Ambient Intelligence

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New Paradigm:

Ambient Intelligence (AmI) is the vision that technology will become invisible, embedded in our natural surroundings, present whenever we need it, enabled by simple and effortless interactions, attuned to all our senses, adaptive to users and context and autonomously acting. High quality information and content must be available to any user, anywhere, at any time, and on any device.

Ref.:
Menno Lindwer, Diana Marculescu, Twan Basten , Rainer Zimmermann, Radu Marculescu , Stefan Jung , Eugenio Cantatore:
Ambient Intelligence Visions and Achievements: Linking Abstract Ideas to Real-World Concepts.

Philips Research, Eindhoven, The Netherlands, Carnegie Mellon University, Pittsburg, PA, USA, Eindhoven University of Technology, Eindhoven, The Netherlands, European Commission, Brussels, Belgium, Infineon Technologies, Corporate Research, Emerging Technologies, Munich, Germany

AMI

The Ambient Intelligence vision is abstract and as such not useful for funding decisions, research project definition, and business plan development. This is in particular the case for the electronic design community. The European Commission intends for the EU to achieve world leadership in Information Societies technologies within ten years.
To that end, it has incorporated the Ambient Intelligence vision in its Sixth Framework. Microelectronics and nanoand optical devices are seen as key technologies. Interesting chip-level challenges are found in, amongst others, explicit modeling of mobility and self-management, and novel computing substrates, based on electronic textiles or organic electronics.

Ambient Intelligence Visions and Achievements: Linking Abstract Ideas to Real-World Concepts

FP6

RESEARCH

INFORMATION SOCIETY TECHNOLOGIES

Introduction

The 'all-communicating' world

In less than 20 years, the phenomenal progress in information technologies and telecommunications has immersed us in an all-communicating world. Computers, telephones, televisions, domestic appliances and cars are packed full of electronics for the exchange of data and information and providing 'intelligent' services designed for maximum efficiency and user comfort. Work, business, administration, health, culture, education… the 'e' prefix has been appended to just about every area of human activity. The information and knowledge society is changing our lifestyles and even our psychological and social behaviour.

http://ec.europa.eu/research/fp6/

FP6

The age of ambient intelligence

For maximum economic and social impact, research on information society technologies must concentrate on the future so-called convergence generation. This involves integrating network access and interfaces into the everyday environment by making available a multitude of services and applications through easy and 'natural' interactions. This vision of 'ambient intelligence' (interactive intelligent environment) places the user, i.e. the human being, at the centre of the future development of the knowledge-based society.

Objectives

- To stimulate the development in Europe of hard-ware and software technologies and applications at the heart of the creation of the information society.
- To increase the competitiveness of European industry and give European citizens in all EU regions the chance to benefit fully from the development of the knowledge-based society.

Budget
€ 3 625 million

http://ec.europa.eu/research/fp6/

What is Ambient Intelligence?

"Ambient Intelligence is a distributed network of intelligent devices that provides us with information, communication and entertainment."
"Ambient Intelligence is a network of hidden intelligent interfaces that recognize our presence and mould our environment to our immediate needs."
"Ambient Intelligence refers to an exciting new paradigm in information technology, in which people are empowered through a digital environment that is aware of their presence and context and is sensitive, adaptive and responsive to their needs, habits, gestures and emotions."

Ambient Intelligence: The Vision of Information Society,
BWZ der Universität Wien, Sommersemester 2002

Ambient Intelligence is based on three key technologies:

- Ubiquitous Computing,
- Ubiquitous Communication and
- Intelligent User Interfaces.

Ambient Intelligence: The Vision of Information Society,
BWZ der Universität Wien, Sommersemester 2002

AMI

Ubiquitous Computing

means the integration of microprocessors into everyday objects like furniture, clothes or toys.

Ubiquitous Communication

should enable these objects to communicate with each other and with the user.

Intelligent User Interface

enables the inhabitants of the AmI to **control** and interact with the environment in a natural (voice, gestures) and personalized way (preferences, context).

Ambient Intelligence: The Vision of Information Society, BWZ der Universität Wien, Sommersemester 2002

EU research efforts in Ambient Intelligence

Erkki Liikanen, Member of the European Commission for Enterprise and Information Society

"The world of Ambient Intelligence will, gradually but surely, emerge from research in the Information Society Technologies (IST) programme of the European Community.
It puts people at the centre of the development of future IST, i.e.'design technologies for people and not make people adapt to technologies'. It aims at making technology invisible, embedded in our natural surrounding and present whenever we need it (e.g. electricity) and at making interaction with the technology simple, effortless and using all our senses."

European
Science and
Technology
Observatory

Fraunhofer Institut Systemtechnik und Innovationsforschung

Science and Technology Roadmapping: Ambient Intelligence in Everyday Life (AmI@Life)

Michael Friedewald (Fraunhofer Institute Systems and Innovation Research ISI)
Olivier Da Costa (Institute for Prospective Technology Studies IPTS)

The Vision of AmI

The concept of Ambient Intelligence, being developed in the ISTAG reports (ISTAG 2001, 2002), provides a vision of the Information Society future where the emphasis is on userfriendliness, efficient and distributed services support, user-empowerment, and support for human interactions.

People are surrounded by intelligent intuitive interfaces that are embedded in all kinds of objects and an environment that is capable of recognising and responding to the presence of different individuals in a seamless, unobtrusive and often invisible way.

Michael Friedewald (Fraunhofer Institute Systems and Innovation Research ISI)
Olivier Da Costa (Institute for Prospective Technology Studies IPTS)

AmI@Life

The vision of AmI assumes a shift in computing from desktop computers to a multiplicity of computing devices in our everyday lives whereby computing moves to the background and intelligent, ambient interfaces to the foreground.

This vision of AmI places the user at the centre of future development. Therefore the technology should be designed for the people rather than making people adapt to the technology. It is less clear however, how this can be realised.

We propose to implement a holistic approach that takes into account that socio-technological systems always have three dimensions:
a technological, a social and a policy dimension.

Michael Friedewald (Fraunhofer Institute Systems and Innovation Research ISI)
Olivier Da Costa (Institute for Prospective Technology Studies IPTS)

AmI@Life

IST today	AmI
PC based	"Our surrounding" is the interface
"Writing and reading	Use all senses, intuitive
"Text" based information search	Context-based knowledge handling
Low bandwidth, separate network	Infinite bandwidth, convergence
Mobile telephony (voice)	Mobile/Wireless full multimedia
Micro scale	Nano-scale
Silicon based	new materials
e-Services just emerging	Wide adoption (e-Health, Learning,..)
< 10% of world population on-line	World-wide adoption

Michael Friedewald (Fraunhofer Institute Systems and Innovation Research ISI)
Olivier Da Costa (Institute for Prospective Technology Studies IPTS)

The Vision of AmI - Ambient Intelligence

- **The technological dimension**
- **The social dimension**
- **The policy dimension**
- **Trusted and Universal Access to Ami@Life**

Michael Friedewald (Fraunhofer Institute Systems and Innovation Research ISI)
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The social dimension

Social, economic and geo-political trends are influencing, to a major or minor extent, everyday life. Some of these are an ageing society, a mosaic society, a multi-cultural society, the European Enlargement, life-long-learning, consumerism, (anti-) globalisation, etc.

Many of them are triggered by IST developments and should thus be taken into account.

Michael Friedewald (Fraunhofer Institute Systems and Innovation Research ISI)
Olivier Da Costa (Institute for Prospective Technology Studies IPTS)

The policy dimension

According to the Lisbon European Council of 2000 and the e-Europe Action Plan (prolonged to 2005), the Commission is committed to ensure European leadership in generic and applied knowledge society technologies, to improve European competitiveness and to enable all European citizens to benefit from the knowledge society. The Lisbon process clearly stated that the European knowledge based society should also be a socially inclusive one.

This places topics of the digital divide and of access to ISTs on the policy agenda. Public policy is needed to address these issues. New technologies should not become a source of exclusion for society. Therefore security, trust and confidence were recognised as key bottlenecks for the deployment of AmI.

Michael Friedewald (Fraunhofer Institute Systems and Innovation Research ISI)
Olivier Da Costa (Institute for Prospective Technology Studies IPTS)

AmI@Life

Application areas for Ambient Intelligence in Everyday Life

- **Housing**
  - Home Automation
  - Communication
  - Rest, Relaxation, and Entertainment
  - Work and Learning
  - Acceptance Factors
- **Mobility and Transport**
  - Management of Multi-Modal Traffic Systems
  - Navigation
  - Safety
  - Mobile Information and Entertainment

Michael Friedewald (Fraunhofer Institute Systems and Innovation Research ISI)
Olivier Da Costa (Institute for Prospective Technology Studies IPTS)

Application areas for Ambient Intelligence

- Shopping and Commerce
  - E-business and E-commerce
  - Evolution of Retailing
- Education and Learning
  - Formal Learning
  - Non-Formal Learning
- Culture, Leisure and Entertainment
  - Cultural Heritage
  - Cultural Participation
  - Media
  - Entertainment
  - Sport & Fitness
  - Avatars

Michael Friedewald (Fraunhofer Institute Systems and Innovation Research ISI)
Olivier Da Costa (Institute for Prospective Technology Studies IPTS)

Application areas for Ambient Intelligence

- Health
  - Prevention
  - Cure
  - Care
  - Support

Michael Friedewald (Fraunhofer Institute Systems and Innovation Research ISI)
Olivier Da Costa (Institute for Prospective Technology Studies IPTS)

Enabling Technologies for Ambient Intelligence Applications

- Networking and Communication
- Microsystems and Electronics
  - Embedded Systems
  - Microprocessors
  - Memories
  - New electronic materials

Michael Friedewald (Fraunhofer Institute Systems and Innovation Research ISI)
Olivier Da Costa (Institute for Prospective Technology Studies IPTS)

Enabling Technologies

- **Software**
  - **Large-scale distributed systems**
  - **GRID Computing**
  - **Workflow management**
  - **Embedded systems**
  - **Lightweight Operating Systems**
  - **New and open standards**
  - **Advanced software engineering (robust development tools and platforms)**
  - **Plug and play**
  - **Self organising and repairing software**
  - **Personalization**

Michael Friedewald (Fraunhofer Institute Systems and Innovation Research ISI)
Olivier Da Costa (Institute for Prospective Technology Studies IPTS)

Enabling Technologies

- Knowledge Management
  - Semantic web
  - Ontology
  - Standards
  - Advanced data warehousing, Knowledge Data Discovery
- Artificial Intelligence
  - Cognitive vision
  - Speech recognition
  - Learning & adaptive systems
  - Context-sensitive & affective computing
  - Artificial Intelligent Agent
  - Perspective of Artificial Intelligence

Michael Friedewald (Fraunhofer Institute Systems and Innovation Research ISI)
Olivier Da Costa (Institute for Prospective Technology Studies IPTS)

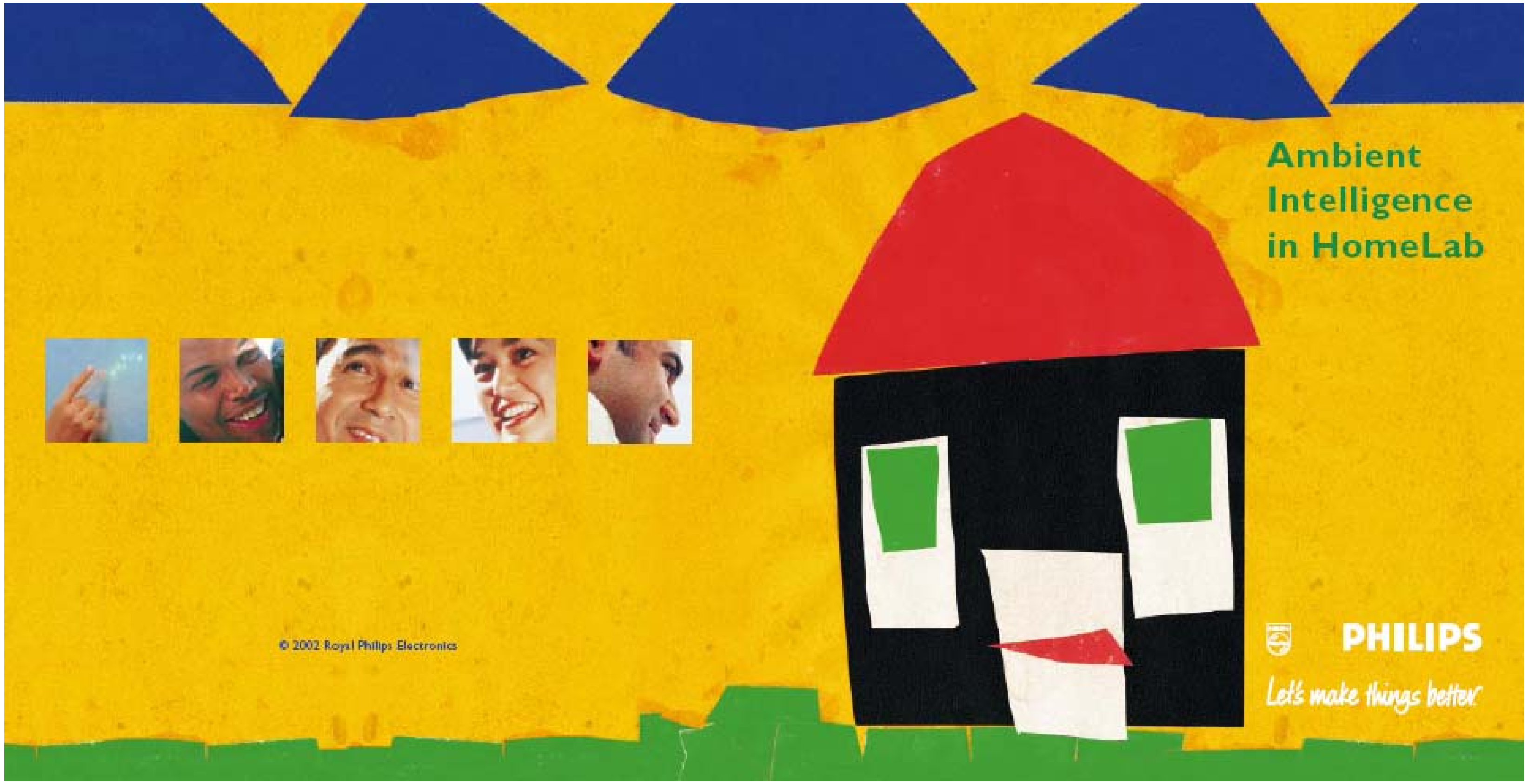
Enabling Technologies

- User Interfaces
- Displays
- Power Sources
- Trust & Security
  - Privacy, anonymity protection
  - Identity Management Systems
  - Digital rights management
  - Secure transactions & Payments
  - Dependability

Michael Friedewald (Fraunhofer Institute Systems and Innovation Research ISI)
Olivier Da Costa (Institute for Prospective Technology Studies IPTS)

AmI - Philips

Example: Philips HomeLab



AmI - Philips

Example Philips:

HOMELAB – advanced feasibility research lab

New system concepts

HomeLab has been designed to allow studies of novel system concepts, which today may still require a lot of equipment to realize, but which can be expected to become compact enough to disappear in the background in the near future. It allows studies of distributed home networking systems which require connecting different rooms and floors as found in a real-home environment.
By prototyping such systems in HomeLab, researchers can discover and solve the issues that emerge in such actual use environments.

AmI - Philips

Situational awareness

Ambient Intelligence systems are envisioned to be supportive, because they are aware of the users, and can adapt to their habits and wishes. Therefore, such systems need to include methods to discover the identity and location of users, devices and objects. Research projects are ongoing to develop optimal technologies, e.g. by investigating the behaviour of radio waves and ultrasound waves in an actual home environment, where furniture and moving people cause a much more complex reflection and transmission behaviour than in an outdoor environment.

AmI - Philips

Natural interaction

Speech is often considered one of the most natural modalities for interaction between users and ambient systems. Thus far, however, improvement of recognition rates in natural language dialogues, and even in the more limited command and control interactions, is hampered by echos and background noise in real environments, forcing users to wear microphones close to their mouths. Novel technologies are being developed to solve these problems, and HomeLab allows such solutions to be tested in a realhome environment. Similar problems are encountered when introducing other modalities, like gesture recognition. Gesture recognition is typically realized using video image processing. Again, whereas nice examples can be demonstrated in special rooms with well controlled light conditions, gesture recognition in a real-home environment, where doors open and close, people walk around, reflections occur from shiny surfaces and light conditions change continuously, requires the development of more fundamental solutions.

AmI - Philips

Mobile assistants

Mastering speech and gesture recognition allows studies into exciting further user interaction concepts, such as mobile, robotic personal assistants. These studies are also conducted in HomeLab. HomeLab provides the actual conditions that such mobile assistants have to be able to cope with, like staircases, multiple rooms and families with children.

AmI - Philips

Connectivity

The Ambient Intelligence systems aim at providing users with the freedom to choose what kind of information or entertainment they want when and where, e.g. on portable screens they can take with them as they move through the house. This means that such systems typically rely on ad-hoc wireless networking of devices. Depending on the type of device (mobile phone, PDA, portable PC, webtablet) and content (photos, films, messages), an appropriate wireless connection is applied, e.g. WLAN (802.11b or 802.11a) for large bandwidth, and Bluetooth or Zigbee for ultra-low power. Optimal systems will likely consist of a combination of such technologies, most of which operate in the same frequency band. HomeLab offers a realistic environment to test effects like mutual interference and the influence of walls and ceilings, and to study, for example, security mechanisms and bridging of networks in home.

AmI - Philips

Ubiquitous sound and vision

The key output modalities needed are sound (music, speech) and vision (images). Whereas today the latter is typically concentrated in one TV screen in the living room, future homes will have display solutions in any space where that is appropriate (kitchen, bedroom, etc.). They will range from small displays for messages to full-wall-sized displays for movies. Entirely new technologies will be required to realize such visions in actual home situations, e.g. where people do not have the room required for existing back-projection solutions, or the money for current large-flat-display technologies. Again, HomeLab offers Philips the opportunity to already create the experiences today that such future technologies will bring tomorrow.

AmI - Philips

Separating functions from boxes

Once the information is fully digital, and ubiquitous connectivity has been realized, it becomes possible to separate the functions actually desired by users (images, sounds) from the boxes that are needed to produce them, thus providing users with a much greater freedom. Users can, for example, choose to place the TV tuners or PCs out of the field of view, and eventually to let them disappear in the background. Many issues emerge when trying to realize such solutions in real-life circumstances, and HomeLab is a rather unique environment for learning how to solve them: in its ‘user spaces’ it provides all the actual elements found in a real house (e.g. walls blocking the infrared remote control), whereas through its ‘research spaces’ ambient solutions that require further miniaturization before they can be made ambient, can already be realized today.

AmI - Philips

Feasibility research

In the months up to the opening, HomeLab has already proven to be a valuable tool to study and demonstrate the feasibility of the novel system concepts developed in several Research projects, and to collect the feedback of visitors and users. Many more projects will populate HomeLab in the coming years.

Related Subjects:

- Ubiquitous Computing
- Pervasive Computing
- Nomadic Computing

English

Language Issues:

English
ubiquitous
Ubiquitous Computing
Similar meaning:
Pervasive
Nomadic Computing
Nomads

Ubicomp

The idea of ubiquitous computing as invisible computation was first articulated by Mark Weiser in 1988 at the Computer Science Lab at Xerox PARC.

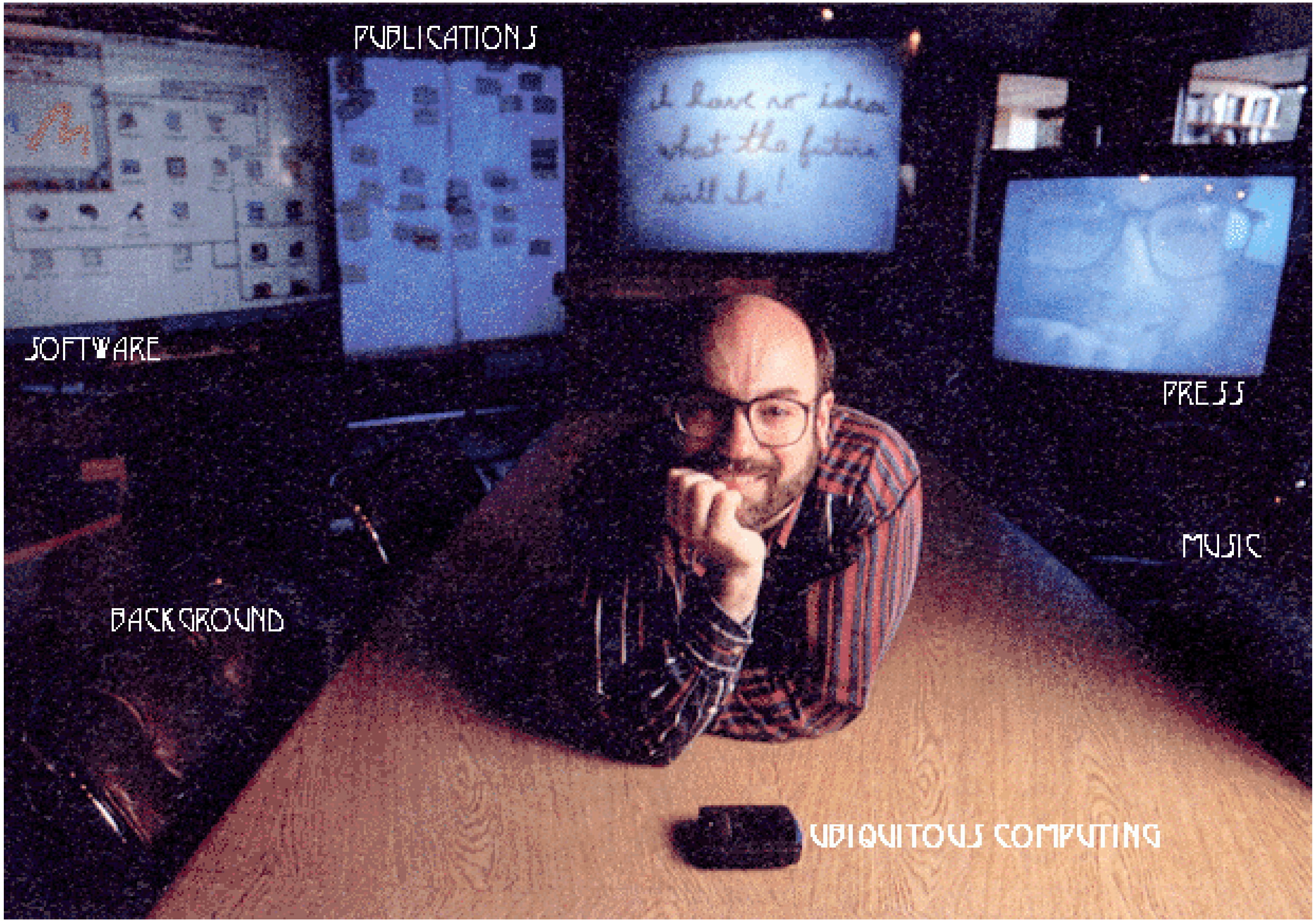
Mark Weiser
July 23, 1952 - April 27, 1999

Xerox PARC:
"*Palo Alto Research Center*"
(now "*Palo Alto Research Center Incorporated*")
http://www.parc.xerox.com/

parc® Palo Alto Research Center

Ref.:
`http://www.ubiq.com/hypertext/weiser/weiser.html`

Mark Weiser


PUBLICATIONS
I have no idea what the future will be!
SOFTWARE
PRESS
MUSIC
BACKGROUND
UBIQUITOUS COMPUTING

Some Computer Science Issues in Ubiquitous Computing

Mark Weiser
March 23, 1993

"Ubiquitous computing is the method of enhancing computer use by making many computers available throughout the physical environment, but making them effectively invisible to the user."

