Bottlenecks of Mobile Evolution

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Member of Nokia Executive Board
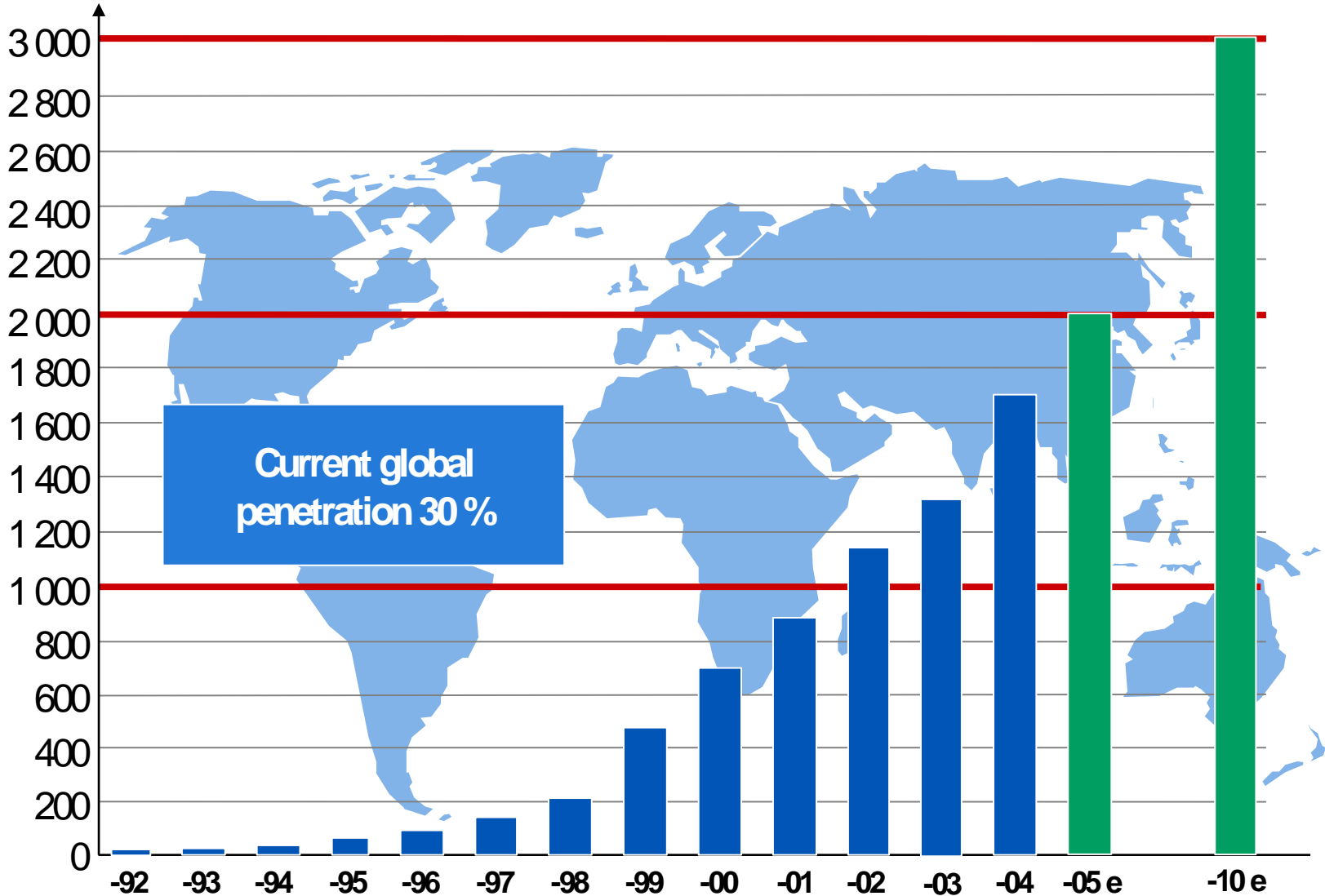
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Contents

- Growing markets
  - GSM
  - WCDMA

- Growing expectations
  - Terminals
  - Services

- Challenges with Technologies
  - From processing to display trends

- Challenges with Product Creation
  - Business ecosystem

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2 Billion mobile service subscribers and growing

3 billion by 2010

Mobile phone subscriptions globally, millions

Current global penetration 30 %

Source: Nokia at 3GSM Cannes, February 2005

x-axis: -92 -93 -94 -95 -96 -97 -98 -99 -00 -01 -02 -03 -04 -05 e -10 e

y-axis: 0 200 400 600 800 1 000 1 200 1 400 1 600 1 800 2 000 2 200 2 400 2 600 2 800 3 000

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GSM market today

Western Europe
364 millions

Eastern Europe
195 millions

USA / Canada
56 millions

Asia & Pacific
516 millions

Middle East
71 millions

Central and
South America
81 millions

Africa
85 millions

Altogether 1,368 billion subscribers in the world

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Regional differences increase - Strong subscriber growth in emerging markets

