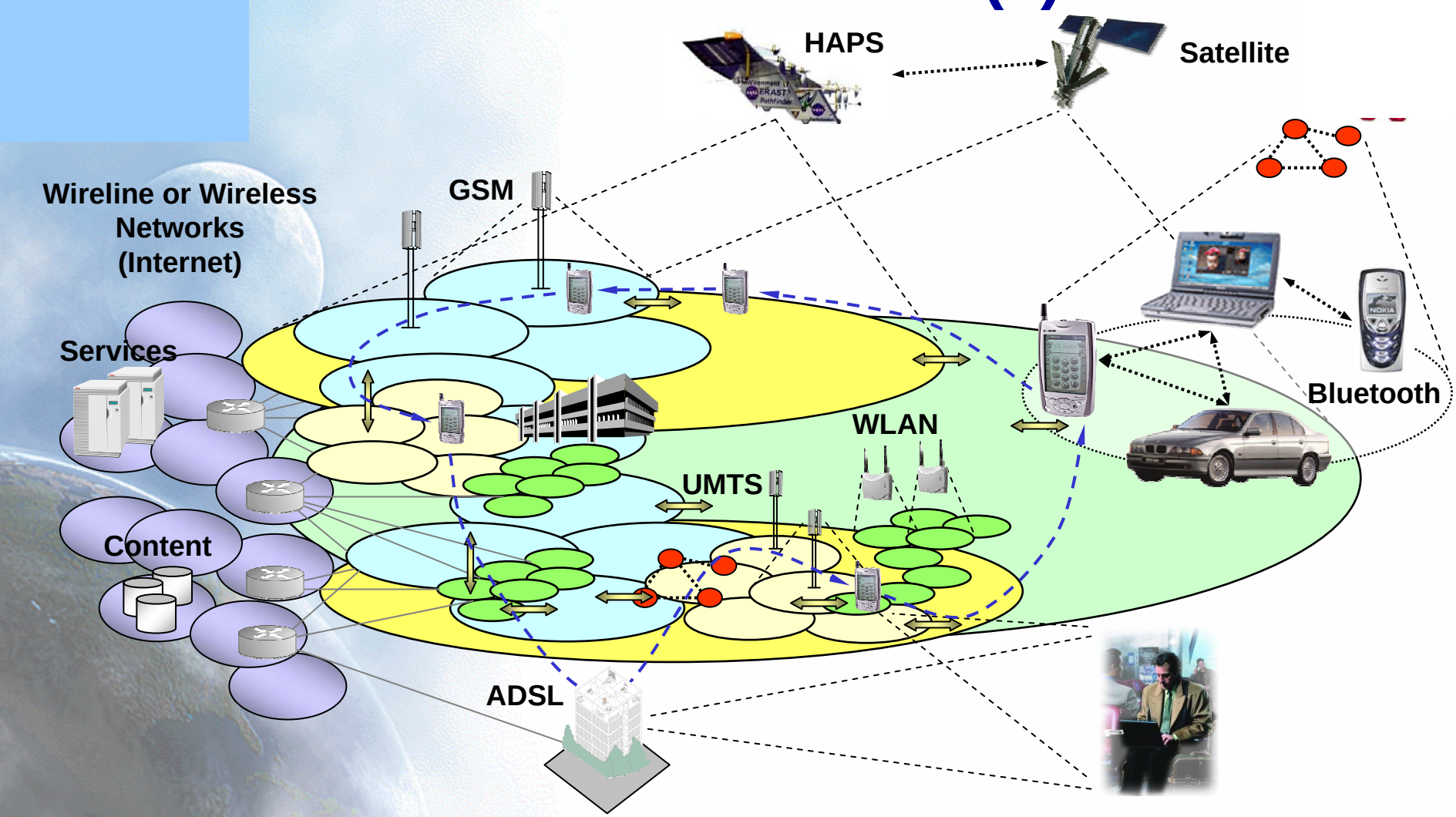
What is needed to Build 4G Networks of Future?