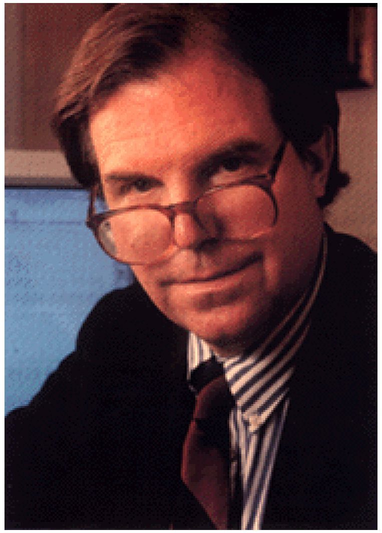
Ubicomp

Scientific American Ubicomp Paper

SCIENTIFIC AMERICAN.COM

Mark Weiser:
The Computer for the 21st Century,
Sci. Amer., 265 (3), 94-104, September 1991

"The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it."



Nicholas Negraponte - MIT Media Labs "Things that think want to link".

This is the doctrine on which pervasive computing is based!

Final Words

Mark Weiser:
The Computer for the 21st Century

"Most important, ubiquitous computers will help overcome the problem of information overload.

There is more information available at our fingertips during a walk in the woods than in any computer system, yet people find a walk among trees relaxing and computers frustrating. Machines that fit the human environment, instead of forcing humans to enter theirs, will make using a computer as refreshing as taking a walk in the woods."

ISTAG

Report from the Information Society Technologies Advisory Group (ISTAG)

March 2006

SHAPING EUROPE'S FUTURE THROUGH ICT

http://www.cordis.lu/ist/istag.htm

ISTAG

The next generation of ICT

Building on and extending the ambient intelligence vision, technology developments are proceeding along well characterised paths. We note four main trajectories for this next generation of ICT. Systems and services that are:

1. **Networked**, **mobile**, **seamless** and **scalable**, offering the capability to be always best connected any time, anywhere and to anything;
2. **Embedded** into the things of everyday life in a way that is either **invisible** to the user or brings new **form-fitting** solutions;
3. **Intelligent** and **personalised**, and therefore more centred on the user and their needs;
4. Rich in **content and experiences** and in **visual** and **multimodal** interaction.

http://www.cordis.lu/ist/istag.htm

Mobile Computing and related expressions:

- Ubiquitous Computing
- Pervasive Computing
- Nomadic Computing
- Wireless Networks (Wireless LANs)
- Wireless Application Protocol (WAP)
- Bluetooth
- Mobile IP
- mobile Agents

Ubiquitous Computing

New scientific area covering many diverse subjects in Computer Science and Telecommunications.

New area in teaching and research, covered by several international initiatives:

- **"Ubiquitous Computing"**
- **EU-Program "Disappearing Computer"**
- **U.S. Program "IT Expeditions into the 21st Century"**

Mark Weiser:

"Ubiquitous computing names the third wave in computing, just now beginning. First were mainframes, each shared by lots of people. Now we are in the personal computing era, person and machine staring uneasily at each other across the desktop. Next comes ubiquitous computing, or the age of calm technology, when technology recedes into the background of our lives."

Calm Technology

Reader

Ubicomp

Ubiquitous Computing

Computers everywhere.

"Making many computers available throughout the physical environment, while making them effectively invisible to the user".

"Ubiquitous Computing is fundamentally characterized by the connection of things in the world with computation".

Ubiquitous computing is considered the Third Wave of computing.

- **The First Wave was many people per computer.**
- **The Second Wave was one person per computer.**
- **The Third Wave will be many computers per person.**

Three key technical issues are: power consumption, user interface, and wireless connectivity.

Current Ubiquitous Computing

In its broadest sense, ubiquitous computing is currently seen to comprise any number of
mobile, wearable, distributed and context-aware computing applications.

In this way, Ubicomp may consist of research into
‘*how information technology can be diffused into everyday objects and settings, and to see how this can lead to new ways of supporting and enhancing people’s lives.*‘

Ref.:
The Disappearing Computer Initiative
(http://www.disappearing-computer.net)

Ubicomp

Current Ubiquitous Computing

‘Integration of physical and digital interaction.’

In addition to research in engineering, computer and hard sciences, continuing investigations in human-computer interaction and computer supported cooperative work draw on psychology, anthropology and sociology

Ref.:
EQUATOR Interdisciplinary Research Collaboration (http://www.equator.ac.uk).

Pervasive Computing:

The trend towards using computers in everyday life, not only including personal computers, but very tiny - even invisible - devices, either mobile or embedded - in almost any type of object imaginable, including cars, tools, appliances, clothing and various consumer goods - all communicating through increasingly interconnected networks.

What is Pervasive?

- Computation that is freely available everywhere.
- A scenario where all devices are networked, human-centric, communicate and interact with each other.

The 6As model of pervasive computing:

- The “authorized access to anytime-anywhere-any device-any network-any data”.

What makes a System ubiquitous:

- Embedded
- Networked
- Available Everywhere
- Context-Awareness
- New Devices

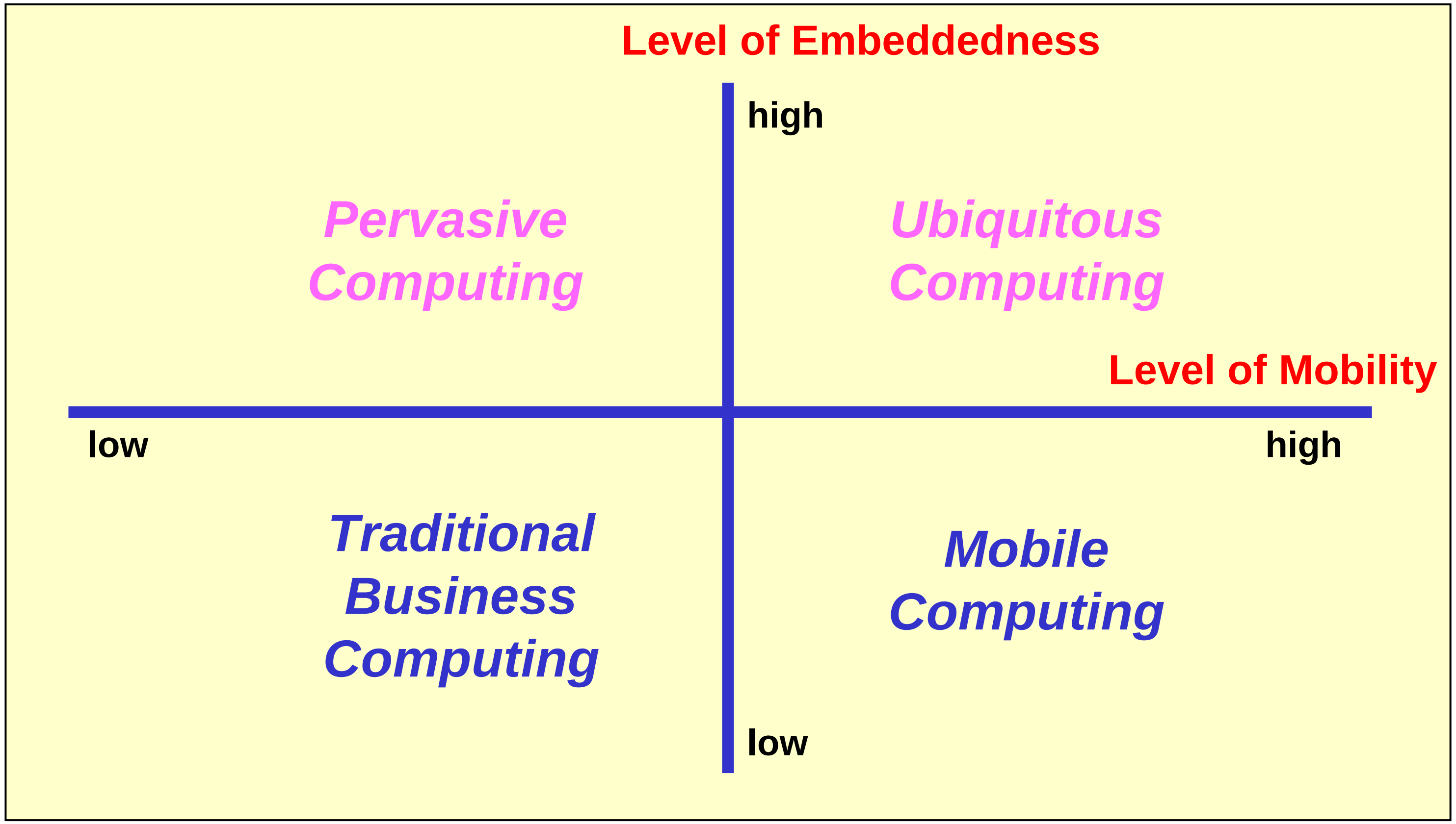
Nomadic computing:

What pervasive devices do is to connect nomadic users.

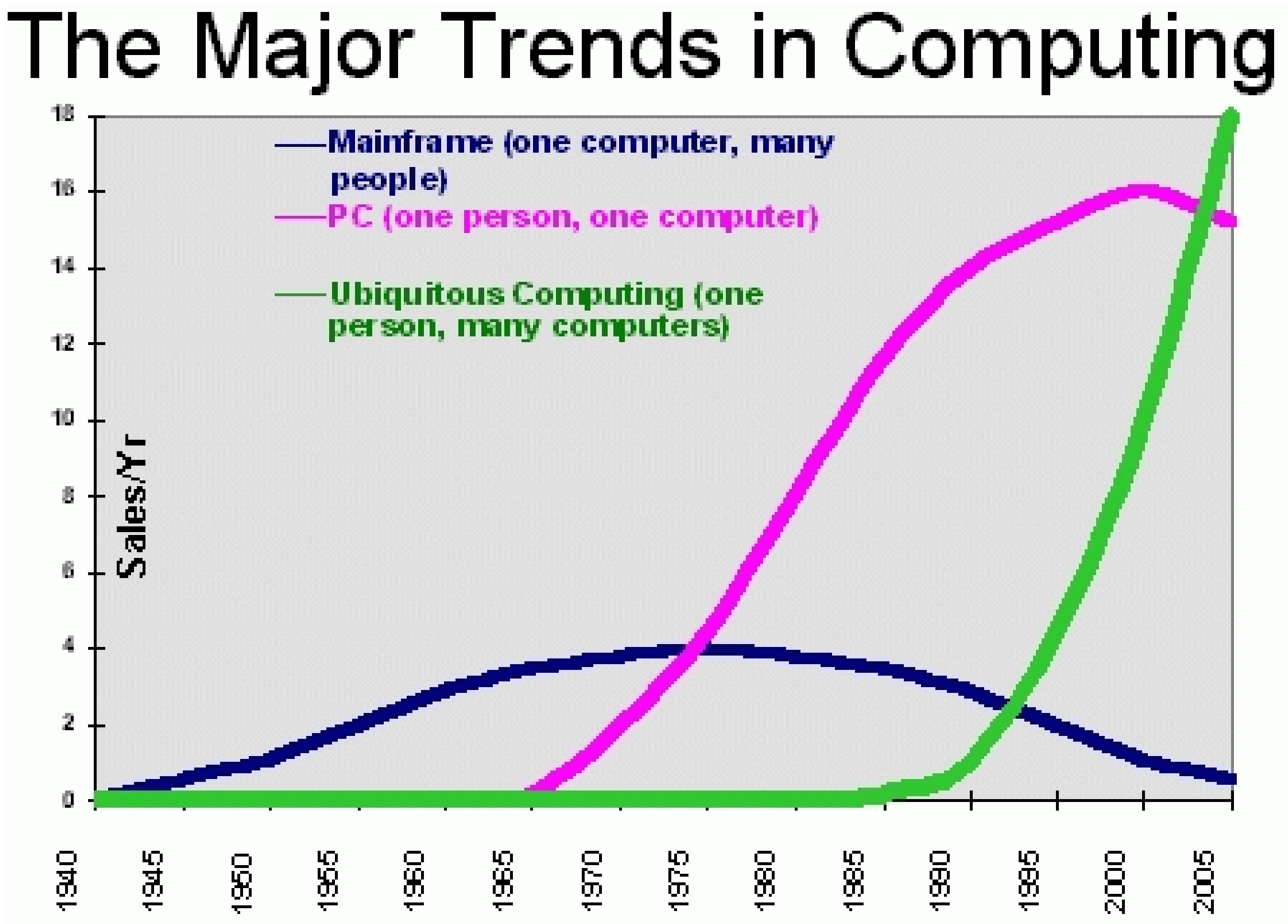
They can access different locations, URLs that point to specific content through barcodes, electronic tags, optical recognition methods and infrared and radio frequency transceivers available on PDAs (personal digital assistants) and laptops through direct or indirect sensing methods.

Trends in Computing

Pervasive Computing and modern Technologies:



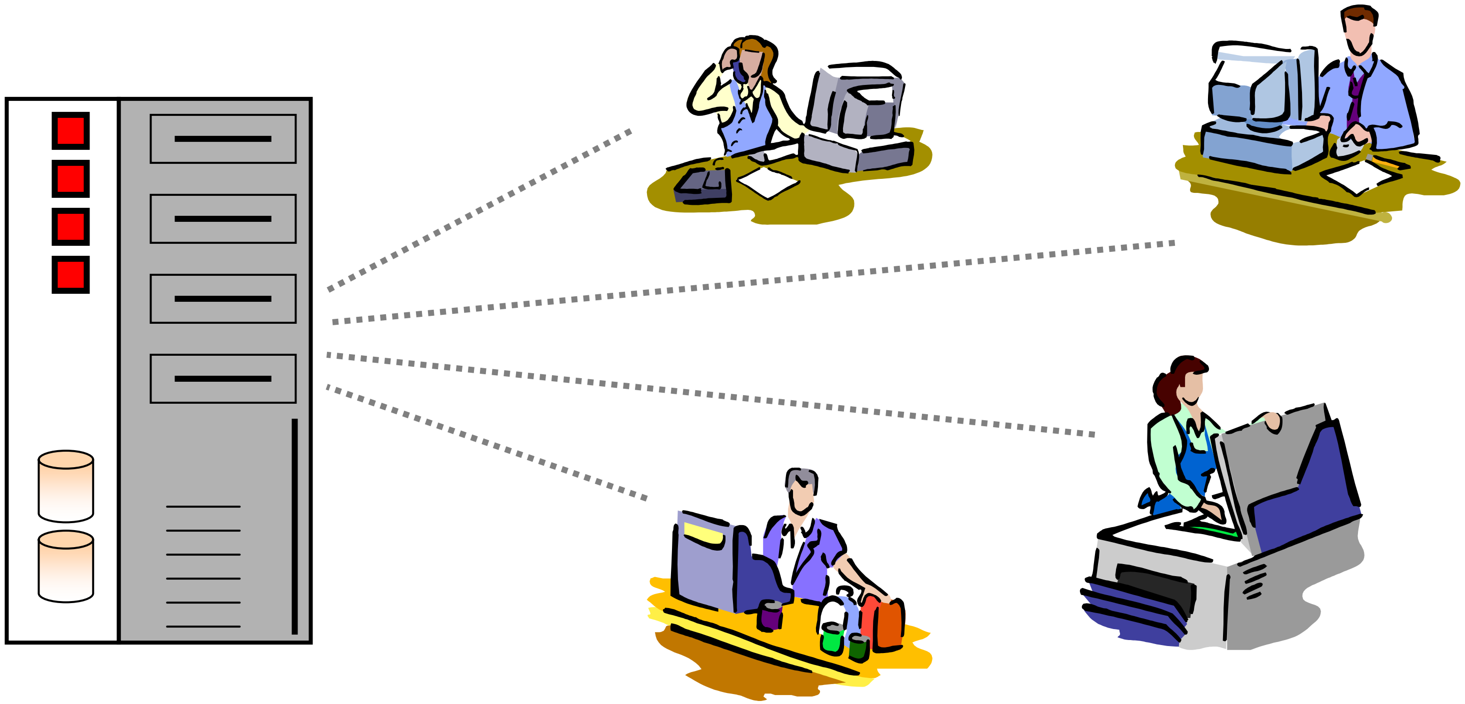
Trends in Computing



Trends

Mainframe Era:

- Many people share one computer



Trends

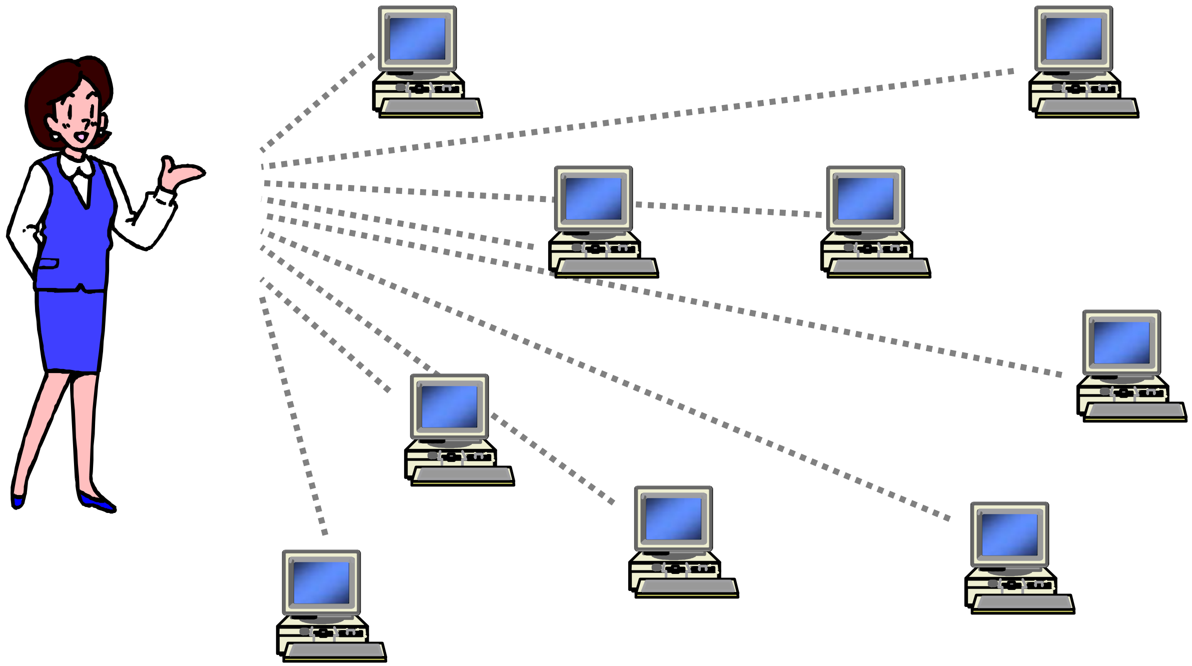
Personal Computer Era:

- One person with one computer

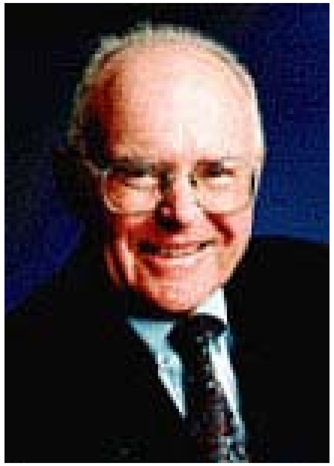
Trends

Ubiquitous Computing Era:

- Many computers serve each person



Moore's Law

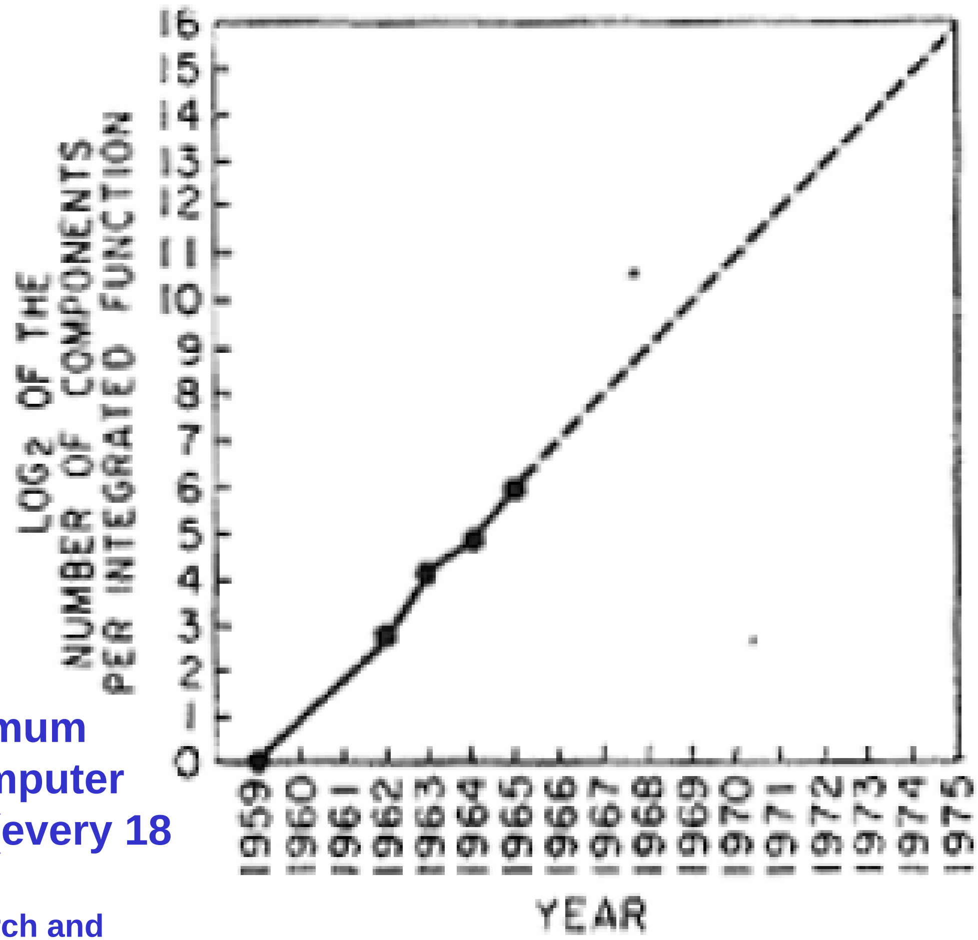


Gordon Moore

Co-founder of Intel in 1968.