Mature EMEA deploys WCDMA

Multi-radio access devices will first become more prevalent in US

APAC leads service and technology innovation in both WCDMA and CDMA

Strong subscriber growth in emerging markets

Cumulative subscriptions by region

Subscription net adds by region
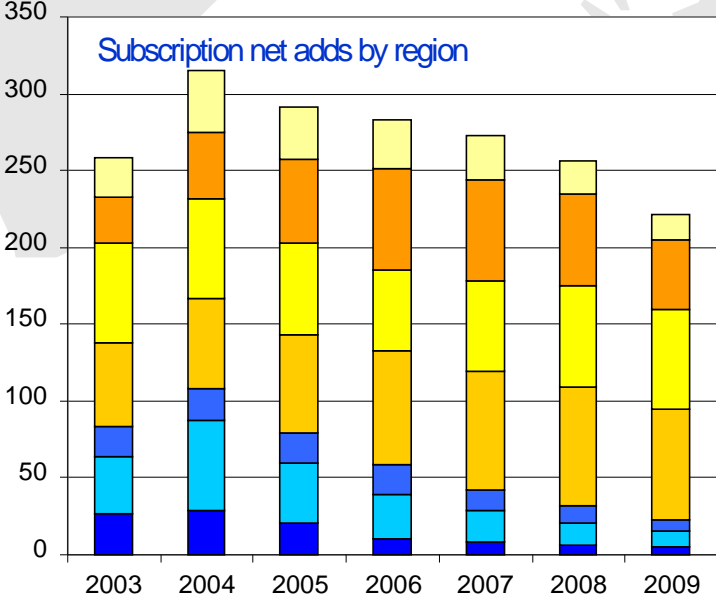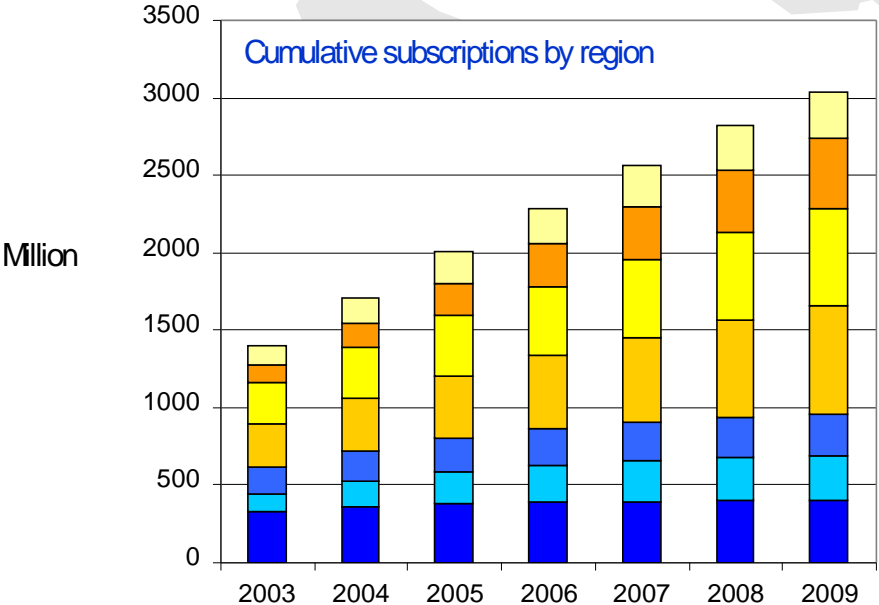
Legend:
- Latin America
- MEA
- China
- APAC
- North America
- Eastern Europe
- Western Europe

Million

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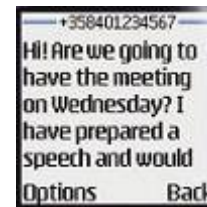# Over 35 million WCDMA subscribers in October 2005

- The highest growth rate of any mobile technology today

- Faster subscriber growth than in GSM in its early days

- 67 commercial WCDMA operators in 31 countries

- In April 2005 150 WCDMA hand set models

WCDMA global subscribers
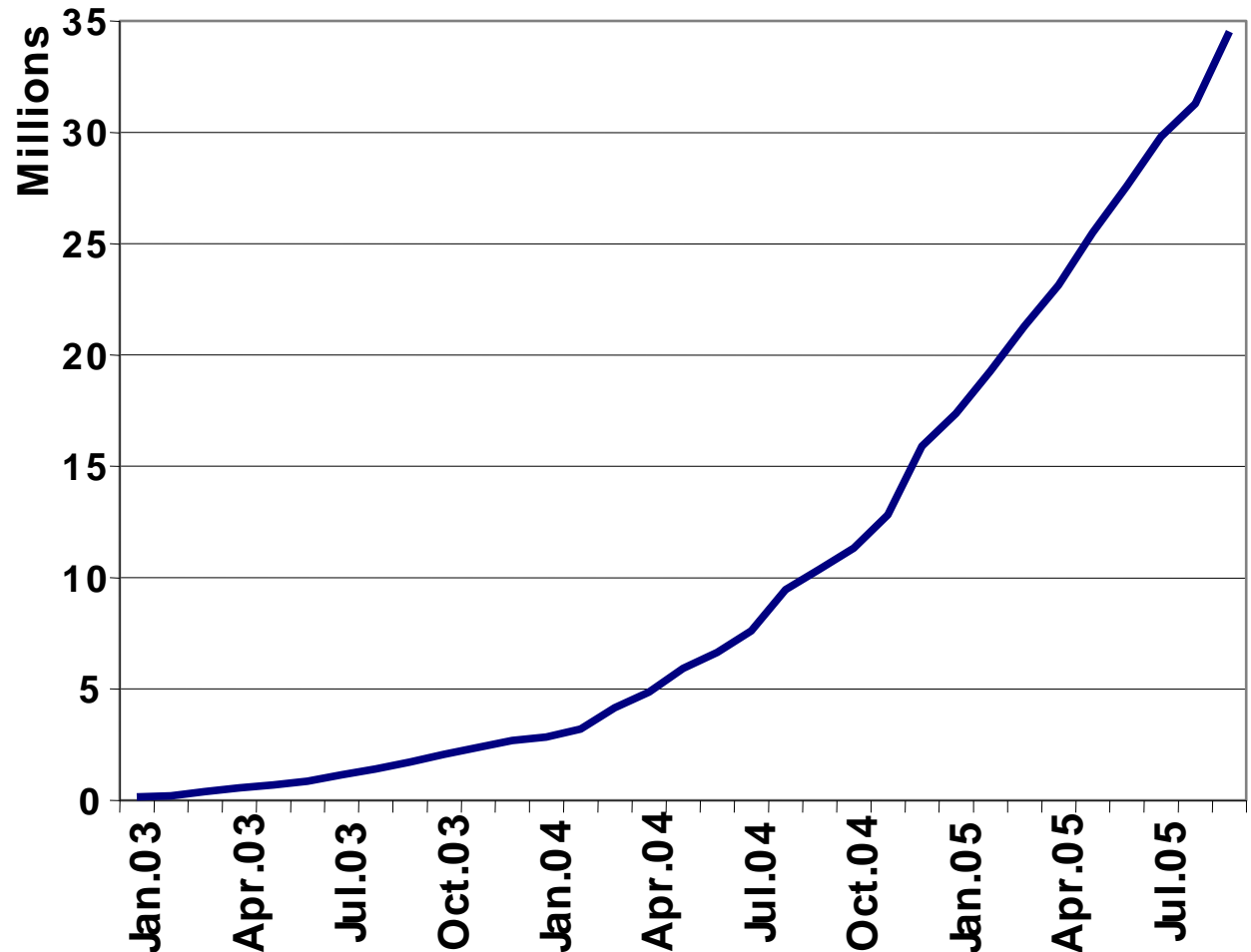
Source: (EMC database, TCA Japan, Press 06.10.05)

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Expectation of Convenience and Simplicity

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Complexity Calls for Very Human Technology