- **Lower Price Points Only Slightly Higher than Alternatives**
- **More Coordination Among Spectrum Regulators Around the World**
- **More Academic Research**
- **Standardization of wireless** networks in terms of modulation techniques, switching schemes and roaming is an absolute necessity for 4G
- **A Voice-independent Business Justification Thinking**
- **Integration Across Different Network Topologies**
- **Non-disruptive Implementation**: 4G must allow us to move from 3G to 4G

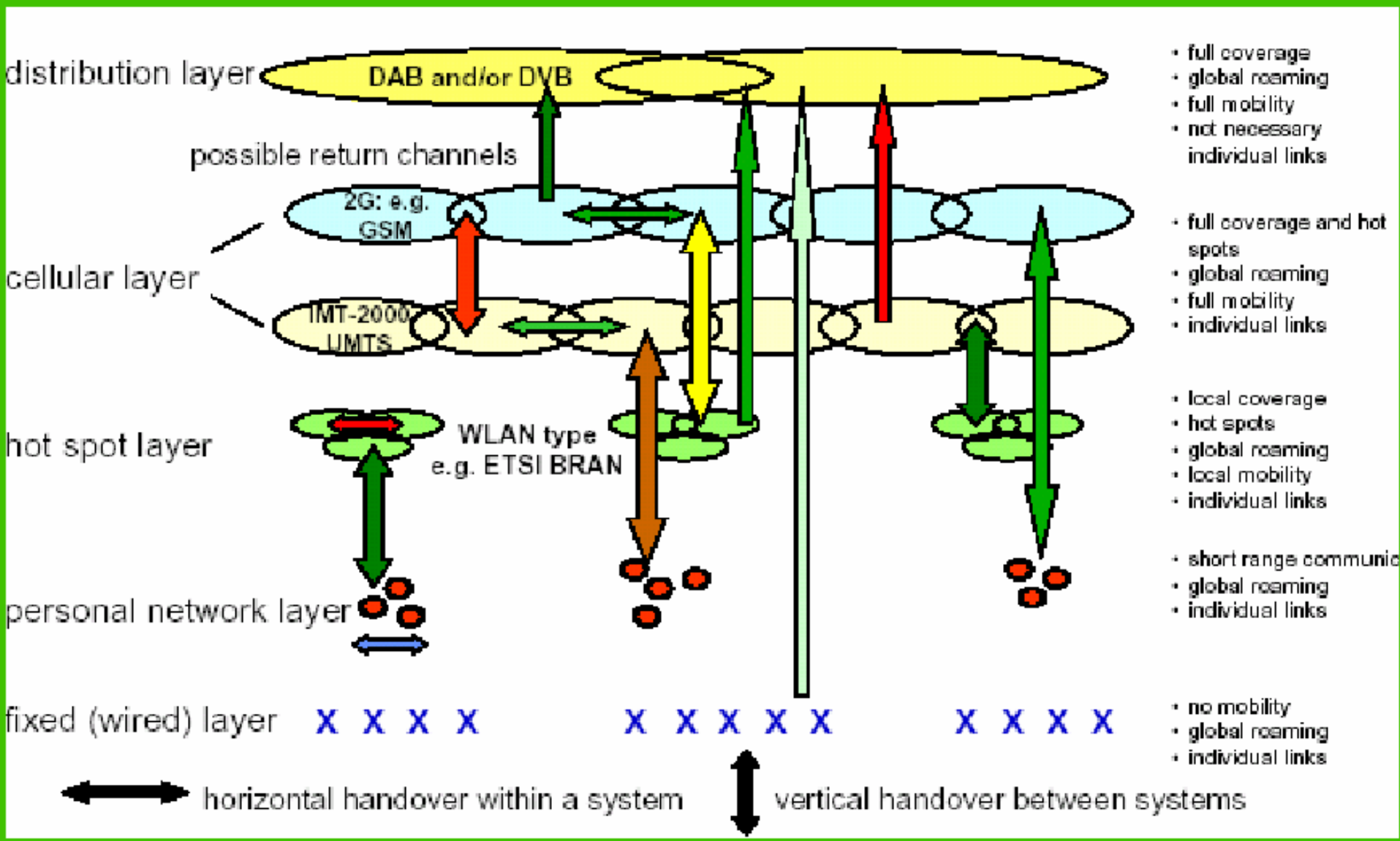
4G networks

(Models, features, air interface)