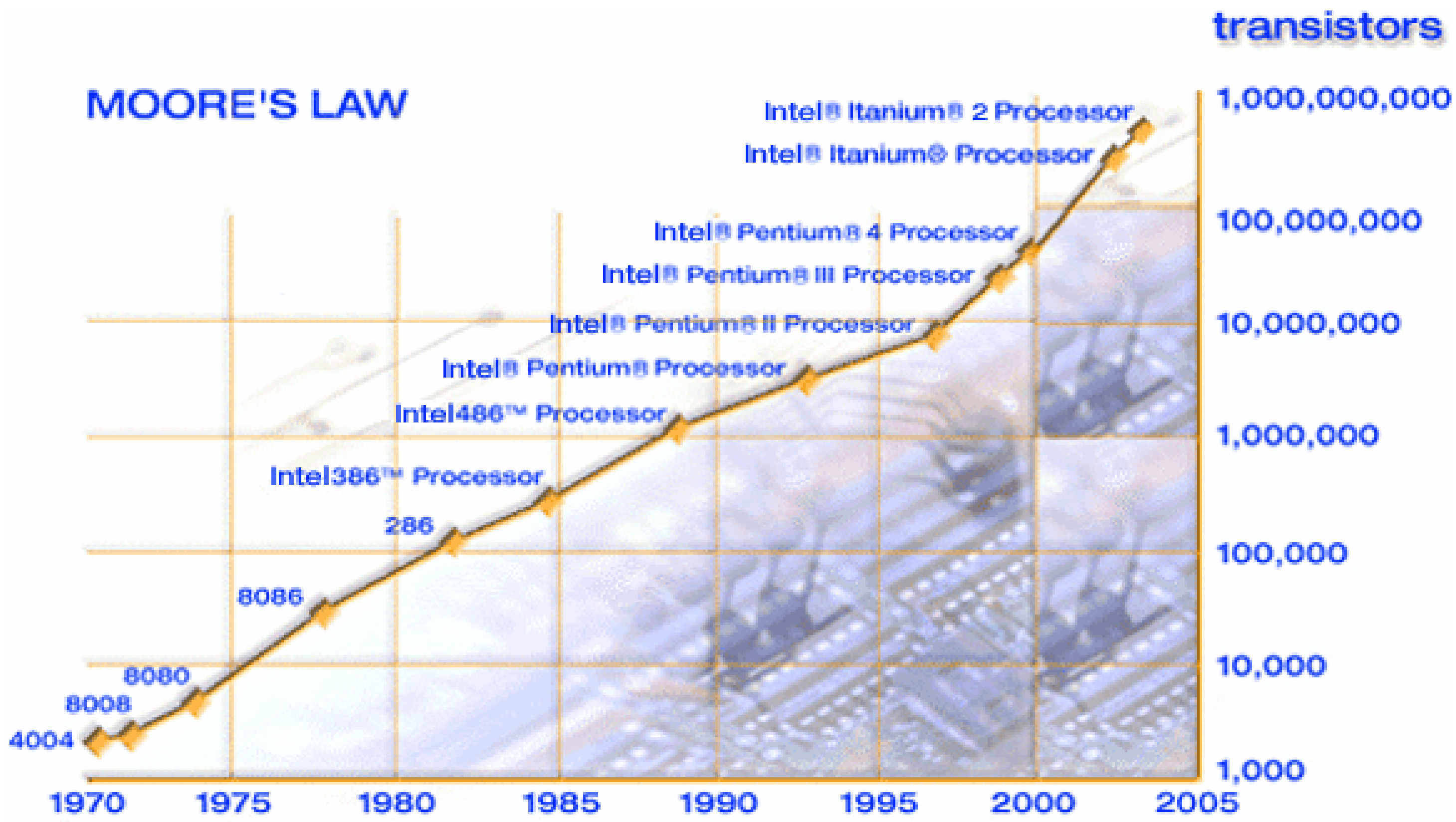
Moore predicted that the maximum number of transistors on a computer chip would double every year (every 18 months).

In 1965 Moore was Director at the Research and Development Laboratories, Fairchild Semiconductor division of Fairchild Camera and Instrument Corp.



Ref.: http://www.intel.com/research/silicon/mooreslaw.htm

Moore's Law



This trend may continue another 10 years (using current technology)

Reader

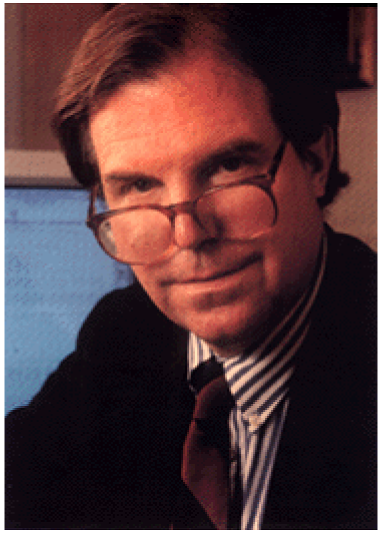
Moore's Law

"It's been 18 months and my computer's power hasn't doubled."

New Eras

“New eras of computing start when the previous era is so strong it is hard to imagine that things could be different”

David Culler, 1999
University of California Berkeley
Dept. of Electrical Engineering and Computer Sciences



Nicholas Negraponte - MIT Media Labs
"Things that think want to link".

This is the doctrine on which pervasive computing is based!

Nomads & Pervasive Computing

"I think there is a world market for maybe five computers"

Thomas Watson, CEO IBM, 1943

"Picture a day when a billion people will interact with a million e-businesses via a trillion interconnected, intelligent devices"

Louis V. Gerstner Jr., CEO IBM, 2005

Nomadics

Some implications of Nomadicity:

- Each persons uses many devices:
    - Total number of nomadic devices >> number of people
- Large number of fixed devices:
    - Many computers embedded in environment
    - Nomadic devices must interact with fixed infrastructure
- Many nomadic devices are essentially PC-peripherals.

Smart Devices

Hardware-architecture definition of "Smart Devices"
BILL of Things' rights (Things have right to):

- **Have an identity**
- **Access other objects**
- **Detect the nature of their environment.**

*Neil Gershenfeld. "**When things start to think**." 1999*

Neil Gershenfeld
Director of the Physics and Media Group at MIT's Media Lab.
Co-Director of the ***Things That Think*** consortium.

Smart Devices

Neil Gershenfeld:

Smart devices cover a continuum from passive electronic tags or minimal data-providing smart cards through networked sensors and actuators to intelligent devices and their networked services. The word "smart" does not in this context indicate a breakthrough in artificial intelligence or autonomousness of the devices in any strong sense

Smart Devices

Project Results

P946 Smart Devices "When Things Start to Think"

Strategic Study

Overview:

The essential message of this strategic study is an inconvenient one:
The upcoming paradigm shift towards Ubiquitous Computing is highly likely to change the IT and Telecommunications business considerably, probably more than the Internet changed Telecommunications a few years ago.

Ref.:
http://www.eurescom.de/public/projectresults/P900-series/946d1.asp

Smart Devices

Minimal definition of a smart device:

A physical object with an *embedded processor*, *memory*, *sensors* and/or *actuators*, and a *network connection*.

Features:

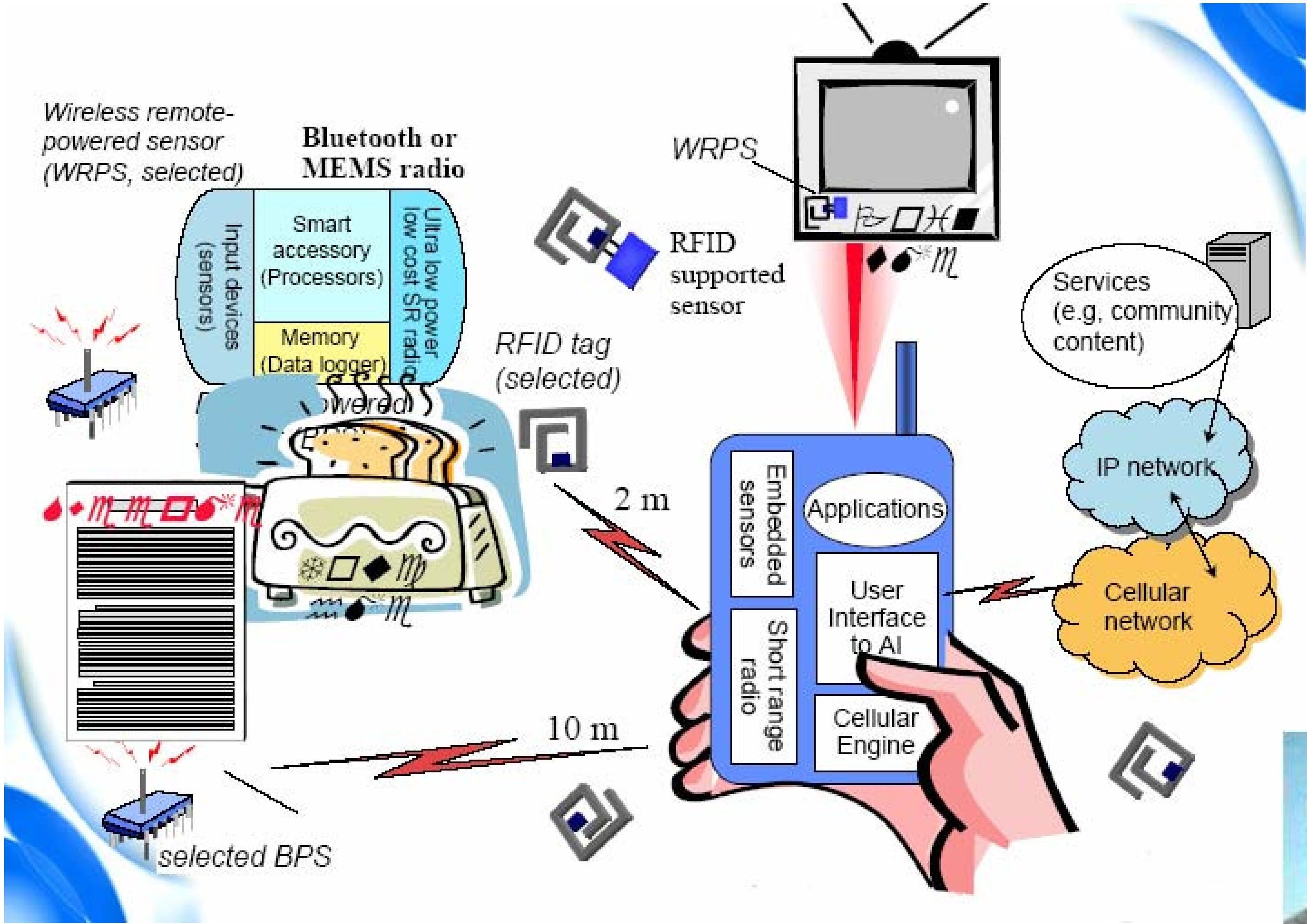
- **Ability to interact with its environment (i.e. as sensor and/or actuator) and/or a user. This is merely the ‘device’ requirement.**
- **Some portion of its interactive functionality observable and/or controllable over a network.**
- **Ability to, with the input from other networked devices if necessary, be able to change its state and its outputs to provide a service.**

Differences between

- a general purpose computer,
- a communication terminal and
- a smart device by the different text sizes

Project P946-GI,
Smart Devices “When Things Start to Think”, 2000

Functional Environment



Ref.:
Heikki Seppä, VTT Information Technology

Final Words

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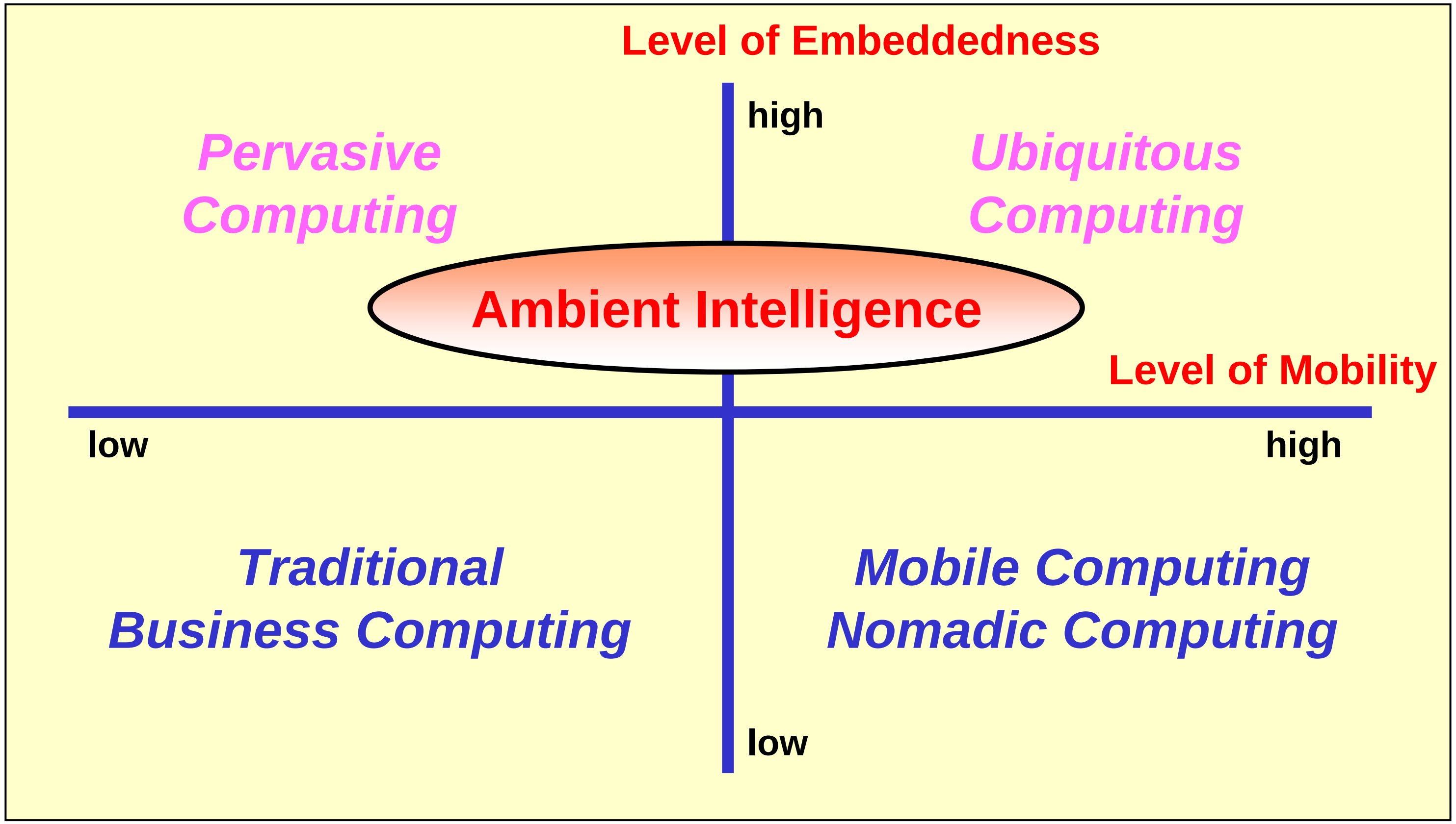
There is more information available at our fingertips during a walk in the woods than in any computer system, yet people find a walk among trees relaxing and computers frustrating. Machines that fit the human environment, instead of forcing humans to enter theirs, will make using a computer as refreshing as taking a walk in the woods."

Trends in Computing

**Relation between
Ubiquitous/Pervasive Computing and Ambient Intelligence:**



Common Goal: Optimization of economical and personal processes

Bibliography

References:

ISTAG-Report:
Ambient Intelligence: from vision to reality
For paricipation – in society and business

AmI technology perspective

System

Components

AMBIENT

- Smart materials
- MEMS tech. & Sensor techn.
- Embedded Systems
- Ubiquitous Communications
- I/O device technology
- Adaptive Software

INTELLIGENCE

- Media Management and handling
- Natural interaction
- Computational intelligence
- Contextual awareness
- Emotional computing

Platform design

Software & Service Architecture, Design, Engineering and Integration

Integration

User/Person

Technology research requirements for AmI

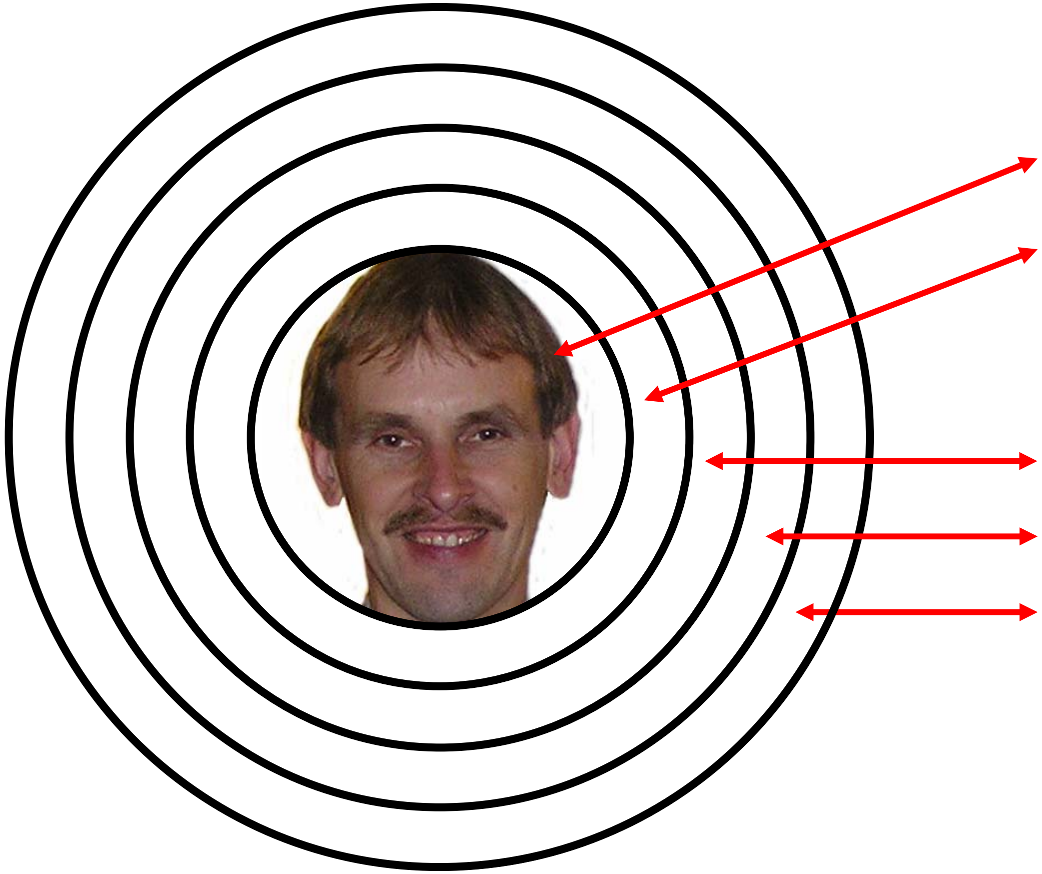
AmI technology perspective

Main structuring differentials:

- A ‘systems’ / ’environment’ / ’background’ view (~‘the ambient’)
  versus
  a ‘user’ / ’person’ / ’foreground’ view (~ ‘the intelligence’)

- A ‘components’ view versus an ‘integration’ view.

Holistic View



User-centric participation

AmI environment aware of:
- User
- Application
- Environment
- Performance contraints

Technically feasible

Usable, acceptable and useful

Adding social & economic value

ISTAG: holistic citizen-centred view.
User-centred, participative, Ambient Intelligence

AmI Scenarios

SCENARIOS FOR AMBIENT INTELLIGENCE IN 2010

The concept of Ambient Intelligence (AmI) provides a vision of the Information Society where the emphasis is on greater user-friendliness, more efficient services support, user-empowerment, and support for human interactions. People are surrounded by intelligent intuitive interfaces that are embedded in all kinds of objects and an environment that is capable of recognising and responding to the presence of different individuals in a seamless, unobtrusive and often invisible way.