More applications

Imaging

TV

Browsing

Music

Gaming

Navigation

Email

SMS

Cameras

IP

Voice

Software

2G

3G

Multiradio

Increasing complexity

More technologies

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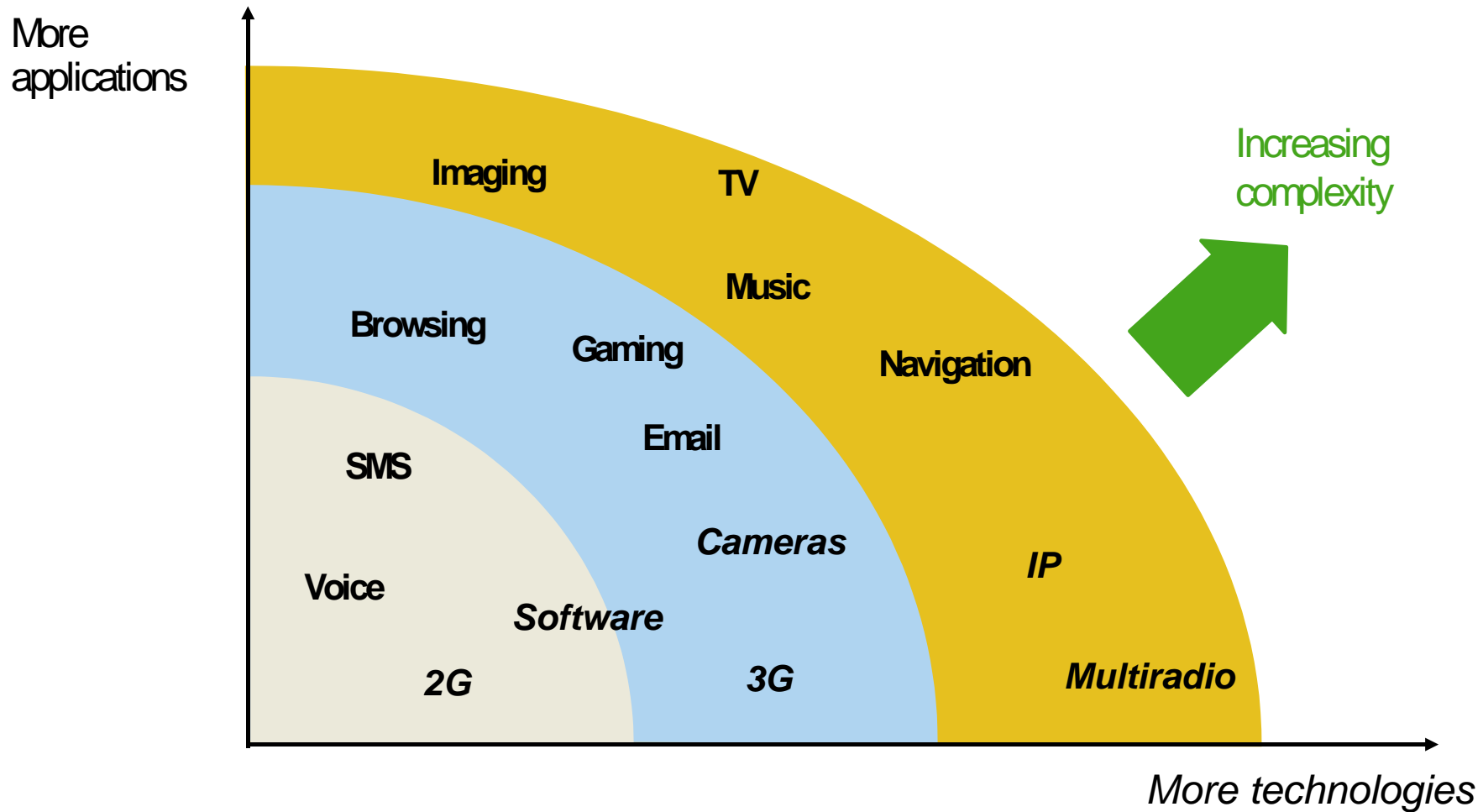
Technology Trends

Future usage sets new challenges

- Heavy usage of device
- Multimedia
- Convergence & Internet
- New applications
  - Business domain
  - Entertainment domain
- Gaming
  - Specially over network
- Computation power
- Data storage
- Data traffic
- 3G evolution, multiradio

Display PPI Evolution in Mobile Phones

Limit of human eye resolution (depending on age, etc.)

Convergence Products

Smart phones

Voice centric

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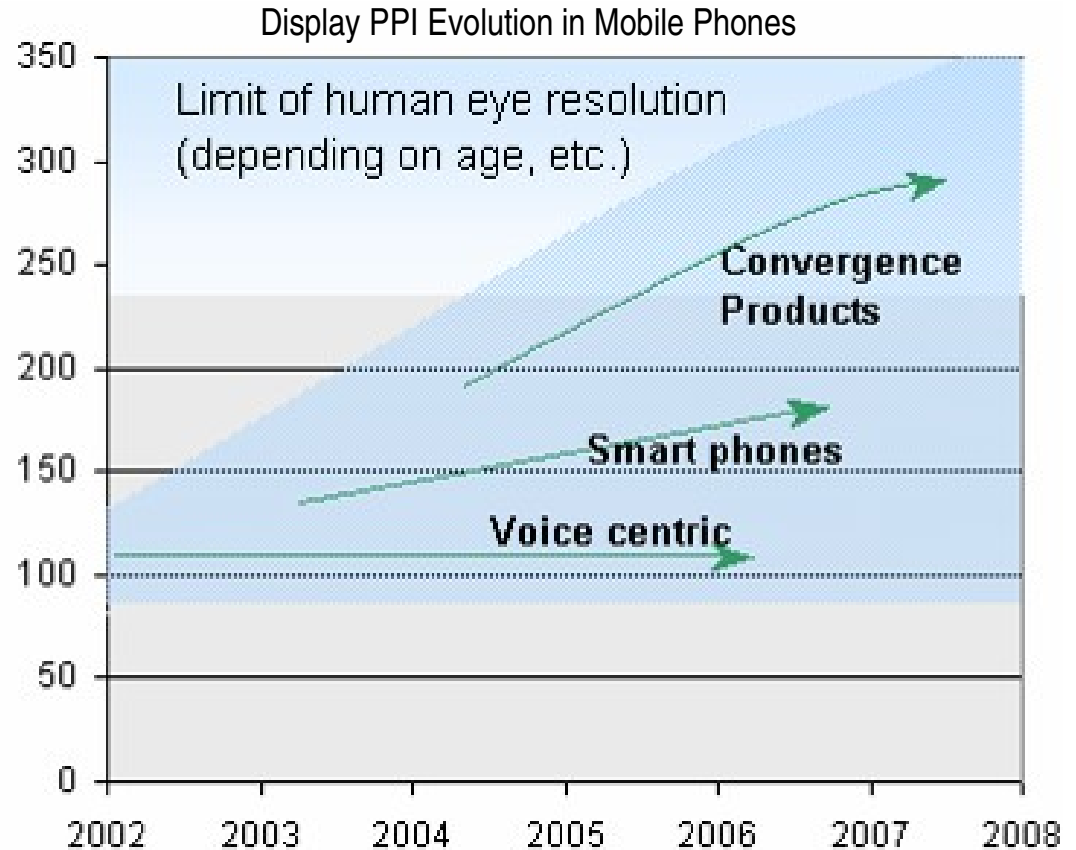
Key Emerging Technologies

- **Mobile TV**

- **Graphics:** 3D graphics and animation (e.g. Flash) will be common in UI and applications and scalable vector graphics (SVG) will move from dedicated gaming devices to mainstream.