The 4G mobile network(s)



Layered structure for 4G



4G features

The **4g** mobile networks could be systems:

- Horizontal communications between different access technology including cellular, cordless, wlan, short-range connectivity, and wired
- A common platform to complement other services Connection through a common, flexible, seamless, IP-based core network
- Advanced media access technology that connects the core network to different access technologies
- Global roaming and interworking between different access technologies; both horizontal (intrasystem) and vertical (intersystem) handover.
- Seamless service negotiation including mobility, security, and QoS

4G Air Interface

- Higher bit rates than 3G
  - (20 Mbps < peak < 200 Mbps)
- Higher spectral efficiency and lower cost per bit than 3G
- Air interface and MAC optimized for IP traffic
  - Adaptive modulation/coding with power control, hybrid ARQ

4G Air Interface

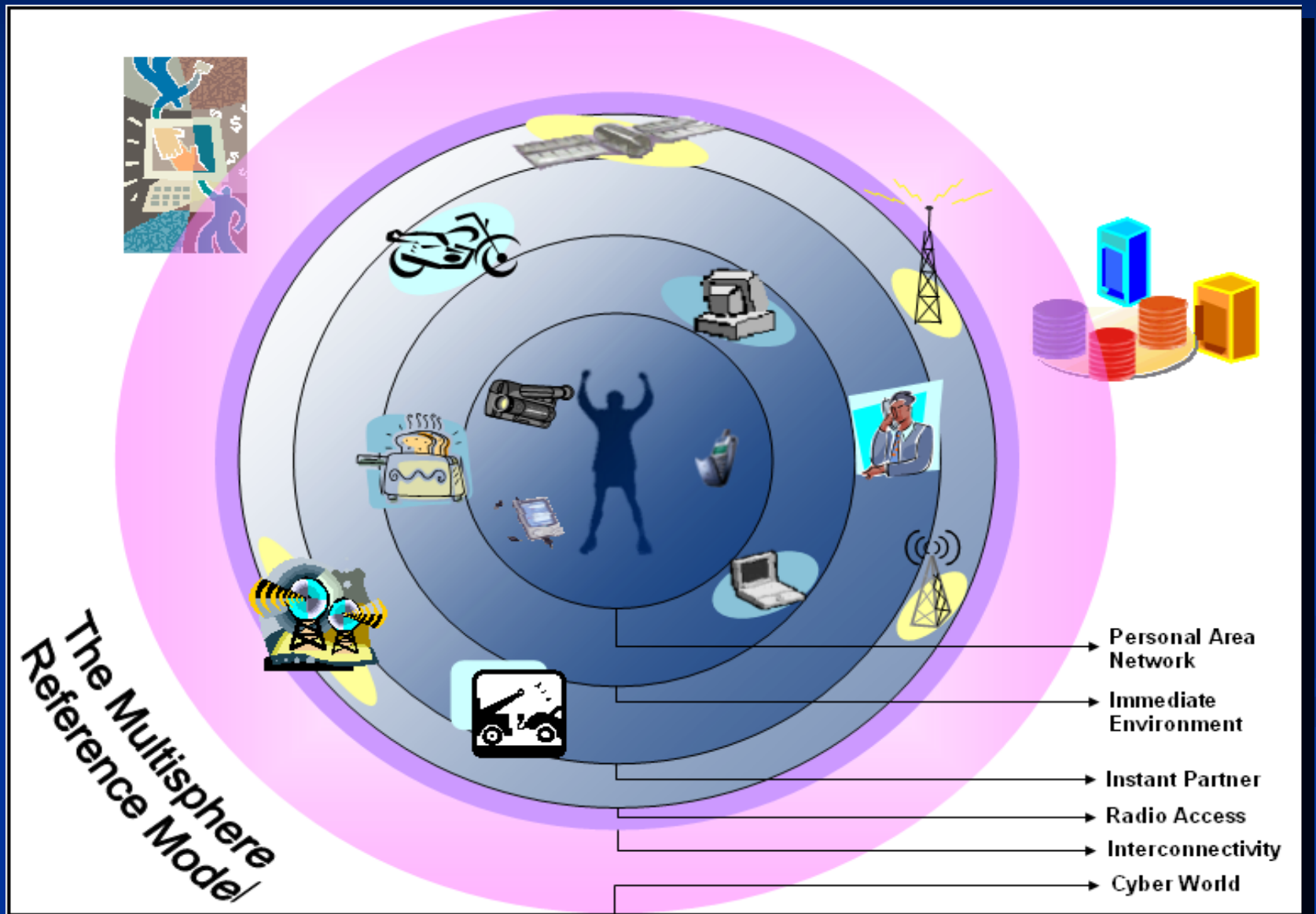
- Smaller cells, on average, than 3G
  - However, cell size will be made as large as possible via:
    - High power base station to boost downlink range
    - Asymmetry - used to boost uplink range when necessary
    - Adaptive antennas option
- Higher frequency band than 3G (below 5 GHz preferred)
- RF channel bandwidths of 20 MHz and higher
- Frequency Domain methods:
  - OFDM is promising for downlink