Scenarios are not traditional extrapolations from the present, but offer provocative glimpses of futures that can (but need not) be realised. Each scenario has a script that is used to work out the key developments in technologies, society, economy, and markets necessary to arrive at the scenario. With the time-scale of significant changes in the ICT industry now shorter than one year, scenario planning provides one of the few structured ways to get an impression of the future.

K. Ducatel, M. Bogdanowicz, F. Scapolo, J. Leijten & J-C. Burgelman, February 2001, IPTS-Seville

Four AmI Scenarios

The scenarios in this report provide a glimpse into potential futures with Ambient Intelligence (AmI). The scenarios are not 'orthogonal' in the sense of giving clearly distinct alternative trajectories. Rather they are complementary and sketch out different design emphases and pathways towards Ambient Intelligence.

The main structuring differentials between the scenarios are:

- **Economic and personal efficiency versus sociability/humanistic drivers (goals);**
- **Communal versus individual as the user orientation driver (actors).**

K. Ducatel, M. Bogdanowicz, F. Scapolo, J. Leijten & J-C. Burgelman, February 2001, IPTS-Seville

AmI Scenarios

"Efficient"

1: Maria: personal ambient communicator

3: Carmen: traffic optimisation

Individual

Community

2: Dimitrios: connecting people and expressing identities

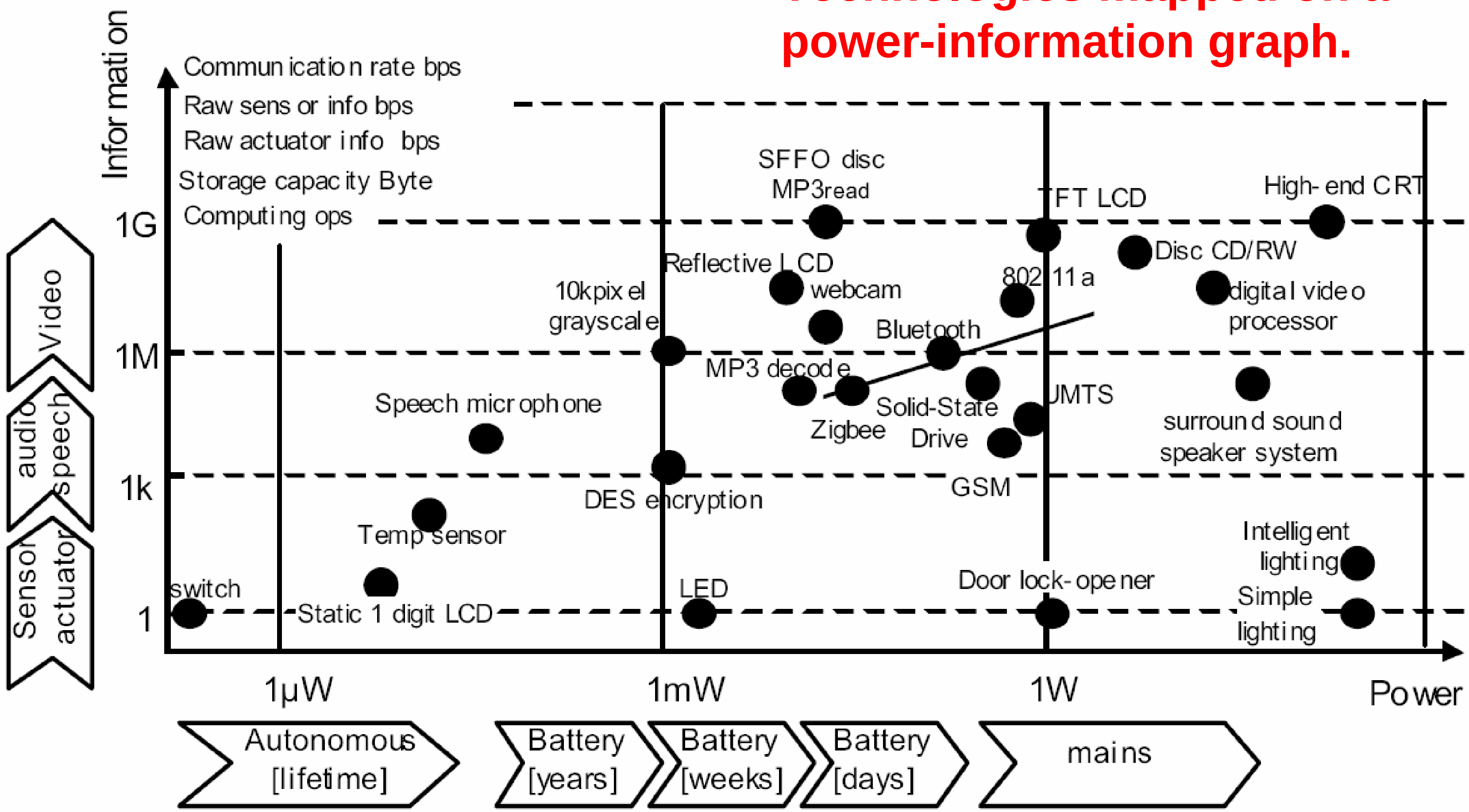
4: Annette and Solomon: social learning by connecting people and creating community memory ambient communicator

"Sociable, humanistic"

K. Ducatel, M. Bogdanowicz, F. Scapolo, J. Leijten & J-C. Burgelman, February 2001, IPTS-Seville

Challenges for Ambient Intelligence

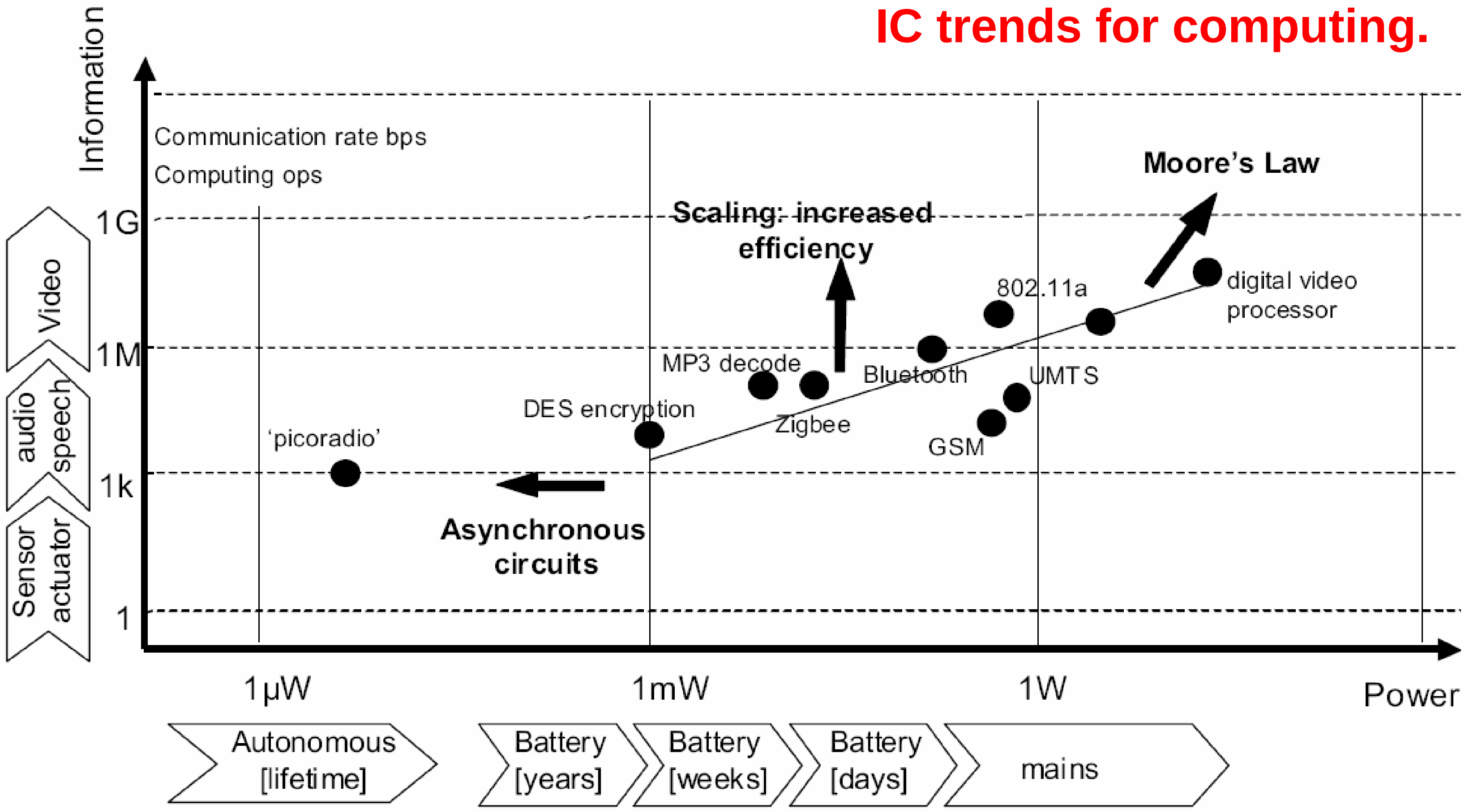
Technologies mapped on a power-information graph.



IC Design Challenges for Ambient Intelligence, Emile Aarts and Raf Roovers, Philips Research Laboratories

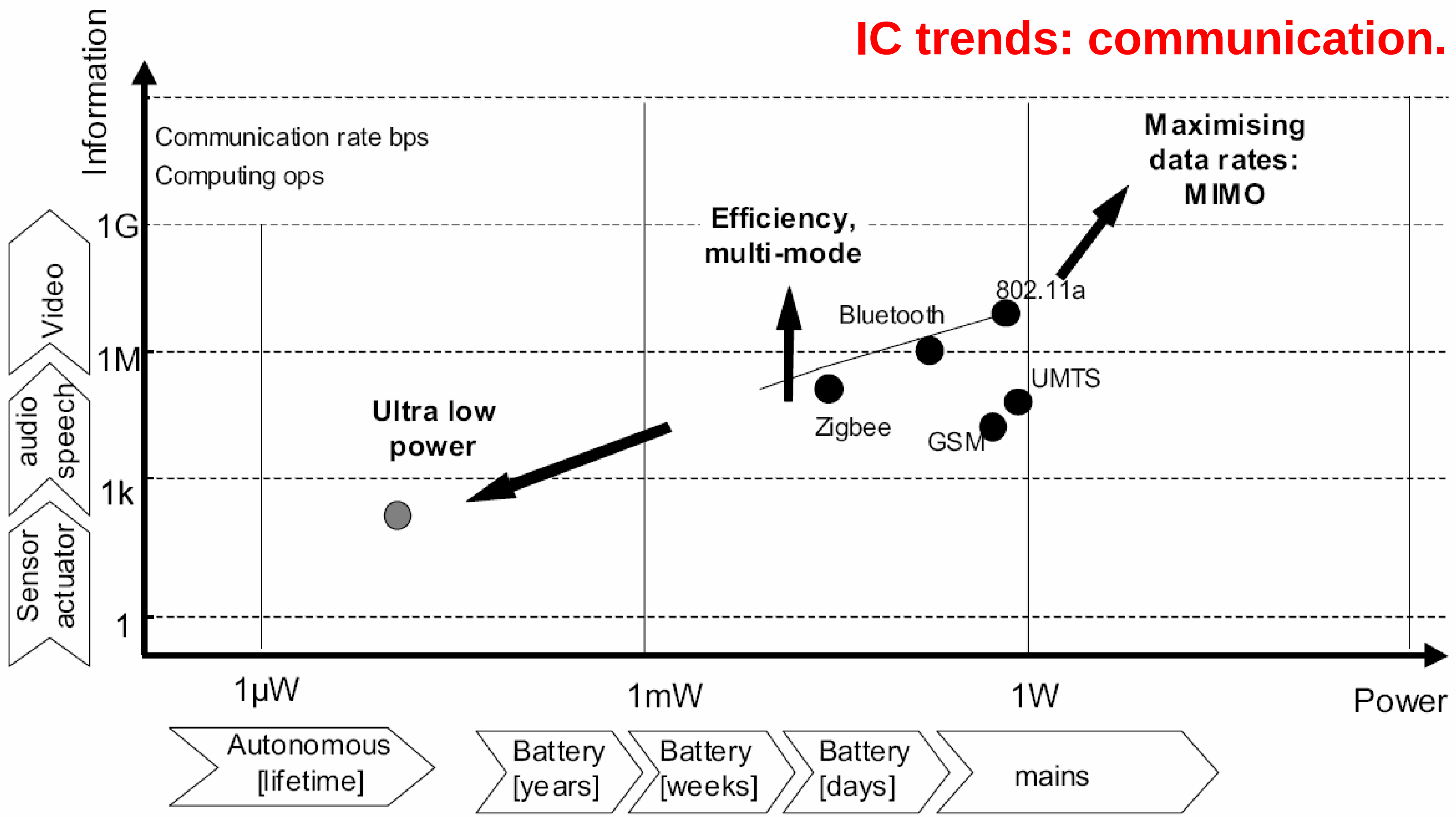
Challenges for Ambient Intelligence

IC trends for computing.



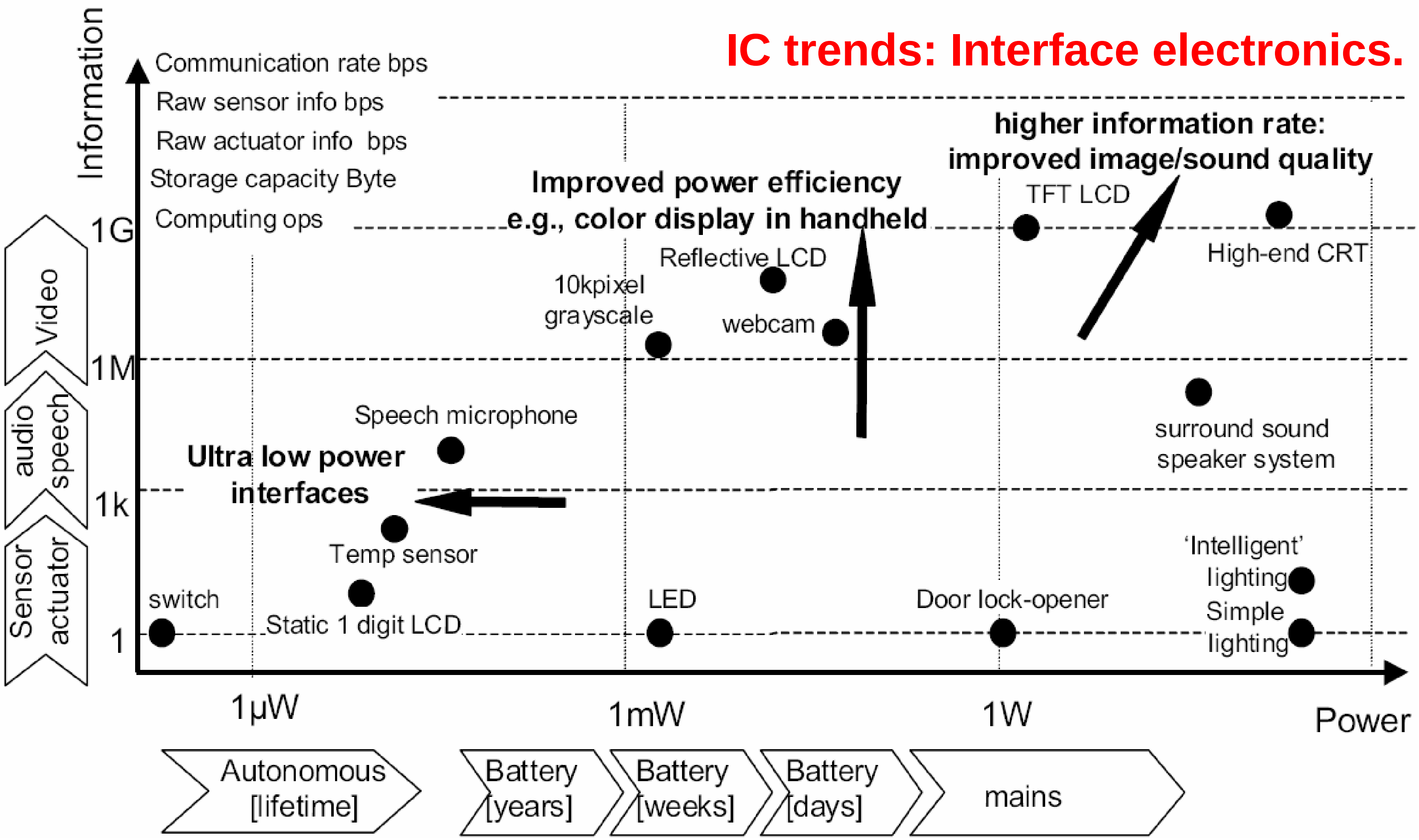
IC Design Challenges for Ambient Intelligence, Emile Aarts and Raf Roovers, Philips Research Laboratories

Challenges for Ambient Intelligence



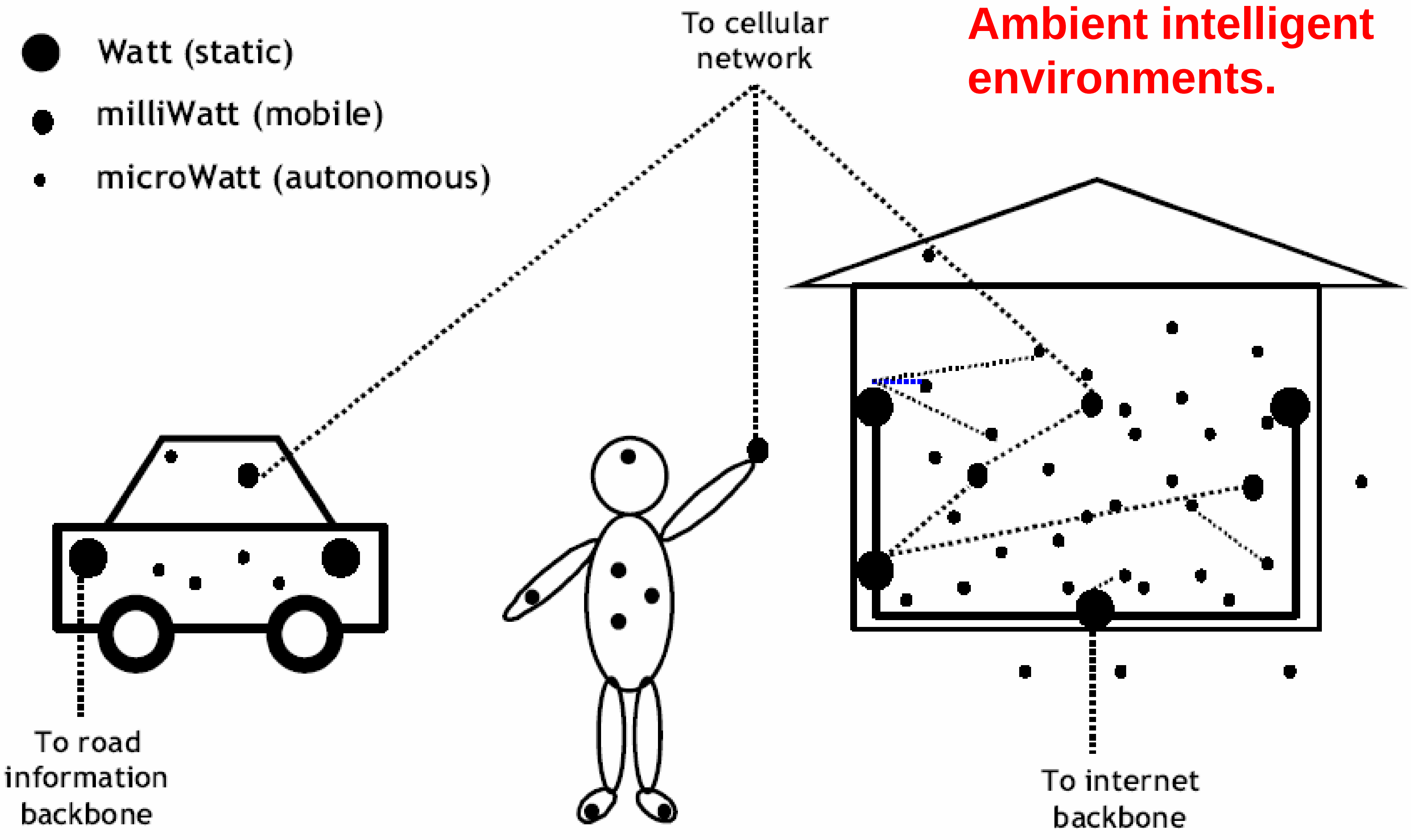
IC Design Challenges for Ambient Intelligence, Emile Aarts and Raf Roovers, Philips Research Laboratories

Challenges for Ambient Intelligence



IC Design Challenges for Ambient Intelligence, Emile Aarts and Raf Roovers, Philips Research Laboratories

Challenges for Ambient Intelligence

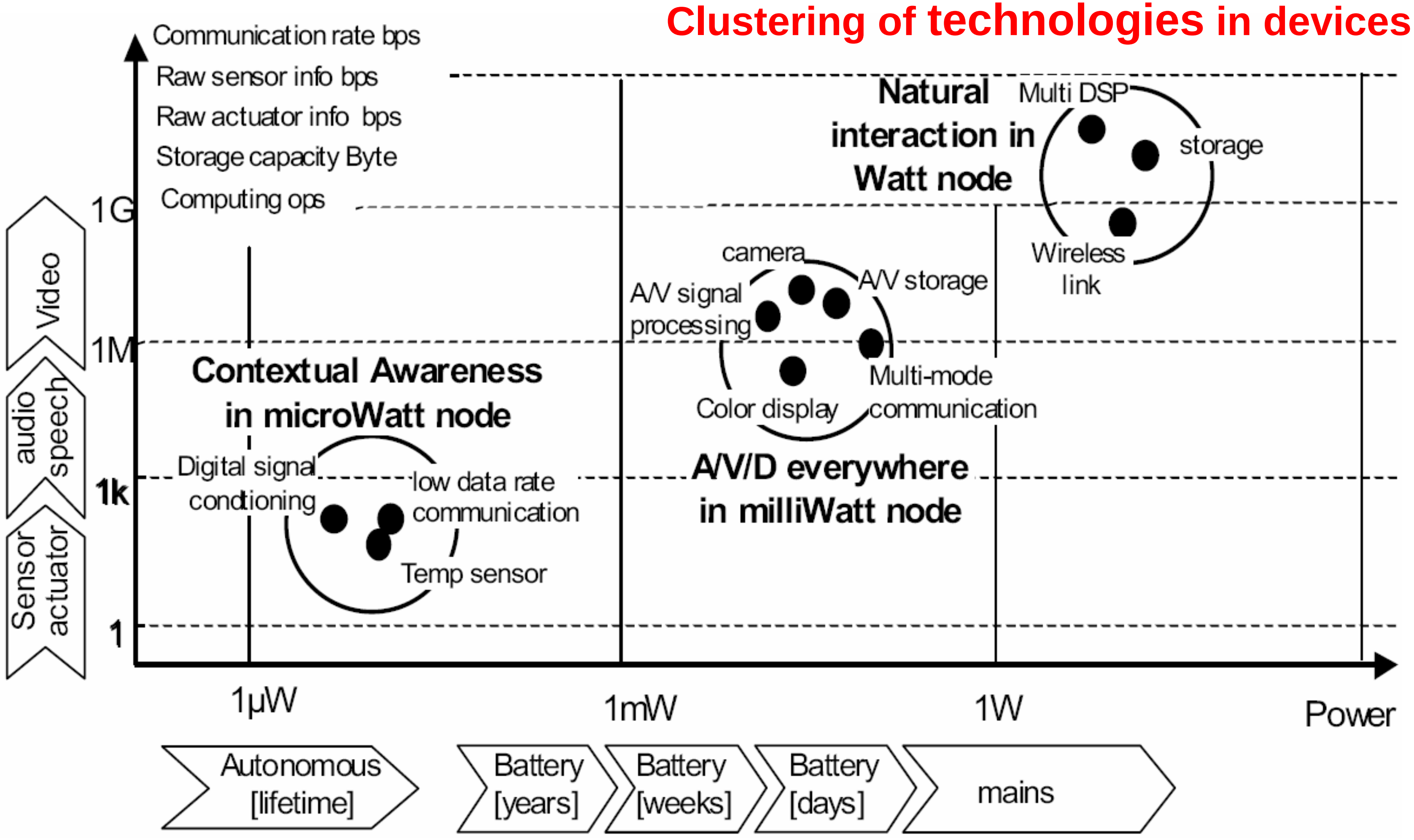


Ambient intelligent environments.