- **Storage**: memory cards (SD, MMC) will provide removable memory up to 2 Gb and integrated hard disks with 2-8Gb will be available starting in high-end in 2005 and moving to mid-range by 2008.

- **Near field communication (NFC)**

- **Sensors** for detecting movement, location, direction and user activity will be available for integration in mobile devices. New application and service areas extending to fitness and healthcare can be enabled.

- **Handwriting and speech recognition** capabilities of mobile devices will improve following the development in PC world. Touchscreen/pen based messaging and speaker independent voice dialing will be available for mass-market devices.

Contents – Challenges with Technology

- Processing capability

- Data rates

- Signal Processing
    - Radio DSP
    - Application DSP

- Multimedia
    - Display
    - Camera

- Terminal architecture and power consumption

- User expectations

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Most Demanding Use Cases

Video recording

- Handling of video stream is seen to be one of the most demanding from performance point of view

Mobile TV

- Video encoding and decoding of D1 (TV) resolution at 30 fps

Still imaging

- Still Image encoding of up to 10 M pixels, snap-to-snap below 0.5 s
- View finder raw data to XGA display with delay less that 100 ms

Video call

- Video call using VGA resolution sensor

- The challenge in office environment comes mostly from multiple simultaneous applications rather than individual application performance
- Audio applications like 3D audio require processing power, but that is less demanding than video performance requirements.

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System Level Understanding Needed

- System design approach
  - Complex HW, SW
  - Integration challenge (size, cost, time-to-market, performance)
  - Not strictly HW or SW design
  - Carefully balancing the HW/SW partitioning

- Power management is vital
  - Energy resources and heat dissipation are very limited
  - Modular design
  - Reasonable communication scheme

- Multimedia systems are not only computation-bound but also communication-bound
  - Limited bandwidths
  - Memory architecture
  - Local buffers, streaming
  - Arise Quality of service issues

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New Technology Requires Advanced Processing

1979

Intel 8086 processor
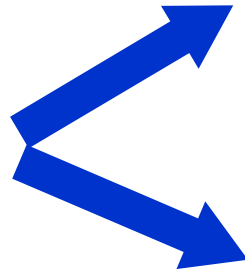
2004

Nokia 6630

27-fold complexity

30-fold performance

2003

Nokia HS-3W

5-fold complexity

2.5-fold performance

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Complexity Estimates

- Current SISO (e.g. WLAN)

  - 64FFT   1538 Multiplications /4 us

  - Equalizer   256 Multiplications /4 us

  - Softbit-Generation: 192 Multiplications / 4 us

    ~0.5 GMult/s

- Future MIMO (e.g. 3.9G)

  - 4* 1kFFT   163840 Multiplications / ~30 us

  - QRD-M   ~350k Multiplications / ~ 30 us (10 Additions   1 Mult)
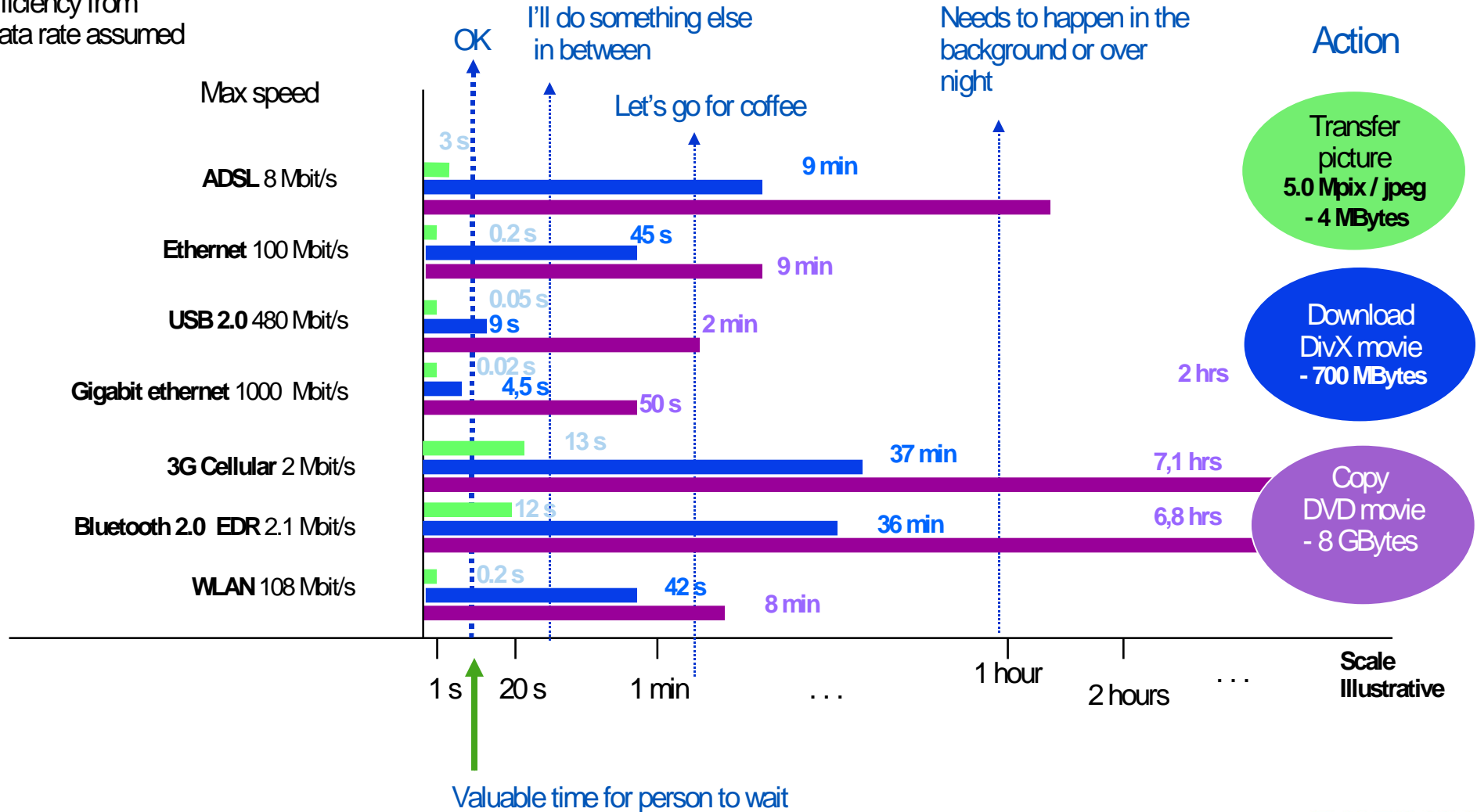
    ~ 17 GMult/s