Industry Initiatives

Industry Initiatives

- WWRF (Wireless World Research Forum)- consisting of Alcatel, Ericsson, Nokia and Siemens have started a research forum for 4G
- NTT DoCoMo has started conceptual (we mean paper) design of a 4G network

The WWRF multi-sphere concept



WWRF

- The result of an EC 5 the FW project IST
- Based initially in the work of 4 major players in the European mobile industry in WSI project
  - And Collaboration of other research institutes.
- 4 groups
  - User's view
  - Applications and services
  - Technologies
  - Spectrum
- http://www.ist-wsi.org

Transmission Technology

4G Transmission Protocols

- ***OFDM***: OFDM is a digital modulation technology in which in one time symbol waveform, thousands of orthogonal waves are multiplexed. This is good for high bandwidth digital data transition.
- ***W-OFDM***: W-OFDM enables data to be encoded on multiple high-speed radio frequencies concurrently. This allows for greater security, increased amounts of data being sent, and the industries most efficient use of bandwidth. W-OFDM enables the implementation of low power multipoint RF networks that minimize interference with adjacent networks. This enables independent channels to operate within the same band allowing multipoint networks and point-to-point backbone systems to be overlaid in the same frequency band.

4G Transmission Protocols

- ***MC-CDMA*** **:** MC-CDMA is actually OFDM with a CDMA overlay. Similar to single-carrier CDMA systems, the users are multiplexed with orthogonal codes to distinguish users in (multi-carrier) MC-CDMA. However in MC-CDMA, each user can be allocated several codes, where the data is spread in time or frequency.

4G Transmission Protocols

- ***LAS-CDMA*** LinkAir Communications is developer of LAS-CDMA (Large Area Synchronized Code Division Multiple Access) a patented 4G wireless technology. LAS-CDMA enables high-speed data and increases voice capacity and latest innovative solution, CDD, merges the highly spectral efficient LAS-CDMA technology with the superior data transmission characteristics of TDD. This resulting combination makes CDD the most spectrally efficient, high-capacity duplexing system available today.

Some results

Table 2. OFDM Parameters for 4G.

Parameter	Value 1	*Value 2*
Operating Frequency	2GHz	*2GHz*
Bandwidth *(B)*	4096 kHz	*4096 kHz*
Useful Symbol Duration *(T)*	62.5 μs	*125 μs*
Guard Interval Duration (T_g)	15.625 μs *(T/4)*	*31.25μs (T/4)*
Total Symbol Duration (T_{symbol})	78.125 μs (with GI = *T/4*)	*156.25 μs (with GI = T/4)*
Inner Channel Coding	Punctured 1/2 rate convolution code, Constraint length 7, $\{133, 171\}_{octal}$	*Punctured 1/2 rate convolution code, Constraint length 7, $\{133, 171\}_{octal}$*
FFT Size	256	*512*
Number of data sub-carriers (N_D)	216	*432*
Sub-carrier spacing *(Δ)*	16 kHz	*8 kHz*