IC Design Challenges for Ambient Intelligence, Emile Aarts and Raf Roovers, Philips Research Laboratories

Challenges for Ambient Intelligence

Clustering of technologies in devices.



IC Design Challenges for Ambient Intelligence, Emile Aarts and Raf Roovers, Philips Research Laboratories

Challenges for Ambient Intelligence

Ambient intelligence functionality distribution over micro-, milli- and Watt node.

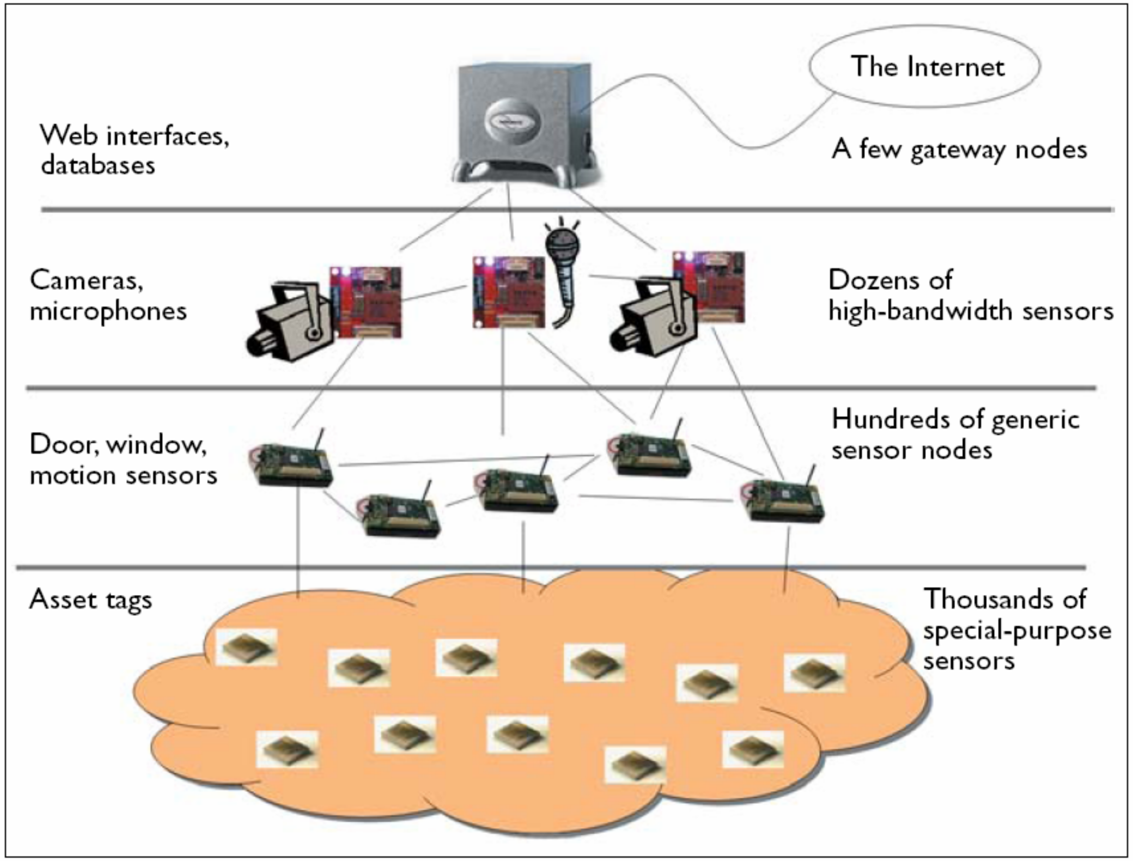
	MicroWatt	MilliWatt	Watt
Awareness	Gathering information from environment	Accessing awareness information	Building awareness intelligence with information
Information everywhere	Data (e.g.smart label)	A/V/data access, personal content management and storage	A/V/data content management and storage
Natural interfaces	Interaction I/O	Interaction I/O	Interaction Intelligence

IC Design Challenges for Ambient Intelligence, Emile Aarts and Raf Roovers, Philips Research Laboratories

Example

AmI-Enabling Technology?

Sensor Networks



Hierarchical deployment of a wireless sensor network. Each platform class handles different types of sensing.

Ref.: Jason Hill, Mike Horton, Ralph Kling, *and* Lakshman Krishnamurthy:
THE PLATFORMS ENABLING WIRELESS SENSOR NETWORKS

Sensor Networks

Node Type	Sample "Name" and Size	Typical Application Sensors	Radio Bandwidth (Kbps)	MIPS Flash RAM	Typical Active Energy (mW)	Typical Sleep Energy (uW)	Typical Duty Cycle (%)
Specialized sensing platform	Spec mm^3	Specialized low-bandwidth sensor or advanced RF tag	<50Kbps	<5 <0.1Mb <4Kb	1.8V*10–15mA	1.8V *1uA	0.1–0.5%
Generic sensing platform	Mote $1\text{-}10cm^3$	General-purpose sensing and communications relay	<100Kbps	<10 <0.5Mb <10Kb	3V*10–15mA	3V *10uA	1–2%
High-bandwidth sensing	Imote $1\text{-}10cm^3$	High-bandwidth sensing (video, acoustic, and vibration)	~500Kbps	<50 <10Mb <128Kb	3V*60mA	3V *100uA	5–10%
Gateway	Stargate $>10cm^3$	High-bandwidth sensing and communications aggregation Gateway node	>500Kbs–10 Mbps	<100 <32Mb <512Kb	3V*200mA	3V *10mA	>50%

Typical operating characteristics of the four classes of sensor-network nodes.

Ref.: Jason Hill, Mike Horton, Ralph Kling, *and* Lakshman Krishnamurthy:
THE PLATFORMS ENABLING WIRELESS SENSOR NETWORKS

Sensor Networks

Node	CPU	Power	Memory	I/O and Sensors	Radio	Remarks
Special-purpose Sensor Nodes						
Spec 2003	4–8Mhz Custom 8-bit	3mW peak 3uW idle	3K RAM	I/O Pads on chip, ADC	50–100Kbps	Full custom silicon, traded RF range and accuracy for low-power operation.
Generic Sensor Nodes						
Rene 1999	ATMEL 8535	.036mW sleep 60mW active	512B RAM 8K Flash	Large expansion connector	10Kbps	Primary TinyOS development platform.
Mica-2 2001	ATMEGA 128	.036mW sleep 60mW active	4K RAM 128K Flash	Large expansion connector	76Kbps	Primary TinyOS development platform.
Telos 2004	Motorola HCS08	.001mW sleep 32mW active	4K RAM	USB and Ethernet	250Kbps	Supports IEEE 802.15.4 standard. Allows higher-layer Zigbee stardard. 1.8V operation
Mica-Z 2004	ATMEGA 128		4K RAM 128K Flash	Large expansion connector	250Kbps	Supports IEEE 802.15.4 standard. Allows higher-layer Zigbee stardard.
High-bandwidth Sensor Nodes						
BT Node 2001	ATMEL Mega 128L 7.328Mhz	50MW idle 285MW active	128KB Flash 4KB EEPROM 4KB SRAM	8-channel 10-bit A/D, 2 UARTS Expandable connectors	Bluetooth	Easy connectivity with cell phones. Supports TinyOS. Multihop using multiple radios/nodes.
Imote 1.0 2003	ARM 7TDMI 12-48MHz	1mW idle 120mW active	64KB SRAM 512KB Flash	UART, USB, GPIO, I^2C, SPI	Bluetooth 1.1	Multihop using scatternets, easy connections to PDAs, phones,TinyOS 1.0, 1.1.
Gateway Nodes						
Stargate 2003	Intel PXA255		64KNSRM	2 PCMICA/CF, com ports, Ethernet, USB	Serial connection to sensor network	Flexible I/O and small form factor power management.
Inrysnc Cerfcube 2003	Intel PXA255		32KB Flash 64KB SRAM	Single CF card, general-purpose I/O		Small form factor, robust industrial support, Linux and Windows CE support.
PC104 nodes	X86 processor		32KB Flash 64KB SRAM	PCI Bus		Embedded Linux or Windows support.

Current sensor network platforms organized by device class.

Ref.: Jason Hill, Mike Horton, Ralph Kling, *and* Lakshman Krishnamurthy: THE PLATFORMS ENABLING WIRELESS SENSOR NETWORKS

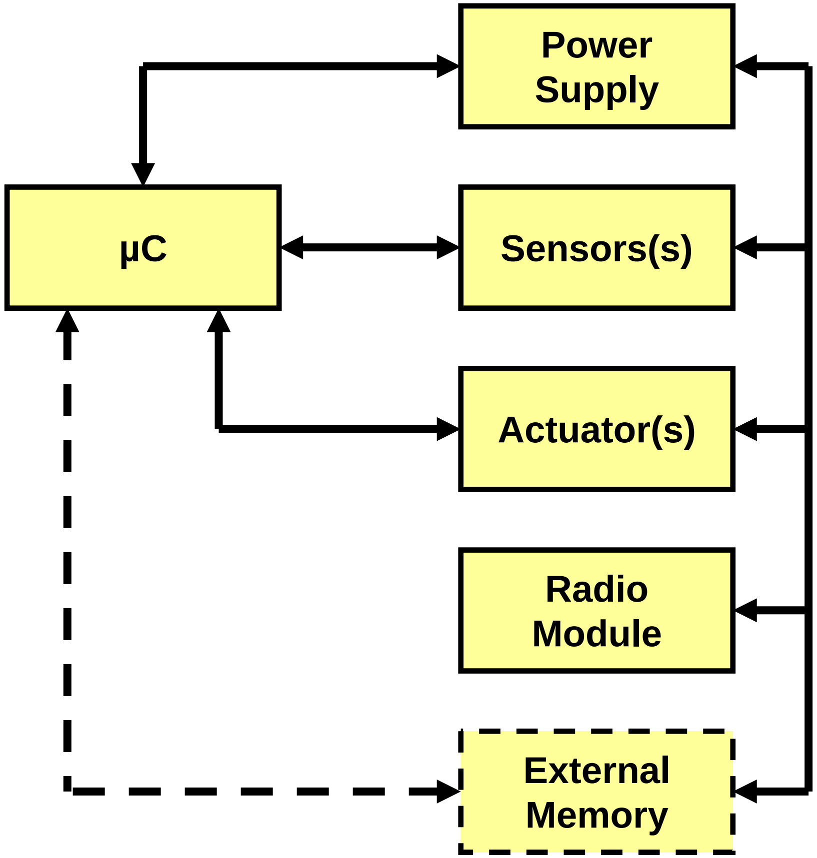
Needs in sensor networks

- **Wireless:**
  Thousands of sensors in a small space
- **Low Power:**
  stand alone sensors
- **Moderate Range:**
  isolated sensors

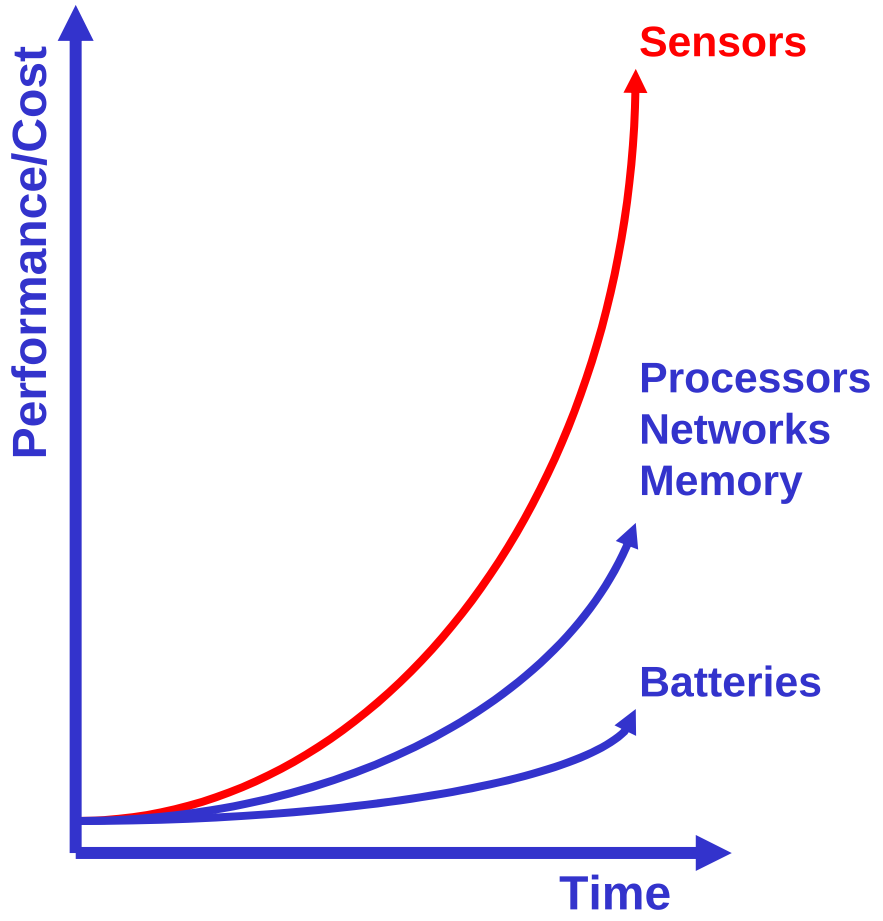
Sensor Networks

Sensor networks are built up of six essential components:

- Microprocessor, Microcontroller unit
- Storage unit,
- Radio unit,
- Sensor(s) unit,
- Actuator(s) unit,
- Power supply unit.



Enabling Technology



Moore's Law:

- fast development of sensors
- miniaturization:
  MEMS
  piezo-materials
- lowering cost

Example: ZigBee

ZigBee™ Alliance
Wireless Control That Simply Works

Objectives

What is ZigBee?

- Open global standard to enable reliable, cost-effective, low-power, wirelessly networked, monitoring and control products
- specification for low data-rate wireless connectivity with fixed, portable and moving devices with no battery or very limited battery consumption requirements typically operating in the POS of 10m
- a longer range at a lower data rate may be an acceptable trade-off?

ZigBee protocol stack

- ZigBee has added to 802.15.4 by defining the network layer of the ZigBee stack to support star, mesh and hybrid networking
- Network management that allows certain node types to sleep most of the time to conserve power

Possible applications

- A wide range of products and applications across consumer, commercial, industrial and government markets world wide
- Focus on remote monitoring and

ZigBee Features

- **Ad-hoc self forming networks**
  - **Mesh, Cluster Tree and Star Topologies**
  - **Reliable broadcast messaging**
  - **Non-guaranteed message delivery**
- **Logical Device Types**
  - **Coordinator, Router and End Device**
- **Applications**
  - **Device and Service Discovery**
  - **Optional acknowledged service**
  - **Messaging with optional responses**
  - ***Mechanism to support mix of Public and Private profiles in the same network, all supported by standard ZigBee network and application features***

continued

Ref.: ZigBee Alliance

ZigBee Features

- Security
  - Symmetric Key with AES-128
  - Authentication and Encryption at MAC, NWK and Application levels.
  - Key Hierarchy: Master Keys, Network Keys and Link Keys
- Qualification
  - Conformance Certification (Platform and Logo)
  - Interoperability Events

Ref.: ZigBee Alliance

Sensor Networks

IEEE 802.15.4 and ZigBee Compliant RF Solution:

IEEE 802.15.4 and ZigBee are the only radio standards that specifically address the requirements of wireless monitoring and control systems. Proven and robust ZigBee compliant platforms, consisting of hardware and software, are available and form a solid basis for development of ZigBee certified products.

The ZigBee specification was ratified by the ZigBee Alliance in December 2004. It is an open and global standard for low-cost, low-power wireless embedded networking.

Ref.: Chipcon

ZigBee Applications

Energy Management and Comfort Functions: •Thermostats •Heating, ventilation, air-conditioning (HVAC) •Control of blinds/shades/rollers/windows	**Lighting Control Systems:** •Power outlets •Dimmers •Switches •Remote Controls
Environmental and Agricultural Monitoring: •Temperature •Carbon dioxide •Humidity •Vibration	**Industrial:** •Industrial plant monitoring and control •Wireless embedded sensor networks in general •Inventory control •Asset tracking
Automatic Meter Reading Systems: •Electricity •Gas •Water	**Health Care / Medical:** •Patient Monitoring
Alarm and Security Systems: •Home security •Smoke detectors •Burglary and social alarms •Access control with location detection •Water leakage systems	**Consumer Electronics:** •Remote Controls •ZigBee enabled mobile phones, e.g. supporting general remote control functionality •Set-Top boxes •PC-peripherals

Ref.: Chipcon

ZigBee Applications

Radio Technologies:
Comparison between ZigBee, Bluetooth and Wi-Fi

Standard	*ZigBee (802.15.4)*	*Bluetooth (802.15.1)*	*Wi-Fi (802.11)*
Transmission range (m)	1 - 100	1 - 10	1 - 100
Battery Life (days)	100 - 1000	1 - 7	½ - 5
Network Size (nodes)	65536	7	32
Stack size (kbyte)	4 - 32	250	1000
Throughput	< 250 kbps	< 2.2 Mbps	< 54Mbps

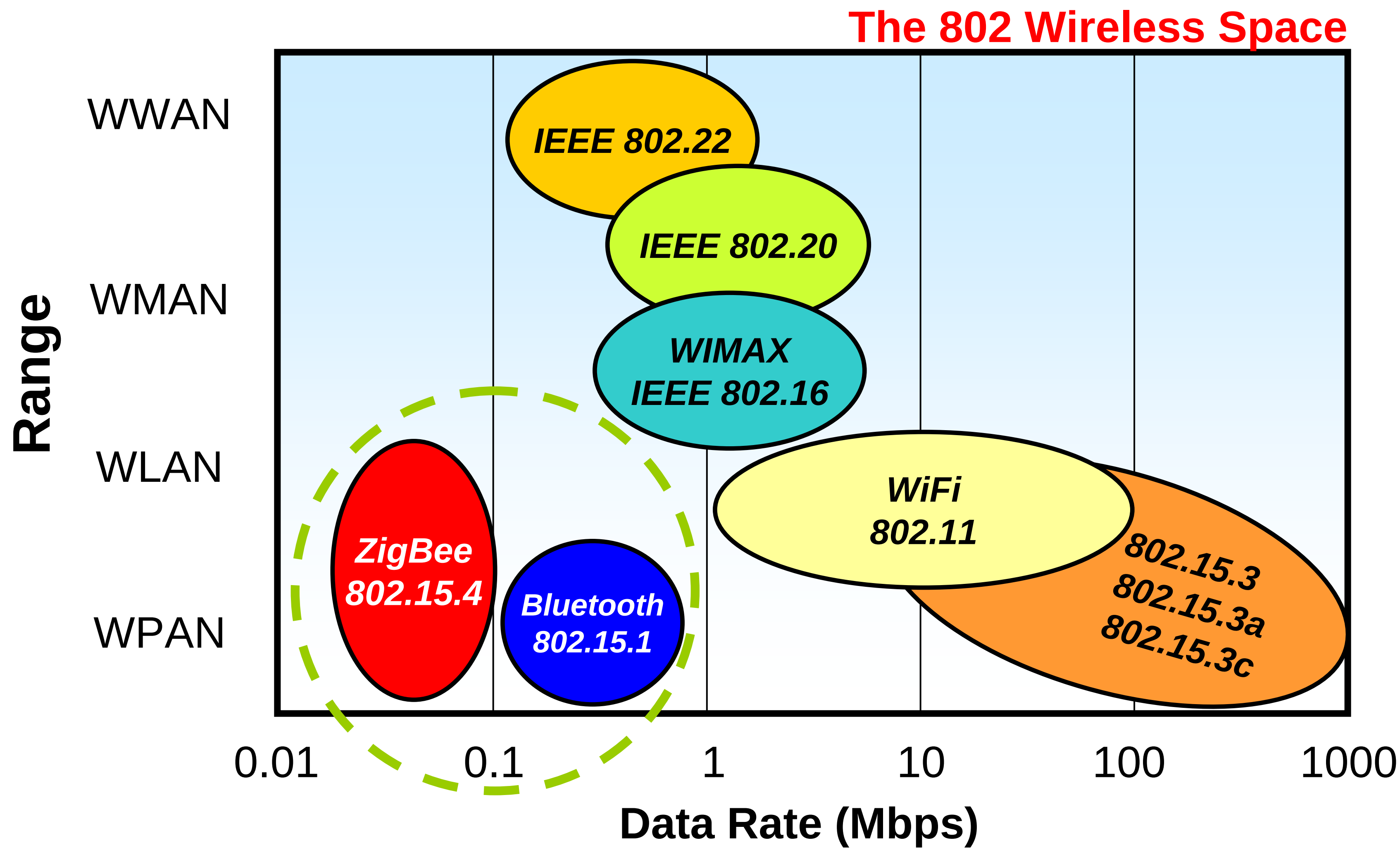
For sensor networks the best solution is ZigBee, especially because of it's very low power consumption.