    Simplified Examples!
    (only mults from FFT to Softbit out, no control, ..)

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100++ Mbps wireless connectivity is needed for good user experience

80% efficiency from
peak data rate assumed

OK

I'll do something else
in between

Needs to happen in the
background or over
night

Let's go for coffee

Action

Max speed

FIXED

ADSL 8 Mbit/s
- 3 s
- 9 min

Ethernet 100 Mbit/s
- 0.2 s
- 45 s
- 9 min

USB 2.0 480 Mbit/s
- 0.05 s
- 9 s
- 2 min

Gigabit ethernet 1000 Mbit/s
- 0.02 s
- 4,5 s
- 50 s

WIRELESS

3G Cellular 2 Mbit/s
- 13 s
- 37 min
- 7,1 hrs

Bluetooth 2.0 EDR 2.1 Mbit/s
- 12 s
- 36 min
- 6,8 hrs

WLAN 108 Mbit/s
- 0.2 s
- 42 s
- 8 min

2 hrs

Transfer
picture
**5.0 Mpix / jpeg
- 4 MBytes**

Download
DivX movie
- 700 MBytes

Copy
DVD movie
- 8 GBytes

**Scale
Illustrative**

1 s | 20 s | 1 min | . . . | 1 hour | 2 hours | . . .

Valuable time for person to wait

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Wireless technology landscape becomes diverse
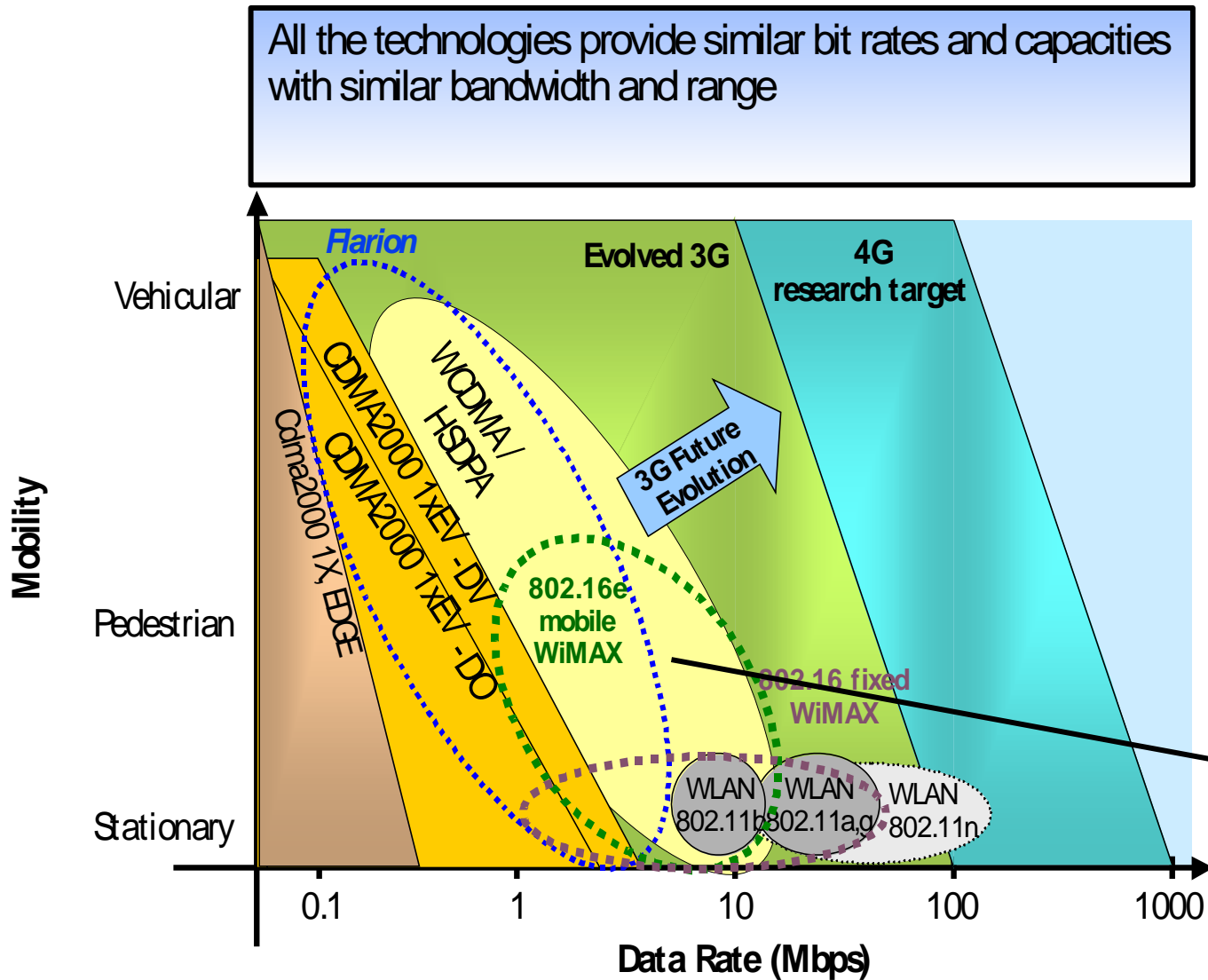
All the technologies provide similar bit rates and capacities with similar bandwidth and range

- (Mobile) Broadband Wireless Access seen as next evolution step for both cellular and fixed wireless Clash of business systems

- Players not strong in cellular technologies eager to push new technologies (WiMAX, Flarion)

WiMAX does not provide mobility – yet

Mobility (axis): Vehicular, Pedestrian, Stationary

Data Rate (Mbps) (axis): 0.1, 1, 10, 100, 1000

Flarion
Evolved 3G
4G research target
WCDMA/HSDPA
Cdma2000 1X EDGE
CDMA2000 1XEV - DV
CDMA2000 1XEV - DO
3G Future Evolution
802.16e mobile WiMAX
802.16 fixed WiMAX
WLAN 802.11b
WLAN 802.11a,g
WLAN 802.11n

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Signal processing in GSM

- GSM evolution (GPRS and EDGE) pushed some functions (Viterbi, bit equalizer) back to HW (UPPWD2, TIKUEDGE)

  - Similar performance boost was needed when WCDMA system functionality was added.