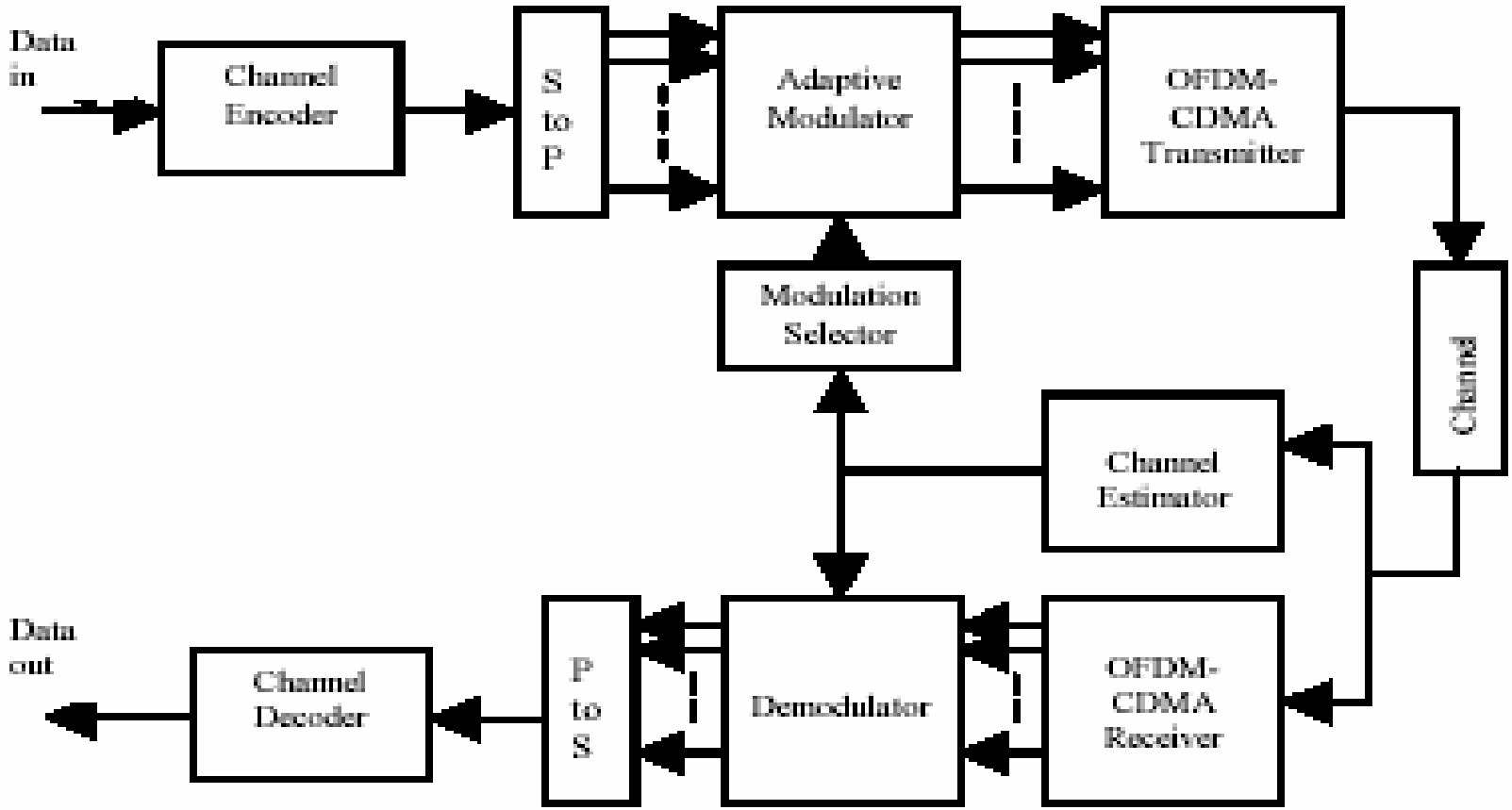


Figure : Adaptive modulation based coded MC-CDMA system

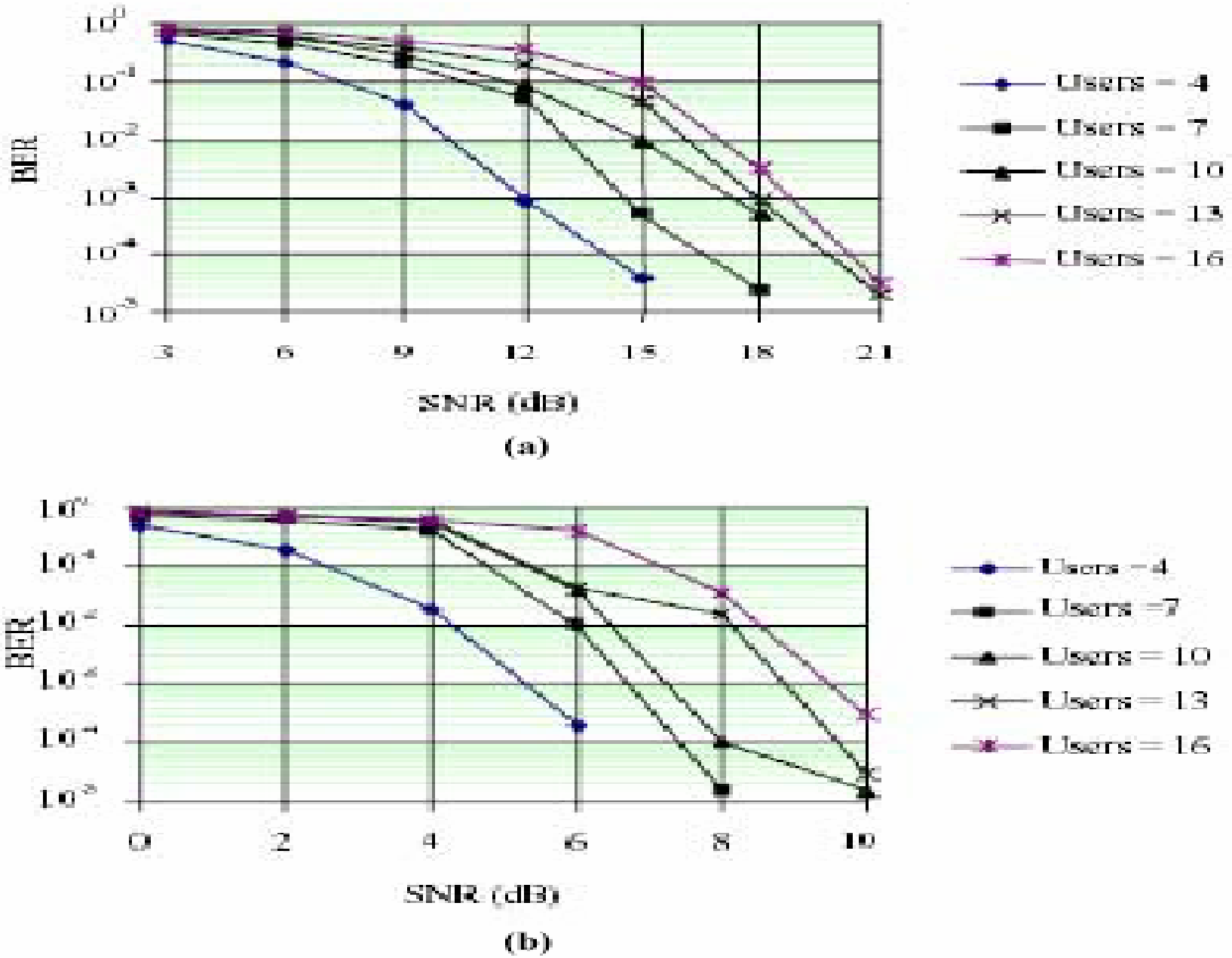


Figure : BER performance of (a) 2-ary CPM and (b) 4-ary CPM based MC-CDMA system for a given number of CDMA users