IEEE 802.15.4:
PHY Frequency Bands and Data Rates

			Spreading Parameters			Data Parameters	
PHY [MHz]	Frequency Band [MHz]	Channel Numbering	Chip Rate	Mode	Bit Rate	Symbol Rate	Modulation
868	868 - 870	0	300k chip/s	BPSK	20 kb/s	20 kbaud	BPSK
915	902 - 928	1 - 10	600k chip/s	BPSK	40 kb/s	40 kbaud	BPSK
2400	2400 – 2483.5	11 - 26	2M chip/s	O-QPSK	250 kb/s	62.5 kbaud	16-ary Orthogonal

BPSK: Binary phase shift keying
O-OPSK: Offset quadrature PSK

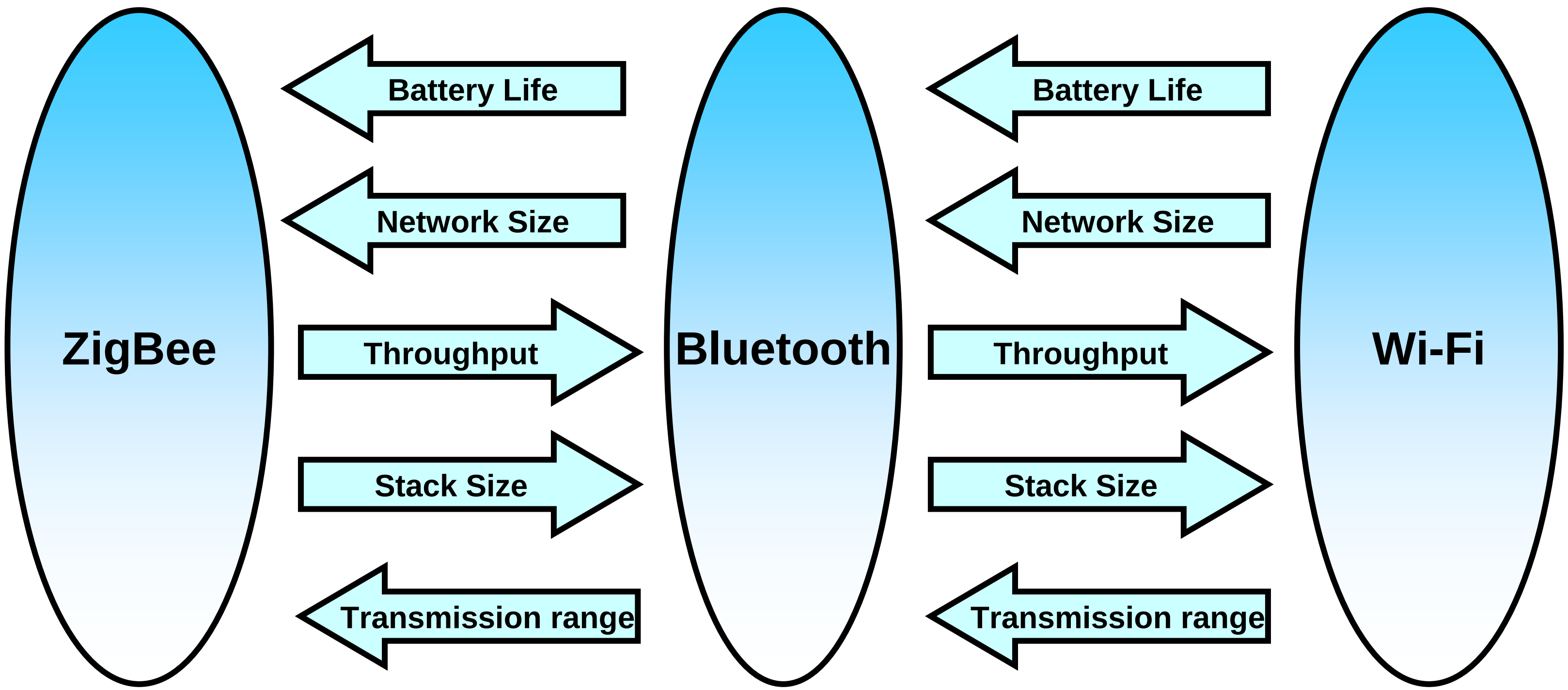
Comparison of wireless technologies



Ref.: ZigBee Alliance

Sensor Networks

Comparison between ZigBee, Bluetooth and Wi-Fi

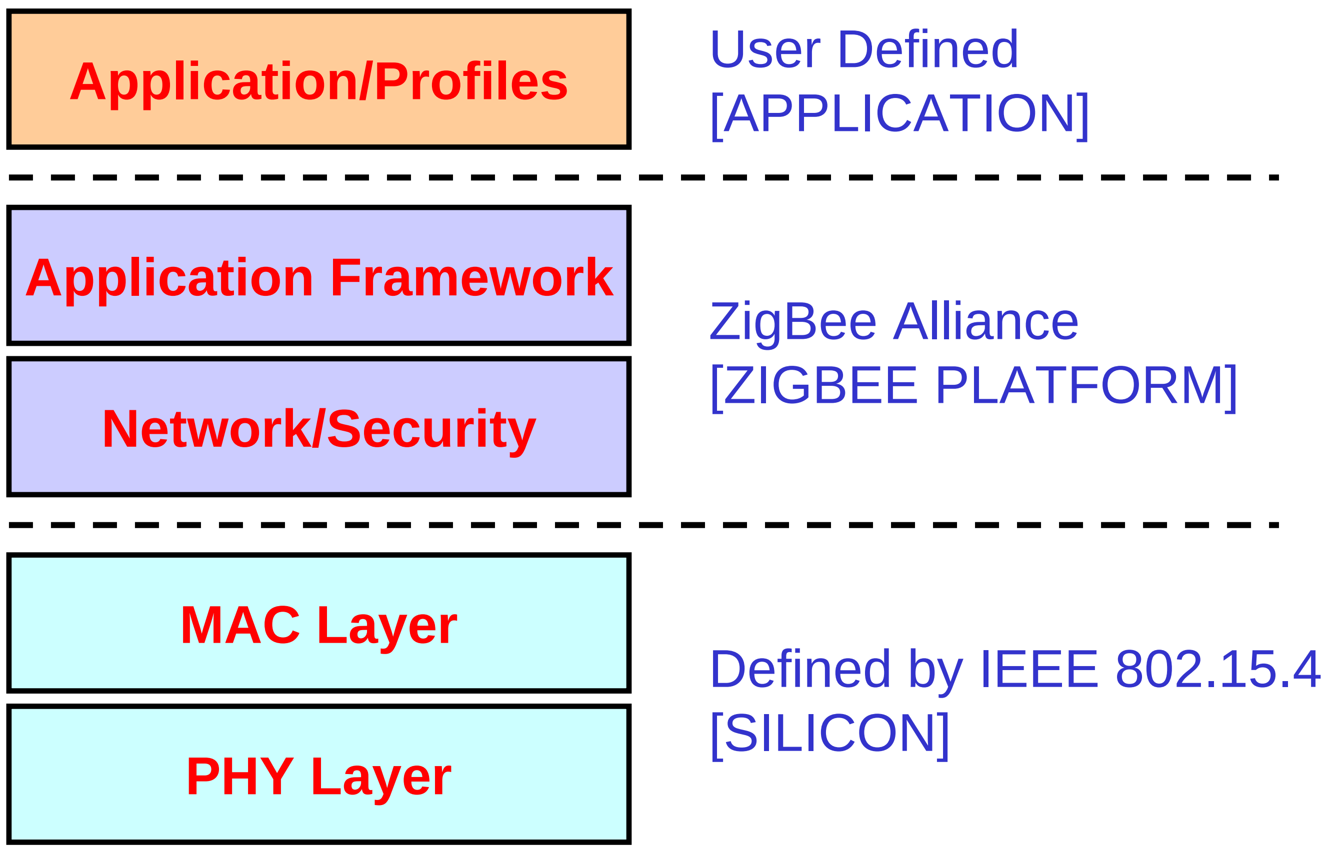


ZigBee related network products

- **Bluetooth**
  - http://www.bluetooth.org
  - http://www.bluetooth.com
- **X10**
  - Powerline protocol first introduced in the 1970's.
  - http://www.x10.com/technology1.htm
- **Z-wave**
  - Proprietary protocol for wireless home control networking.
  - http://www.z-wavealliance.com/
- **INSTEON**
  - Peer-to-peer mesh networking product that features a hybrid radio/powerline transmission
  - http://www.insteon.net
- **nanoNET**
  - Proprietary set of wireless sensor protocols, designed to compete with ZigBee.
  - http://www.nanotron.com/

802.15.4 / ZigBee Architecture

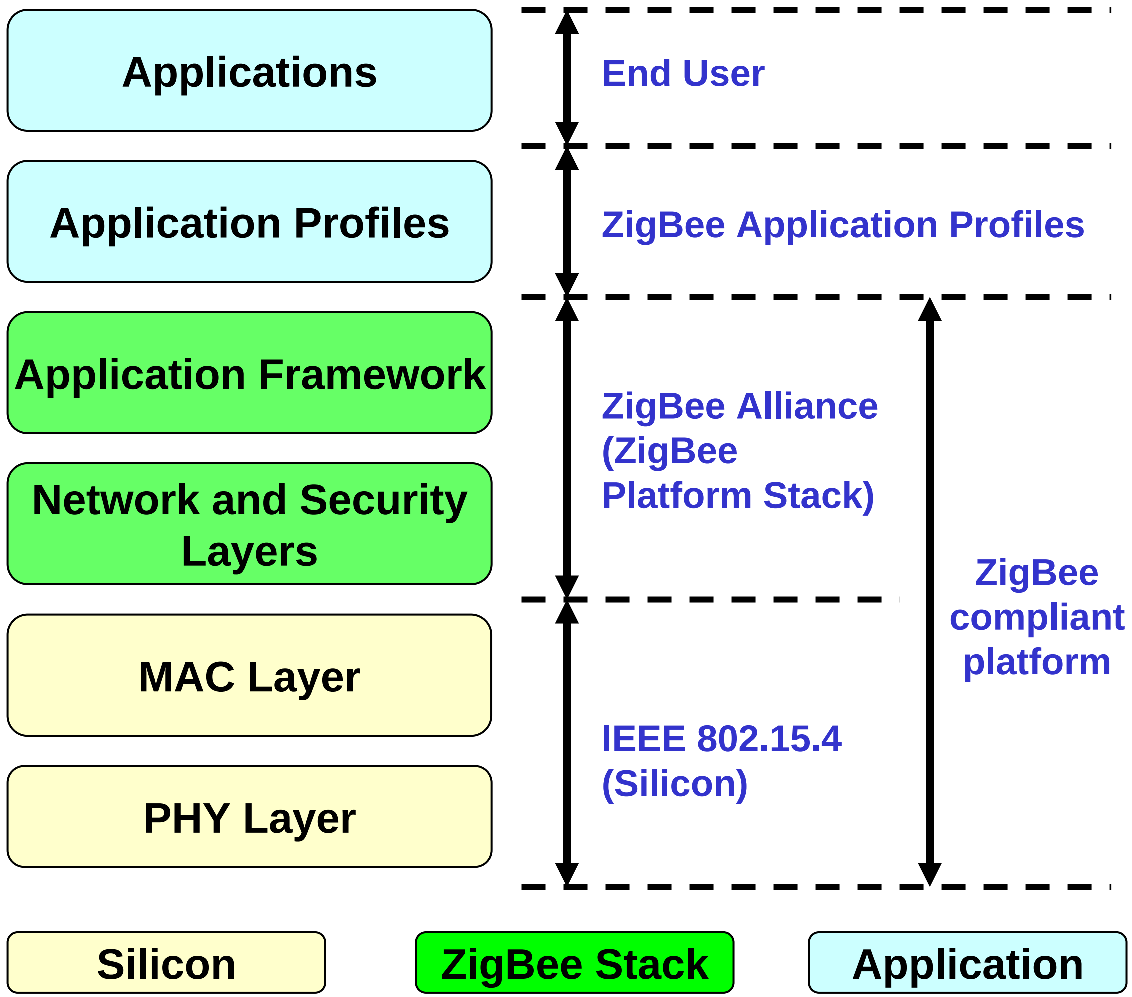
Three tier structure of ZigBee



Sensor Networks

ZigBee Stack:

ZigBee is built on the robust PHY (Physical) and MAC (Medium Access Control) layers defined by the IEEE 802.15.4 standard. Above the PHY and MAC layers ZigBee defines mesh, peer-to-peer, and cluster tree network topologies with data security features and interoperable application profiles:



Ref.: Chipcon

ZigBee

ZigBee Network Topology:

Applications for topology models

- **Cluster tree networks**
  - Employ multi-hop routing
  - Can be very large:
    255 clusters of 254 nodes each = 64,770 nodes
  - May span physically large areas
  - Suitable for latency-tolerant applications

Ref.: Andreas Riener, Johannes Kepler University, Linz, Austria

ZigBee – Physical Layer

ISM band

- The ISM (industrial, scientific and medical) radio bands were orig. Internationally reserved for (non-commercial) RF- (radio frequency) applications for industrial, scientific and medical purposes
- Recently also used for license-free error-tolerant communication applications like WLAN, Bluetooth, ZigBee
- Possible frequencies: 900 Mhz, 2.4 Ghz band and 5.8 Ghz band

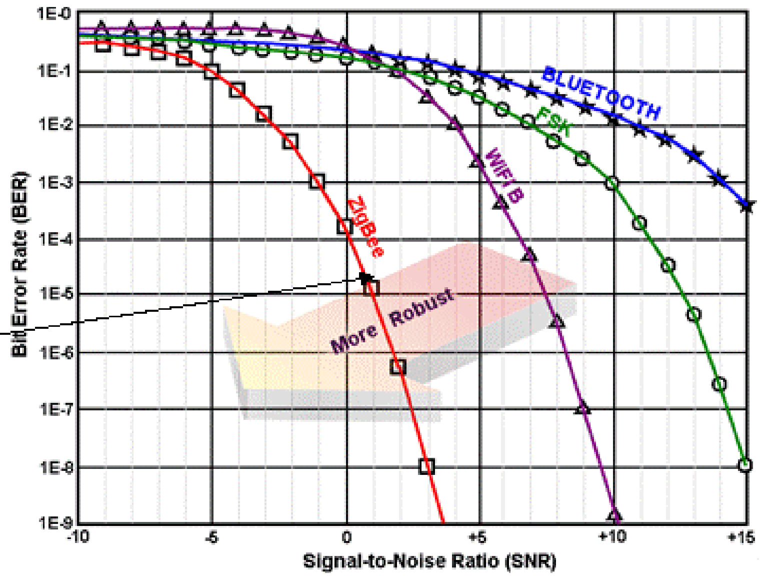
ZigBee transmission rates:

- The 2400 Mhz (2.4 Ghz) frequency band is recognized as global standard in almost any country (2400 to 2483,50 Mhz @ 250kbps)
- The 868 Mhz band has been designed to use as fallback-band (with lower data rate) in europe (868 to 870 Mhz @ 20kbps)
- The 915 Mhz band is used as fallback-band in (North-)America, Australia, etc. (902 to 928 Mhz @ 40kbps)

Ref.: Andreas Riener, Johannes Kepler University, Linz, Austria

ZigBee – Signal-to-Noise Ratio

ZigBee technology relies upon IEEE 802.15.4, which has excellent performance in low SNR environments

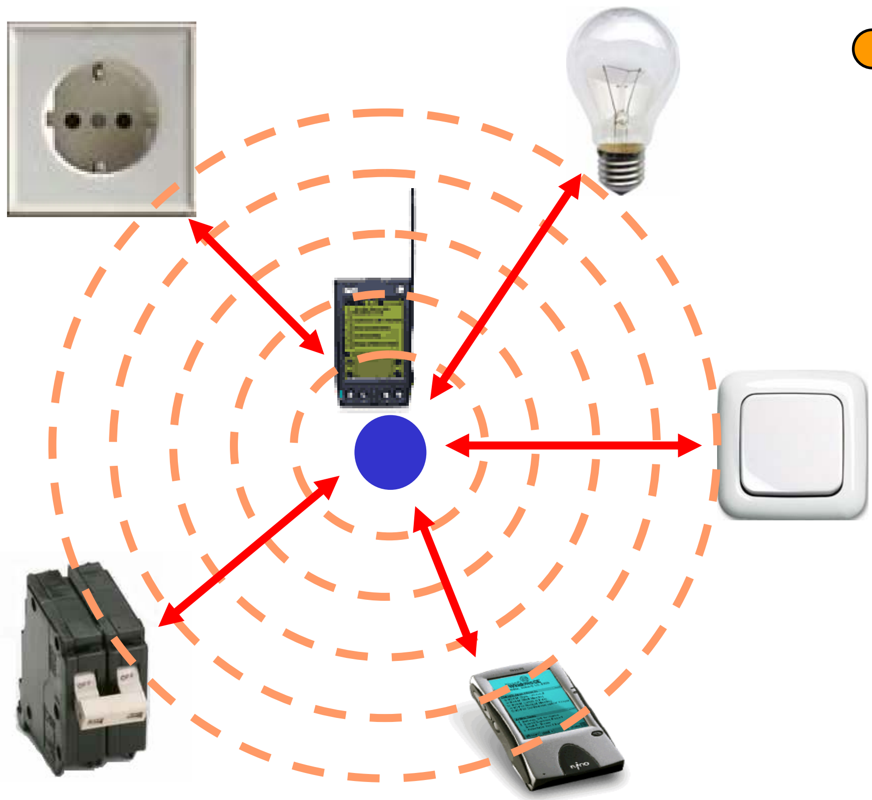


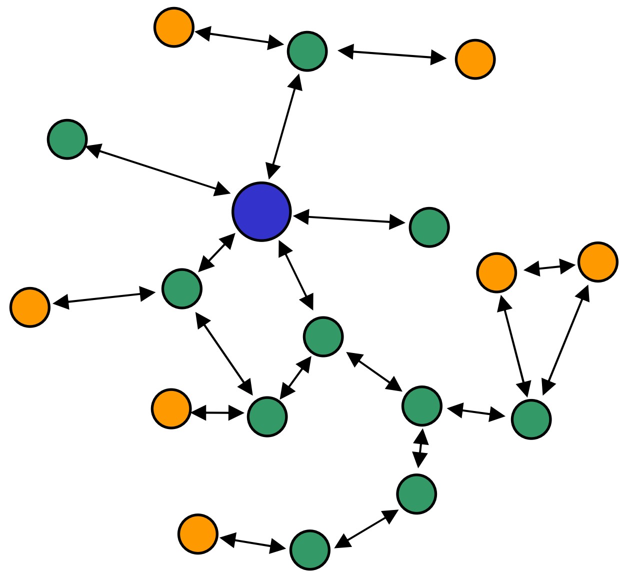
Frequency Band	License Required?	Geographic Region	Data Rate	Channel Number(s)
868.3 MHz	No	Europe	20kbps	0
902-928 MHz	No	Americas	40kbps	1-10
2405-2480 MHz	No	Worldwide	250kbps	11-26

ZigBee Alliance

Ref.: ZigBee Alliance

802.15.4 Application Space





- **Sensors & Controls:**
  - **Home Automation**
  - **Industrial Automation**
  - **Remote Metering**
  - **Automotive Networks**
  - **Interactive Toys**
  - **Active RFID/ asset tracking**
  - **Medical**

Ref.: ZigBee Alliance

Sensor/Control Network Requirements

- Large networks (large number of devices and large coverage area) that can form autonomously and that will operate very reliably for years without any operator intervention
- Very long battery life (years off of a AA cell), very low infrastructure cost (low device & setup costs) and very low complexity and small size
- Device data rate and QoS needs are low
- Standardized protocols are necessary to allow multiple vendors to interoperate

Ref.: ZigBee Alliance

ZigBee

802.15.4 General Characteristics

- Data rates of 250 kb/s, 40 kb/s and 20 kb/s.
- Star or Peer-to-Peer operation.
- Support for low latency devices.
- Fully handshaked protocol for transfer reliability.
- Low power consumption.
- Frequency Bands of Operation
  - 16 channels in the 2.4GHz ISM* band
  - 10 channels in the 915MHz ISM band
  - 1 channel in the European 868MHz band.