- In GSM the signal processing is done mostly with HW because of EDGE and multi-slot EGPRS requirements

  - Still old legacy GSM speech channel, which is mostly processed with DSP processor

  - Actually only applications, speech coders/decoders still need DSP type processing power

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OFDM

- OFDM seems to be the preferred solution in broadband wireless standards
  - Simpler digital receiver (=equalizer) at high data rates in multipath environment
    - Saves battery = good for mobile equipment
  - Lower analog-to-digital conversion rate
    - Synchronization works even at Nyquist rate
  - Little or no implementation penalty in transmitter
    - Same power efficiency in RF amplifiers as in single carrier when same bit/s/Hz used

- However, OFDM and MIMO concepts require much more signal processing than needed for the conventional cellular radios.

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Increasing Signal Processing Challenges in Wireless Access Modem

- Distributed architectures
  - Clearer logical and physical architecture enabling less power consumption in multifunction terminals.
  - Freeing up the processing capacity of the MCU to application software

- Increasing complexity in modem
  - Radio evolution from the GSM towards foreseeable 3G releases, HSDPA and HSUPA, MIMO
  - Increasing the role of signal processing.

- HW evolution driver to increase the signal processing requirements at RF
  - Software Defined Radio, HW configurable by SW
  - Increase the role of signal processing in the area of traditional radio technologies

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Display resolution grows

640 x 320
AM LCD

800 x 480
(Wide VGA)
AM LCD

SVGA/XGA
based

640 x 200
AM LCD

176x 208 (qCIF+)
AM LCD

128 x 160 (qqVGA)
AM LCD, PM LCD

352 x 416

HVGA, VGA
qVGA, qqVGA

240 x 320
(qVGA)
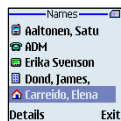
128x128, PM LCD, AM LCD

208 x 208

96x65/68, PM LCD
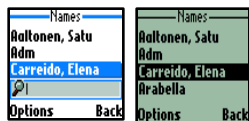
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Camera Capabilities

- Present situation
  - picture taken with Nokia S70, 2.0MPix

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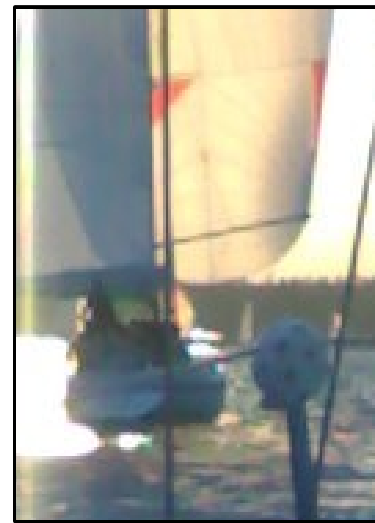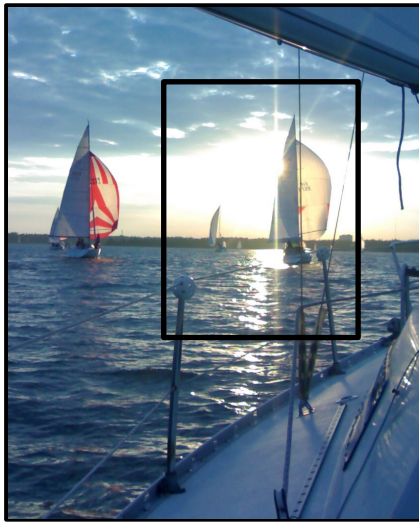
Challenges for Multimedia Signal Processing

- Fundamentally new compression technologies to keep up with the increasing
  - Quality in audio, imaging, and video
  - Image resolutions
  - Video resolutions and frame rates

- Is there need to separate still and moving picture
  - How about if high quality still images could be extracted from moving picture

- Robustness in object recognition and tracking

- Robust context- / content-aware speech / image / video recognition

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Architecture of a Cellular Device

...etc...