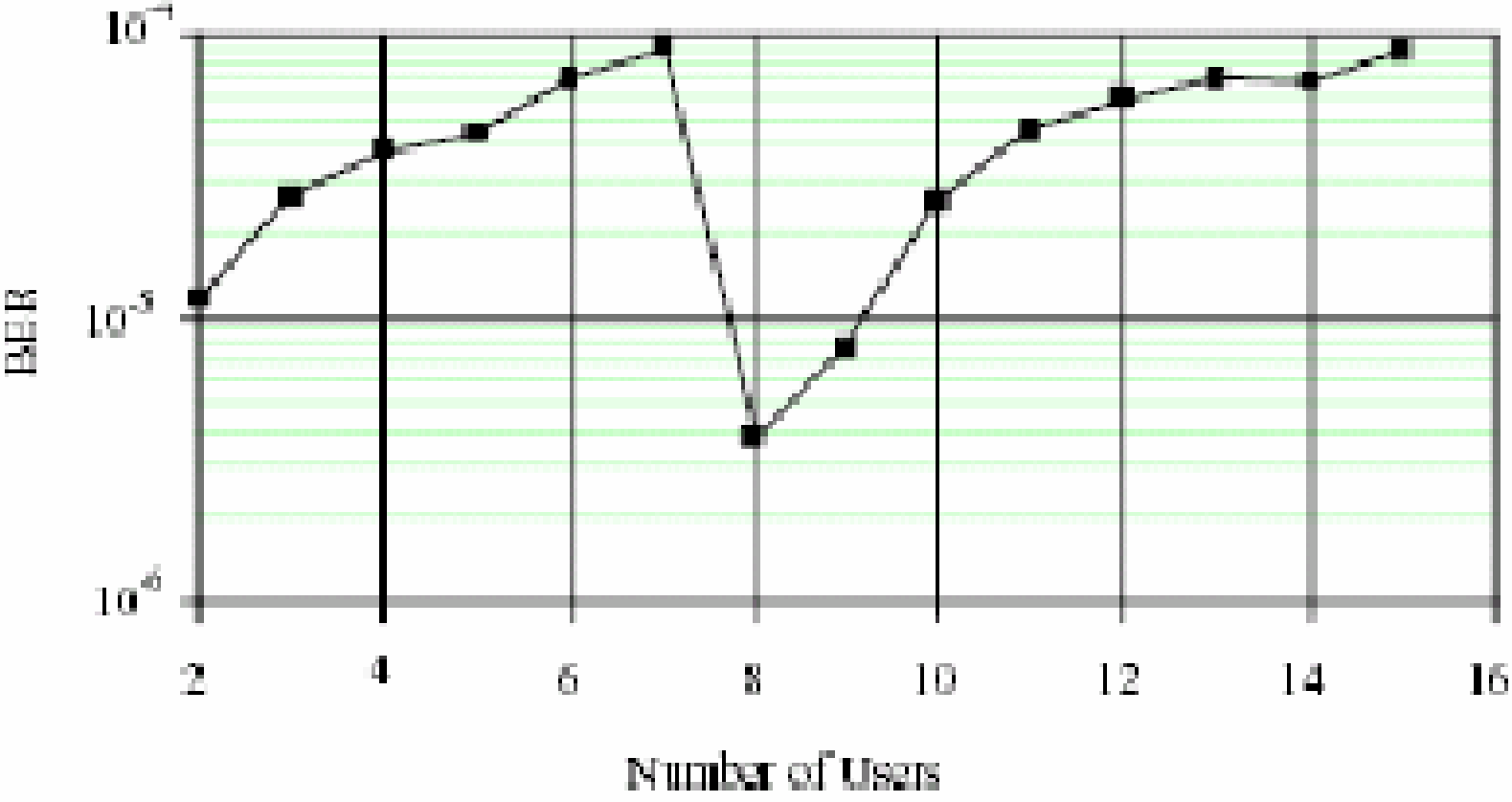


Figure : BER performance of adaptive M-ary CPM (M=2, 4) MC-CDMA system with CSNR=15dB

Conclusion

- 4G can be imagined of as an integrated wireless system that enables seamless roaming between technologies.
- A promising 4G can support interactive multimedia services with wider bandwidths, and higher bit rates.
- 4G still to come.

HW

- Define the 4G, its motivation, new things, and main 4G network features and compare it to 3G.
- What is WWRF? And what are its objectives? What is the WSI (Wireless Strategic Initiative) project ? And what are the WSI's project objective?

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Thank you!

Q&A's