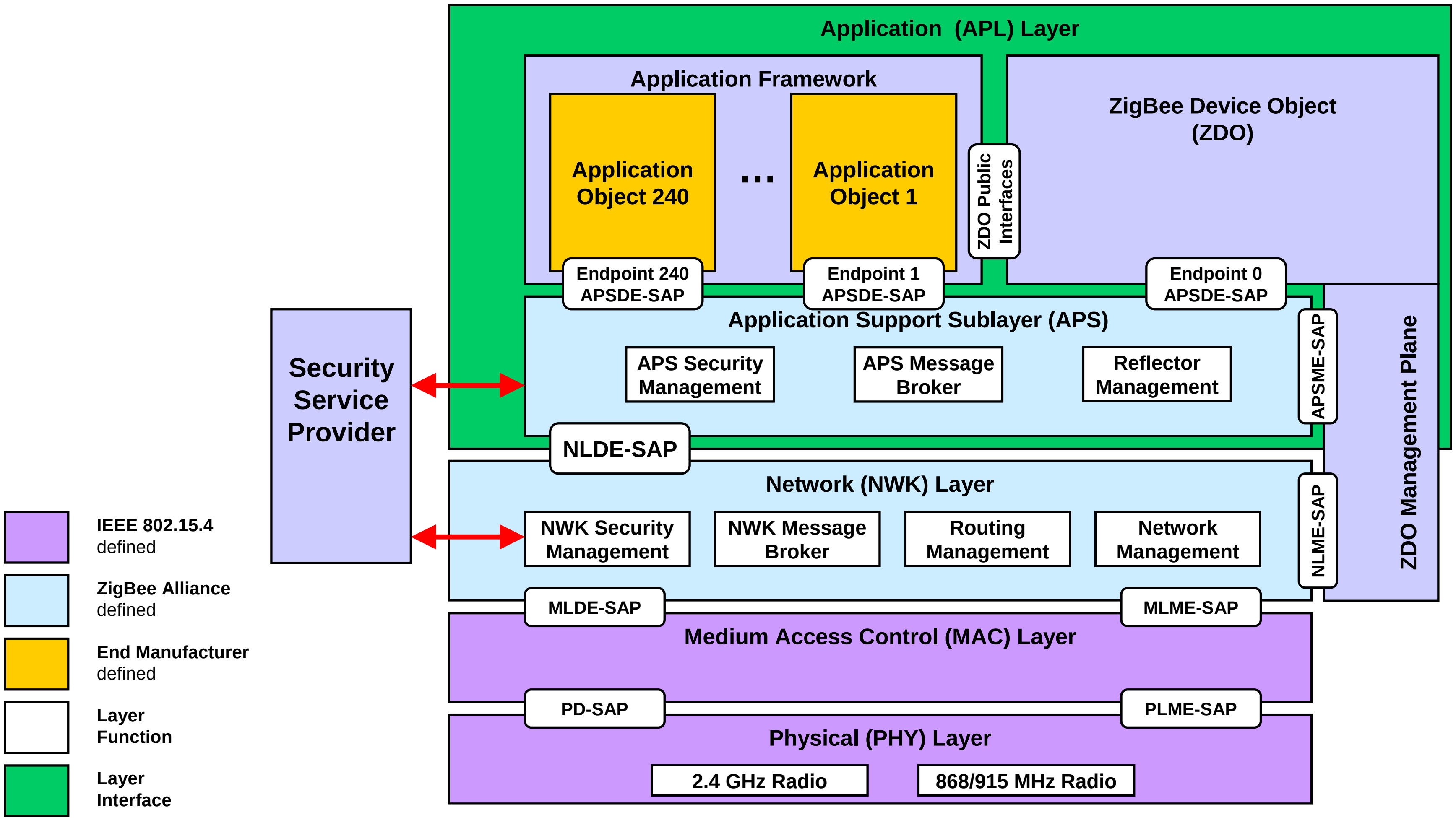
*** ISM: Industrial, Scientific, Medical**

ZigBee – device types/classes (1)

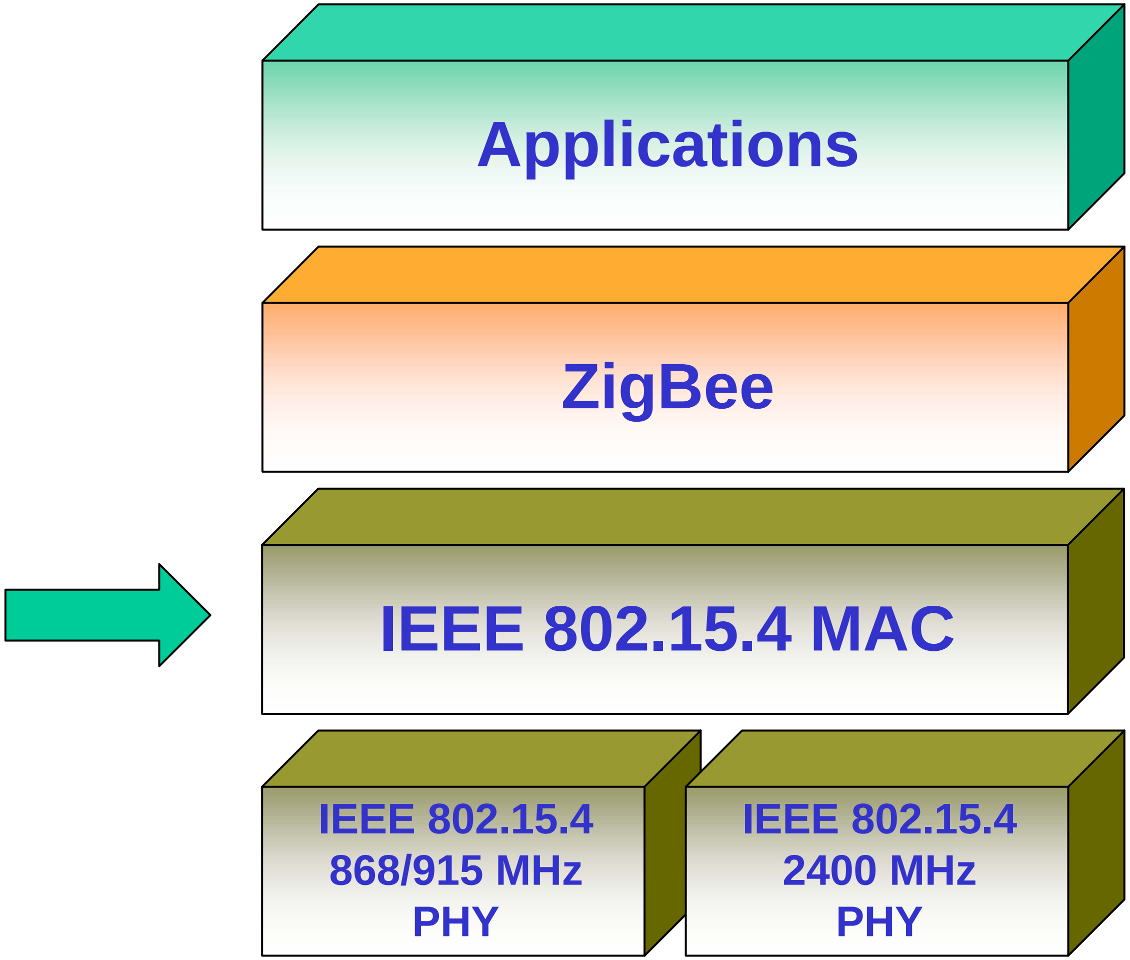
ZigBee coordinator (ZC)

- Acts as 802.15.4 PANC (**p**ersonal **a**rea **n**etwork **c**oordinator)
- The most capable device
- Is the root of the network tree, initiates network formation
- Capability of bridging to other networks
- Exactly one ZC in a network
- Enabled to store information about the network, including acting as the repository for security keys

802.15.4 / ZigBee Architecture



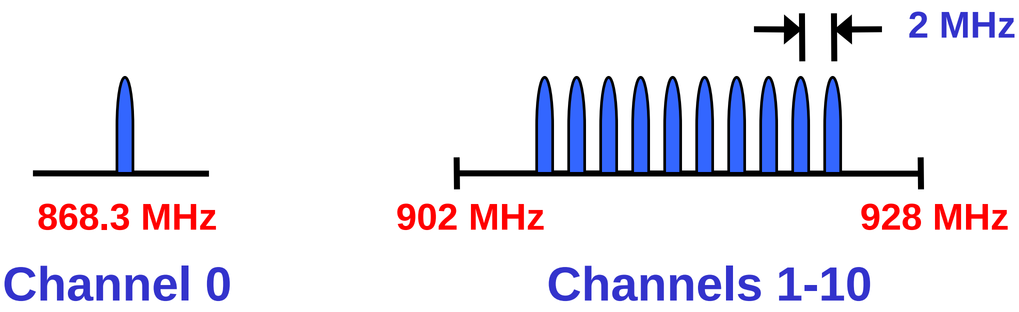
802.15.4 / ZigBee Architecture



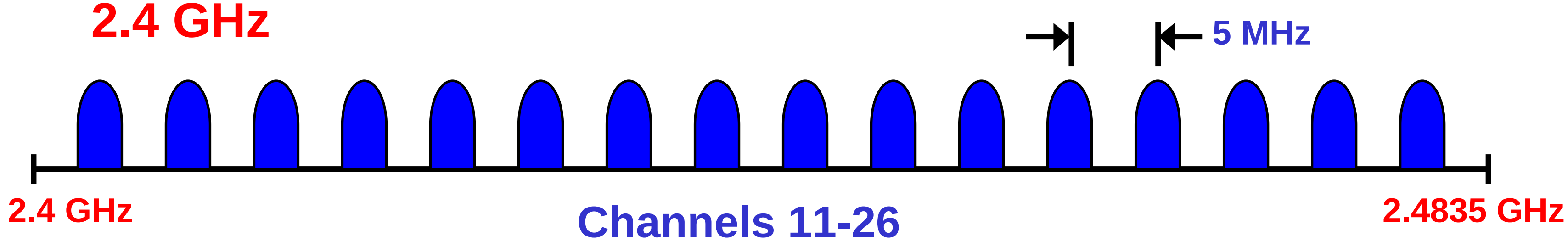
- Packet generation
- Packet reception
- Data transparency
- Power Management

PHY Overview
Operating Frequency Bands

PHY
868MHz / 915MHz



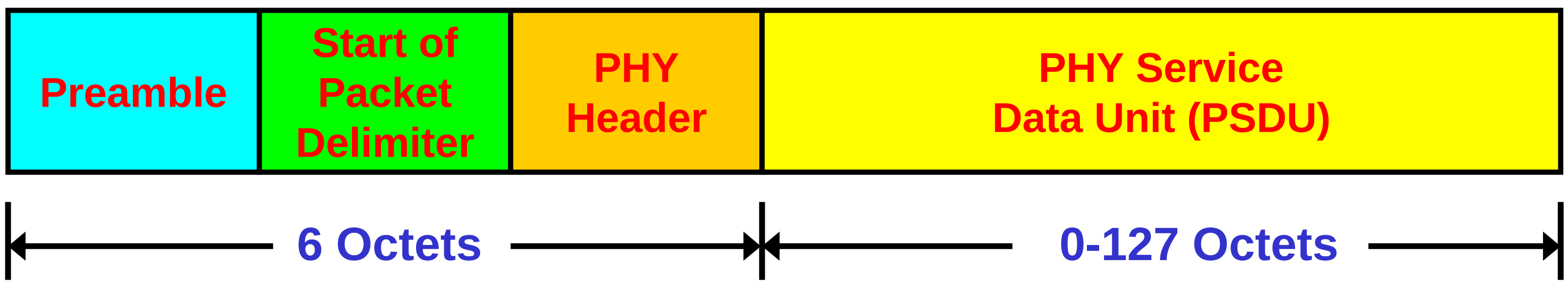
PHY
2.4 GHz



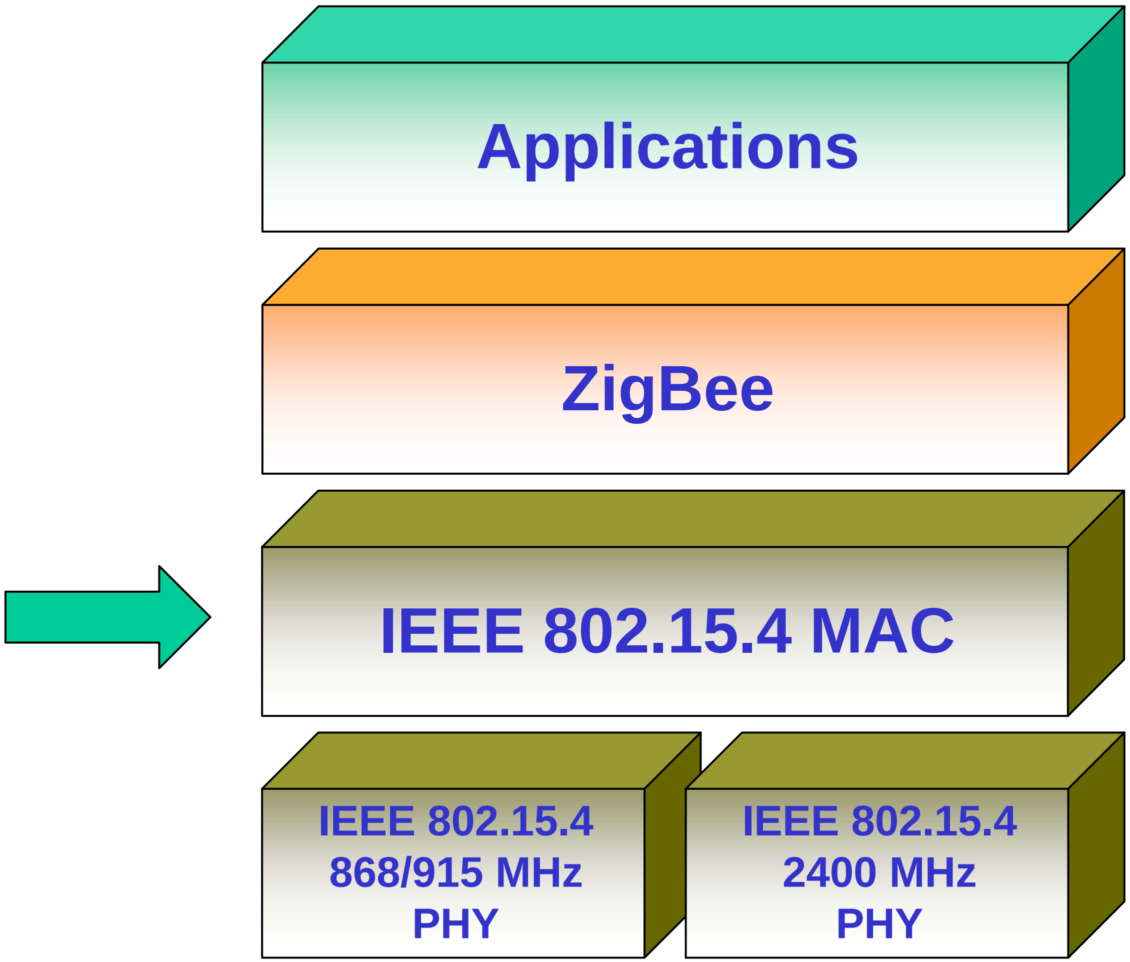
PHY Overview - Packet Structure

PHY Packet Fields

- Preamble (32 bits) – synchronization
- Start of Packet Delimiter (8 bits)
- PHY Header (8 bits) – PSDU length
- PSDU (0 to 1016 bits) – Data field



802.15.4 / ZigBee Architecture



- Channel acquisition
- Contention management
- NIC address
- Error Correction

MAC Overview
Design Drivers

Simple but flexible protocol

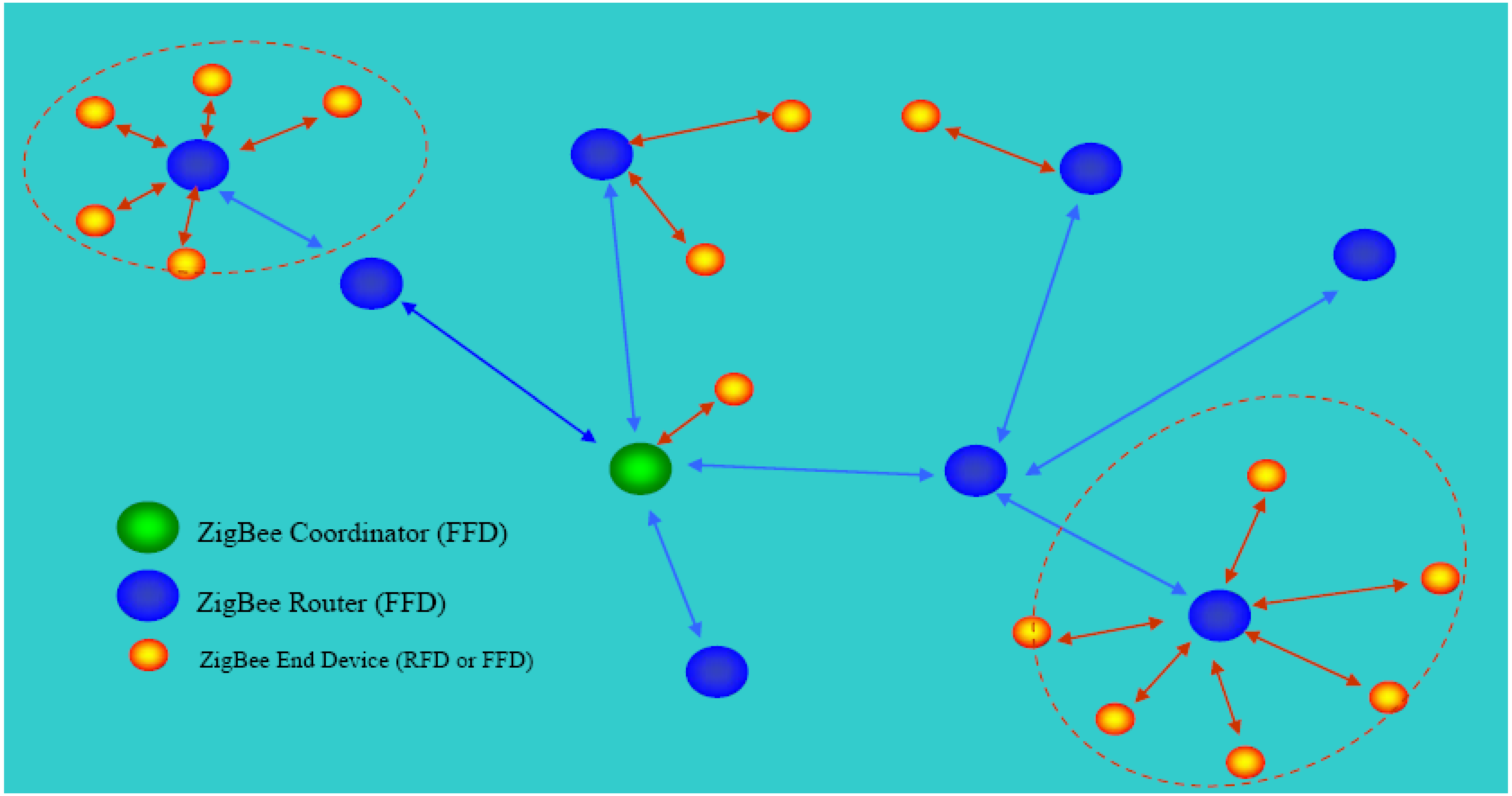
- Extremely low cost
- Ease of implementation
- Reliable data transfer
- Short range operation
- Very low power consumption

MAC Overview - Device Classes

- **Full function device (FFD)**
  - Any topology
  - Network coordinator capable
  - Talks to any other device
- **Reduced function device (RFD)**
  - Limited to star topology
  - Cannot become a network coordinator
  - Talks only to a network coordinator
  - Very simple implementation

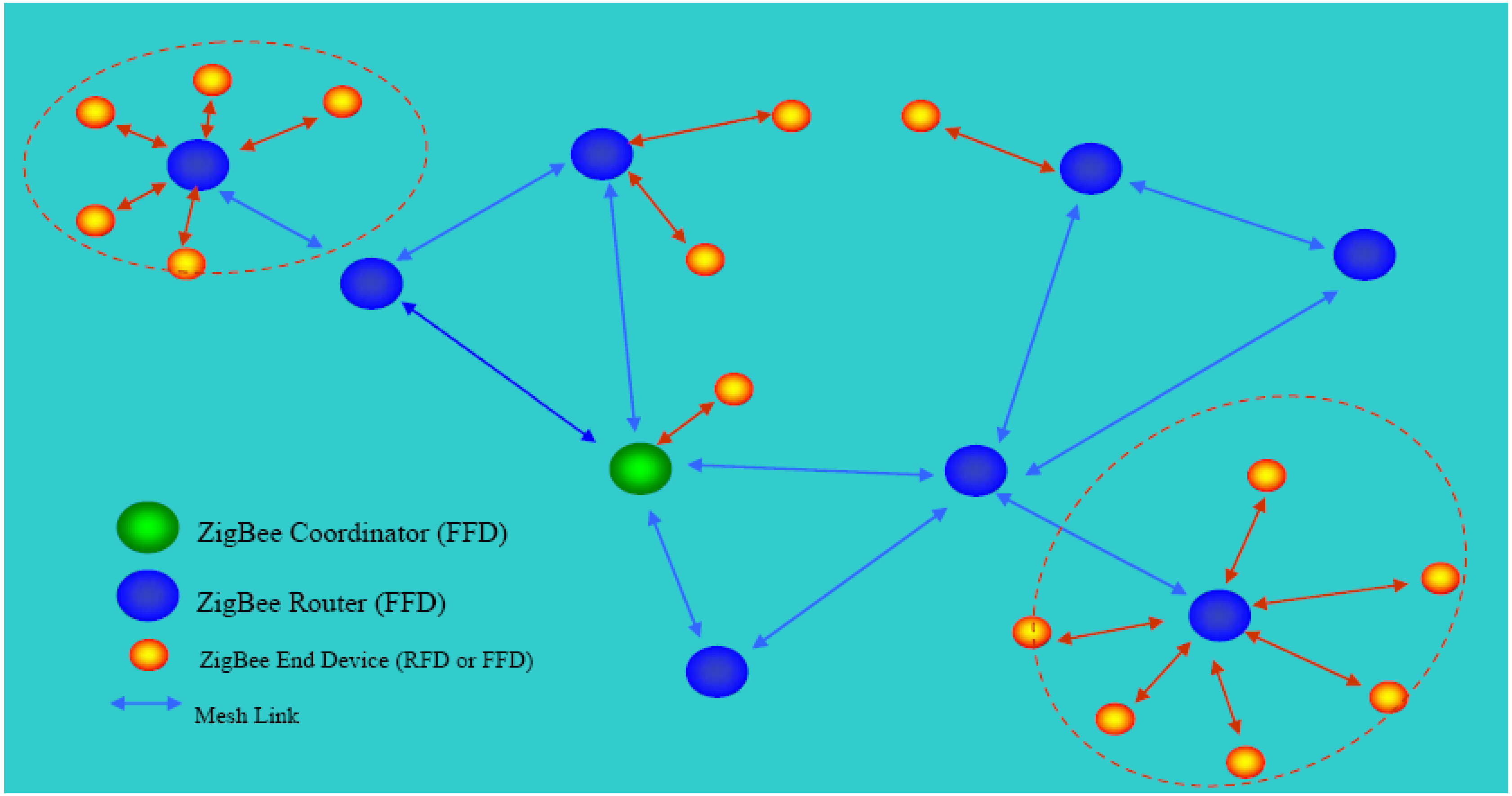
IEEE 802.15.4 Summary

ZigBee Network Communication Model (Tree)