FM radio

DVB-H

WLAN

Bluetooth

Display

Camera

Input Device

STD
SDRAM

Application SW

Symbian OS

ASIC
Multimedia Chip

HW acceler.
DSP
MCU
SRAM

Protocol SW

ASIC
System Chip
GSM/EDGE/ WCDMA/ CDMA2000 RFIF

System Logic
DSP
MCU
SRAM

GPS

Antennas, RF

ASIC
Analog Chip
Audio Codec
BB regulators
Energy mgmt

STD
Memory Card

STD
Flash

STD
Flash

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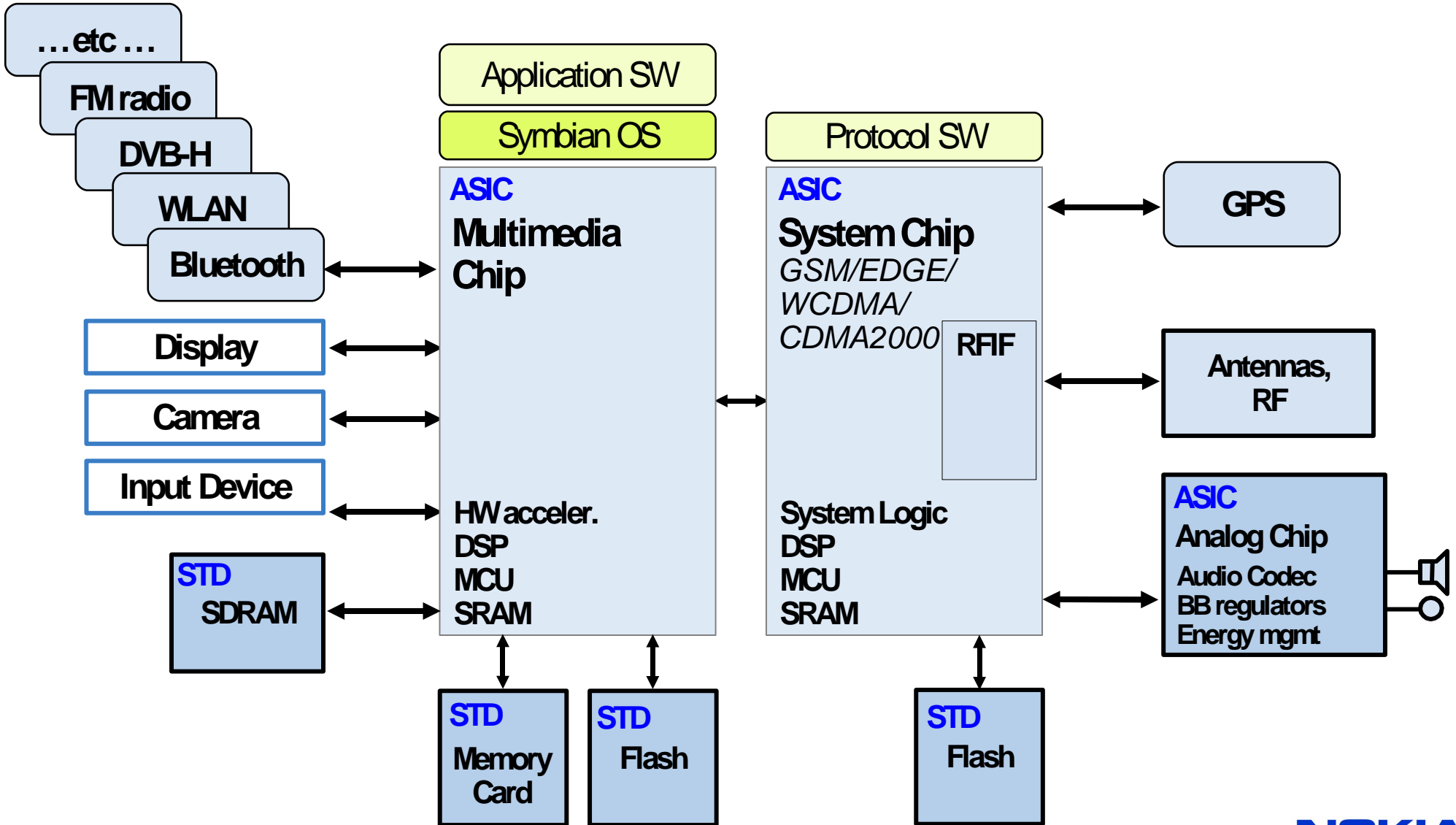
Physical level architecture – more and more complex

Sensor subsystem — I2C — Peripheral bus — Ext IO — Pre-processing ASIP

OMAP/Symbian — MCU, M DMA, SoC bus, Ext IO, Low-end Vector graphics subsystem

Storage — CF, Nano disk, MStick, Ext IO, Controller +Security +RM

Connectivity — BT, Irda, UART, I2C, USB, SSI, Ext IO, Peripheral bus

Interconnections & Protocols

High End Game Engine — Ext IO, SoC bus, MCU, M

Multiradio modem — RF, MCU L2/3, MCU L1, M DMA, Ext IO, SoC bus, WLAN, WCDMA, EGPRS

Imaging & Audio — Ext IO, MCU, SoC bus, Camera Subsystem ASIP, DMA M

High End 2D/3D Vector Graphics Engine — Ext IO, SoC bus, CTRL ASIP, Accelerator logic, Frame buffer

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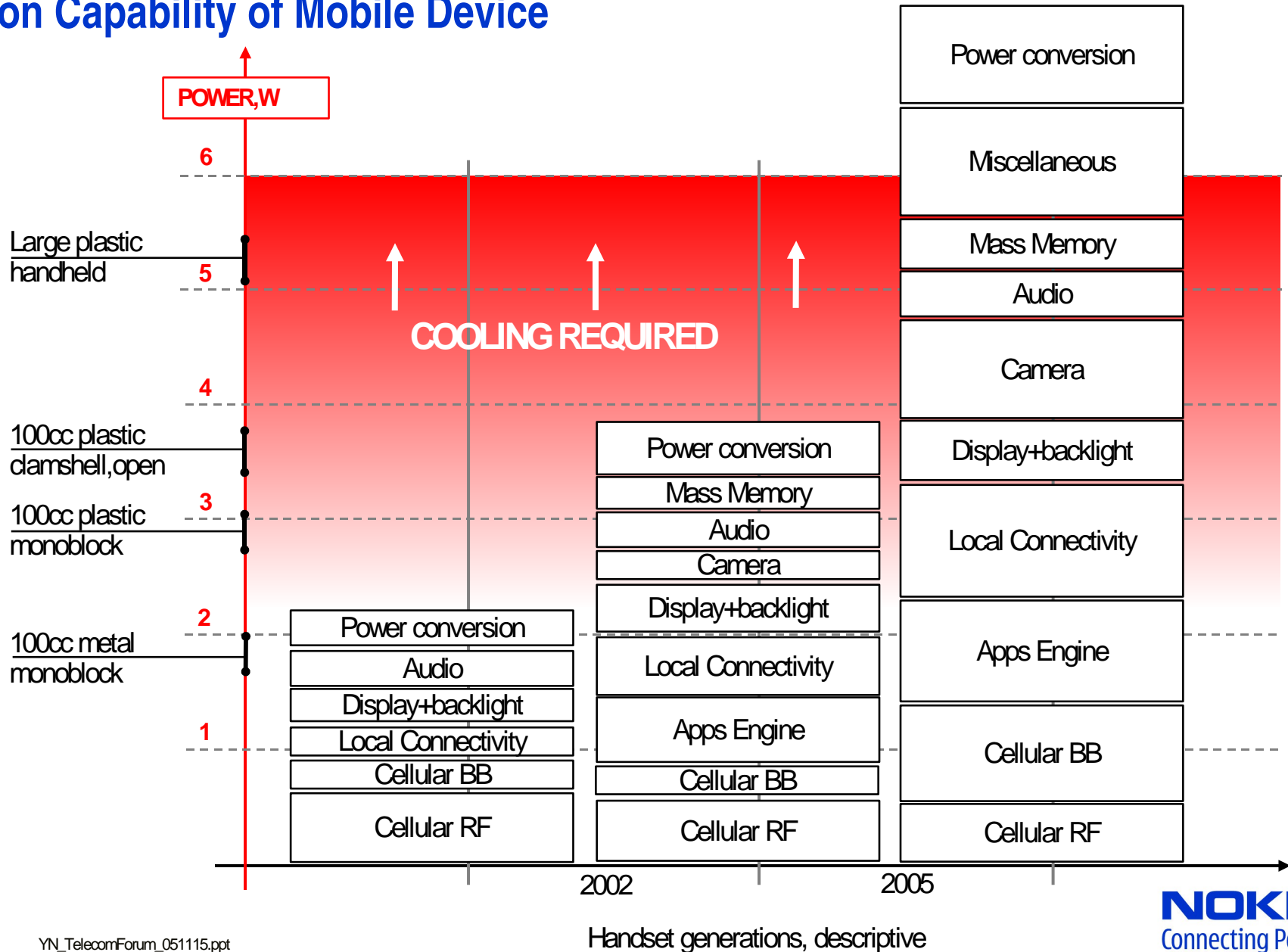**Connecting People**

Multiradio

- Diverging application needs are driving for diversity of radios

- Challenges with placing

- 2G/3G together with UWB, WLAN, RFID, Bluetooth, FM Radio, DVB-H, GPS, MIMO…

Antennas →

1   2   3   4 5 6   7

UWB RF ID FM 2G/3G Cellular diversity RX

WLAN Blue tooth DVB-H GPS

8   9   10   11

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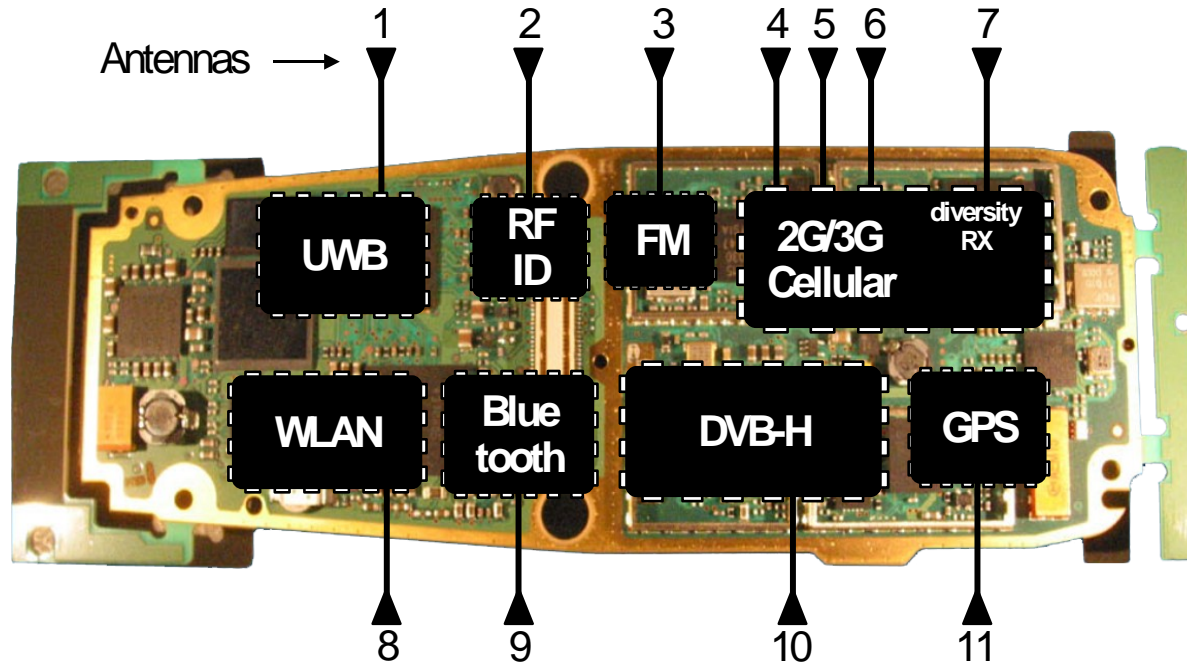
Gross Power Consumption Exceeds Thermal Dissipation Capability of Mobile Device

POWER,W

6

Large plastic handheld

5

COOLING REQUIRED

4

100cc plastic clamshell,open

3

100cc plastic monoblock

2

100cc metal monoblock

1

		Power conversion
		Miscellaneous
		Mass Memory
		Audio
		Camera
	Power conversion	Display+backlight
	Mass Memory	
	Audio	Local Connectivity
	Camera	
Power conversion	Display+backlight	
Audio	Local Connectivity	Apps Engine
Display+backlight		
Local Connectivity	Apps Engine	
Cellular BB		Cellular BB
Cellular BB	Cellular BB	
Cellular RF	Cellular RF	Cellular RF

2002   2005

Handset generations, descriptive

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Pure Technology is not enough

- It's not only about data rates but performance, cost, user experience, services
- When the tripod is in balance possibility for creation and usage of content emerges with user experience

Technological
Capability

Service
Offering

Cost
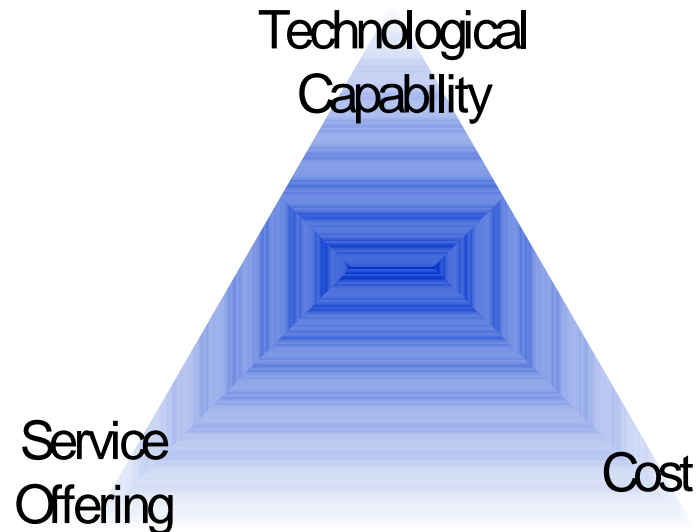
- Business ecosystem:
  - Content provider, Content aggregation, Invoicing, Transport provider(s), Technology providers

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Examples and Requirements

- Building successful ecosystem requires collaboration of several players

- **Mobile TV**
  - Terminals, program, broadcasting, invoicing
  - Competing technologies: DVB-H, DMB, ISDB-T, MediaFlo
- **Visual radio**
  - Terminals, content, broadcasting, servers, invoicing
- **Mobile Search**
  - Yellow pages, search engine, map database

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Creating a Product is Teamwork

- Fitting in all the required technology

- Iteration

- Refinement

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