IEEE 802.15.4 Summary

ZigBee Network Communication Model (Mesh)



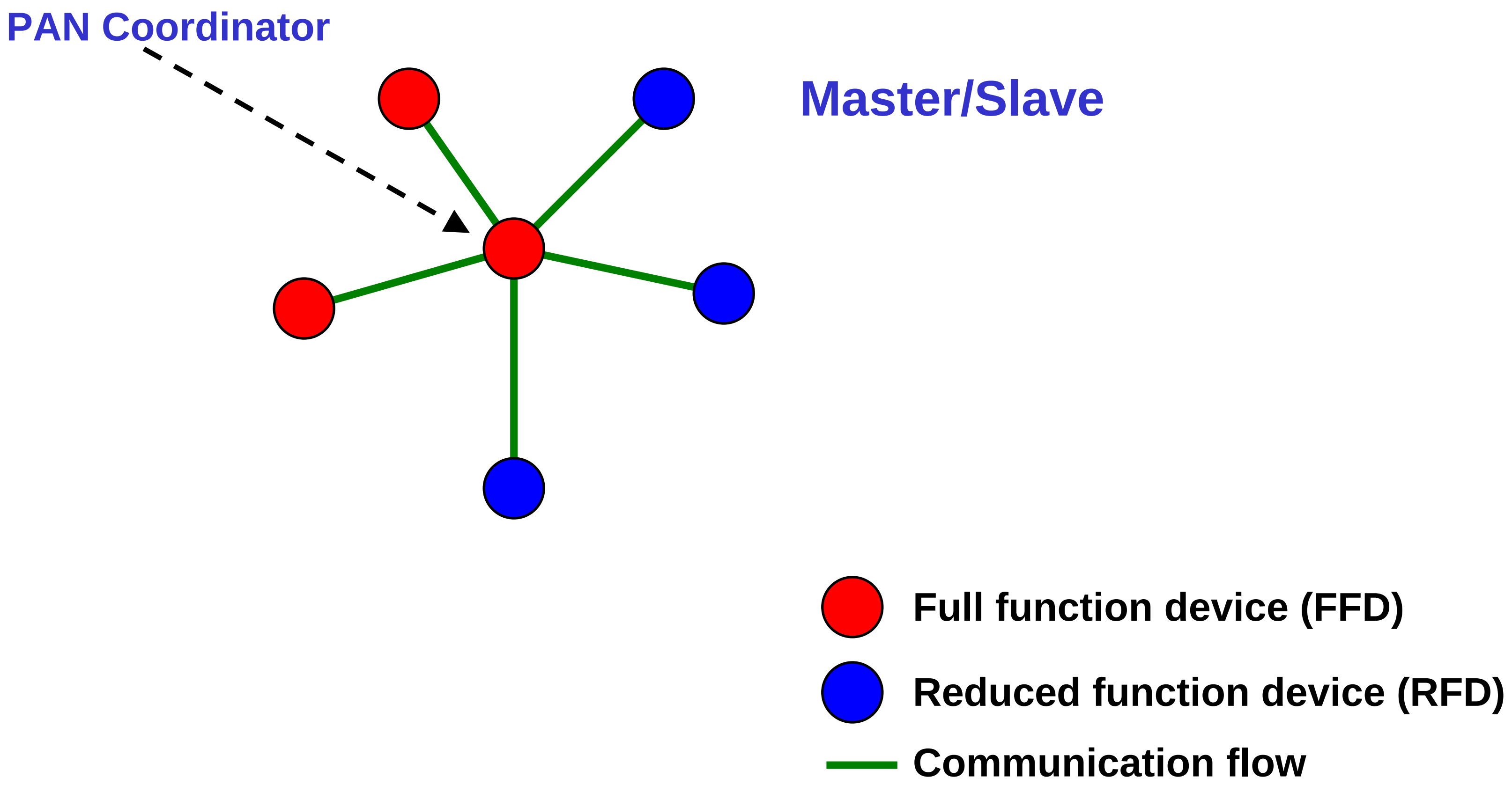
IEEE 802.15.4 Summary

ZigBee Network Topologies

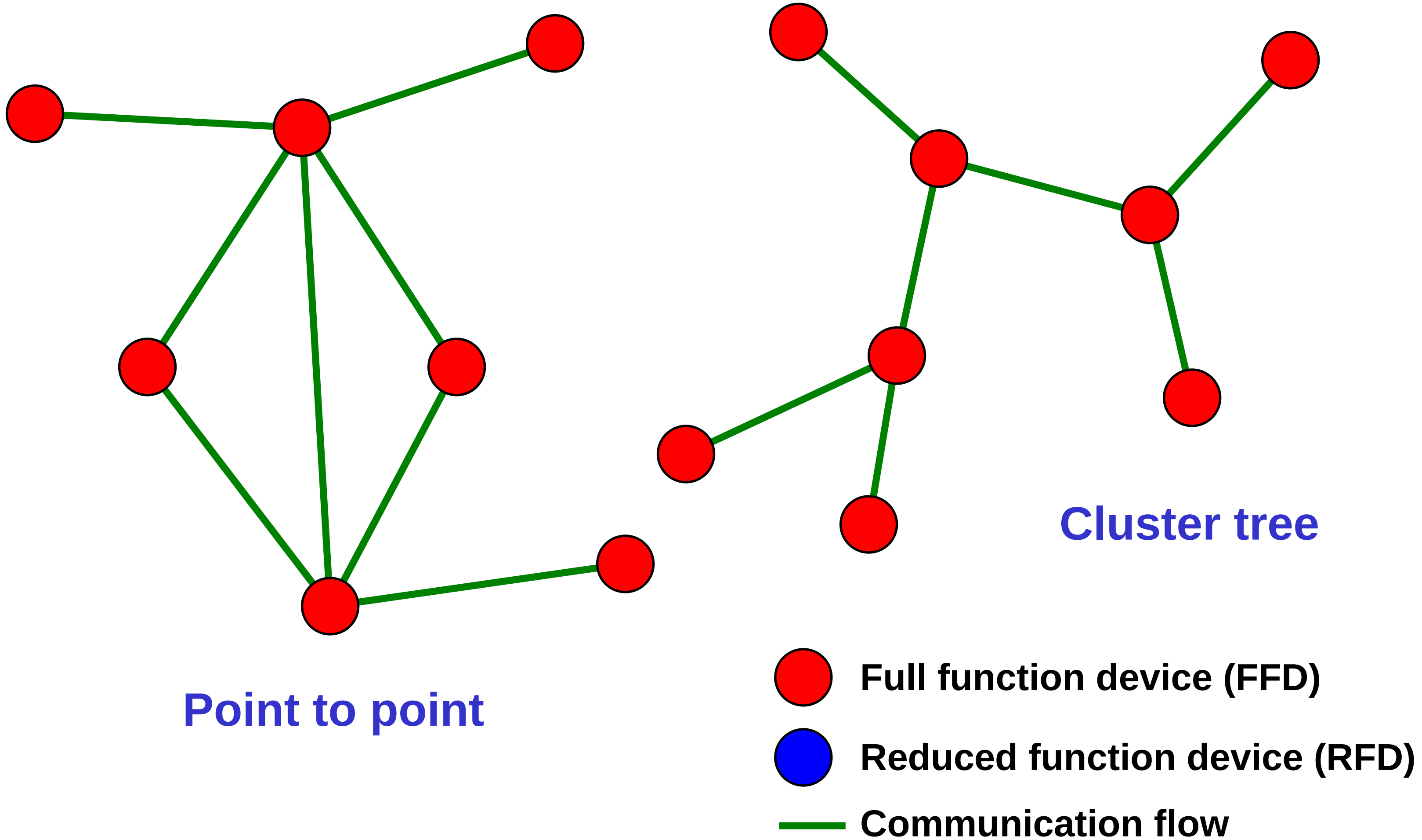
- ***Star***
  networks support a single ZigBee coordinator with one or more ZigBee End Devices (up to 65,536 in theory)
- ***Cluster tree***
  networks provide for a beaconing multi-hop network
  - Permits battery management of coordinator and routers
  - Must tolerate high latency due to beacon collision avoidance
  - Must use “netmask” type tree routing
- ***Mesh***
  network routing permits path formation from any source device to any destination device
  - Radio Receivers on coordinator and routers must be on at all times
  - Employs ZigBee joint routing solution including tree and table driven routing
  - Table routing employs a simplified version of Ad Hoc On Demand Distance Vector Routing (AODV). This is an Internet Engineering Task Force (IETF) Mobile Ad Hoc Networking (MANET) submission

IEEE 802.15.4 Summary

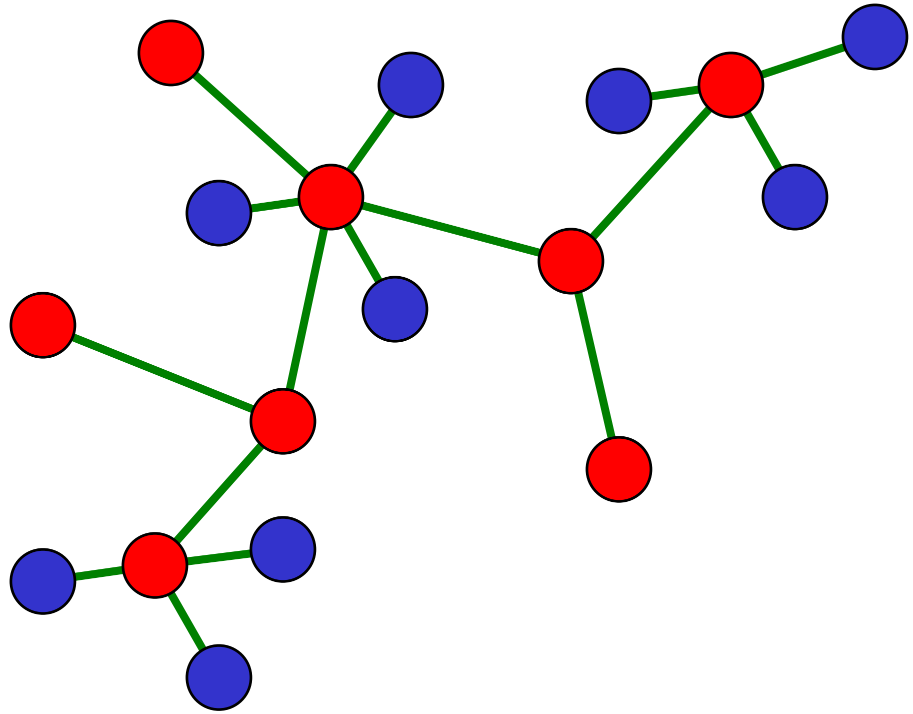
MAC Overview - Star Topology



MAC Overview - Peer-Peer Topology



MAC Overview - Combined Topology



Clustered stars:
for example, cluster nodes exist between rooms of a hotel and each room has a star network for control.

Full function device (FFD)

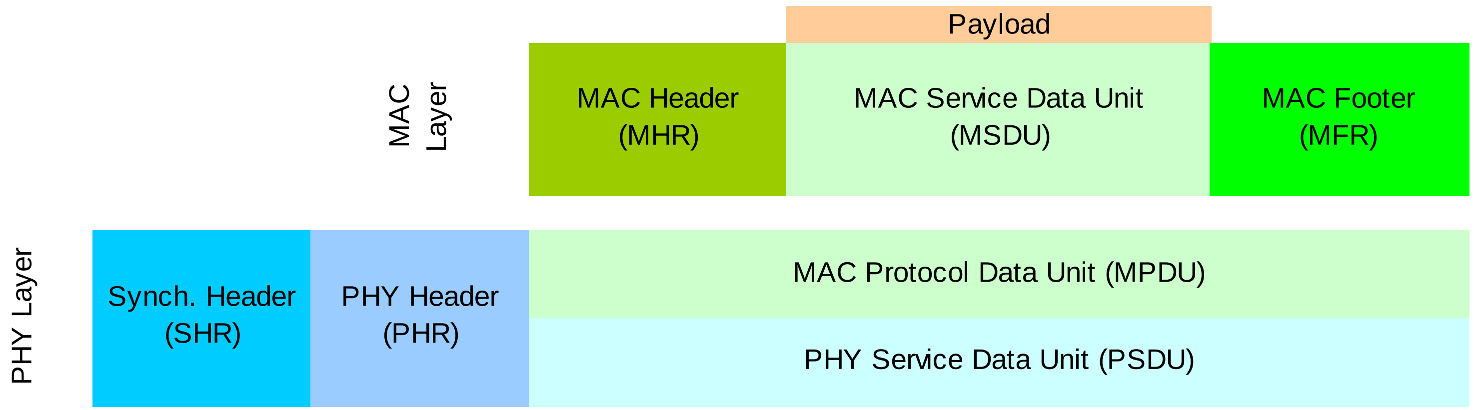
Reduced function device (RFD)

Communication flow

MAC Overview – General Frame Structure

Four Types of MAC Frames

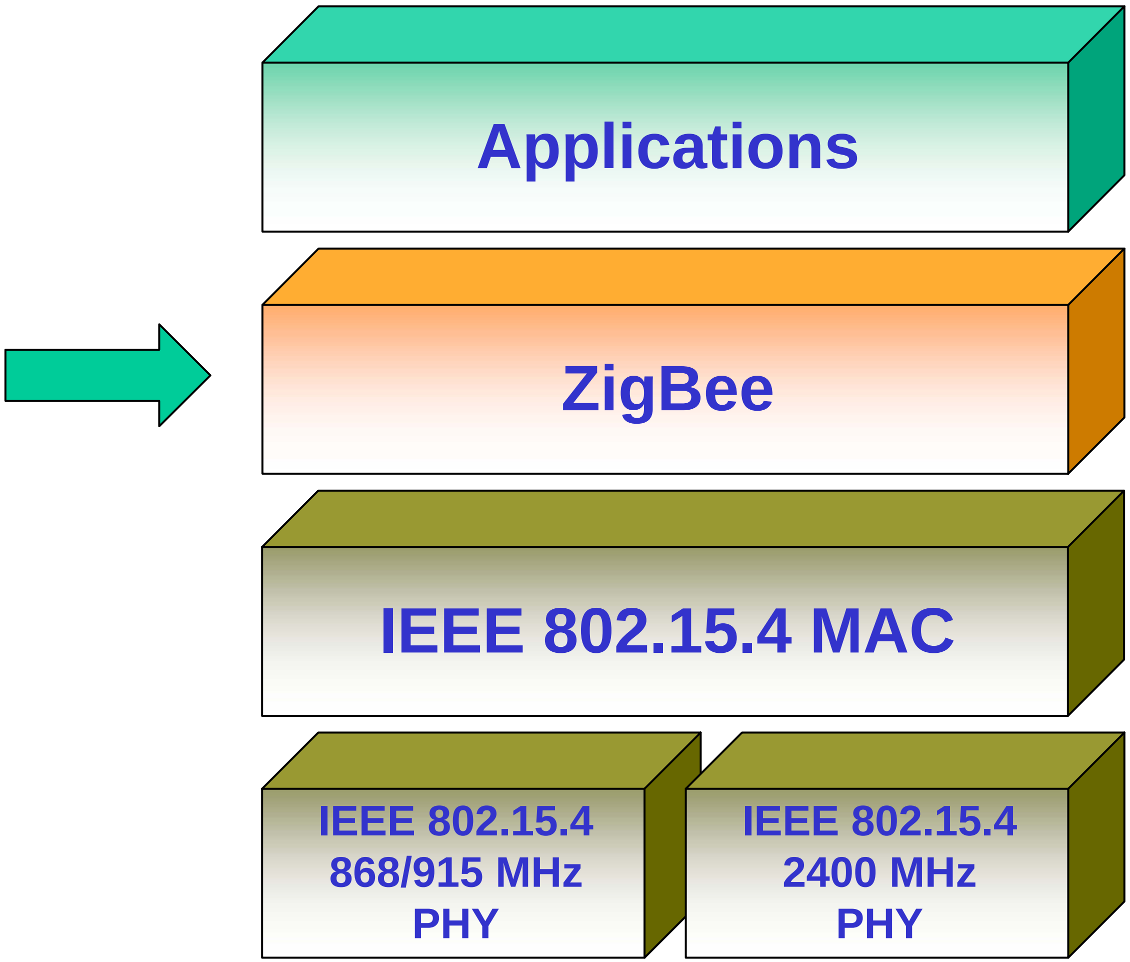
- Data Frame
- Beacon Frame
- Acknowledgment Frame
- MAC Command Frame



MAC Overview - Traffic Types

- **Periodic data**
  - Application defined rate (e.g. sensors)
- **Intermittent data**
  - Application/external stimulus defined rate (e.g. light switch)
- **Repetitive low latency data**
  - Allocation of time slots (e.g. mouse)

802.15.4 / ZigBee Architecture



- Network Routing
- Address translation
- Packet Segmentation
- Profiles

Applying ZigBee

ZigBee - Example

Example:
Pimpstar LED Car Rims

Rims are programmable using a laptop and can display images as the car rolls down the street.

Video

ZigBee - Example

Fraunhofer Institut Integrierte Schaltungen

Example:
ZigBee™ – Sensor Network:

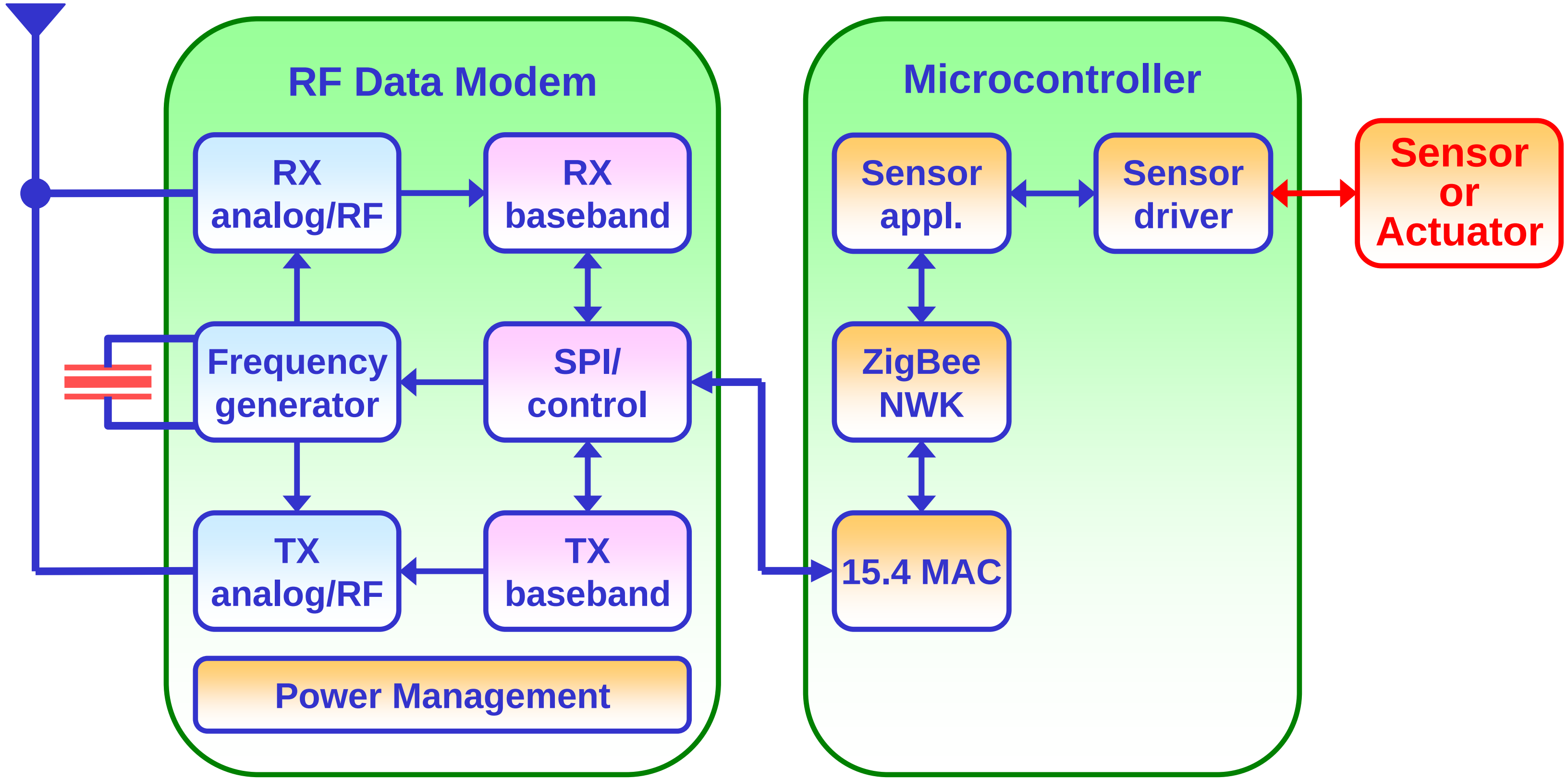
ZigBee™ Alliance

Wireless transmission of vital body parameters.

Video

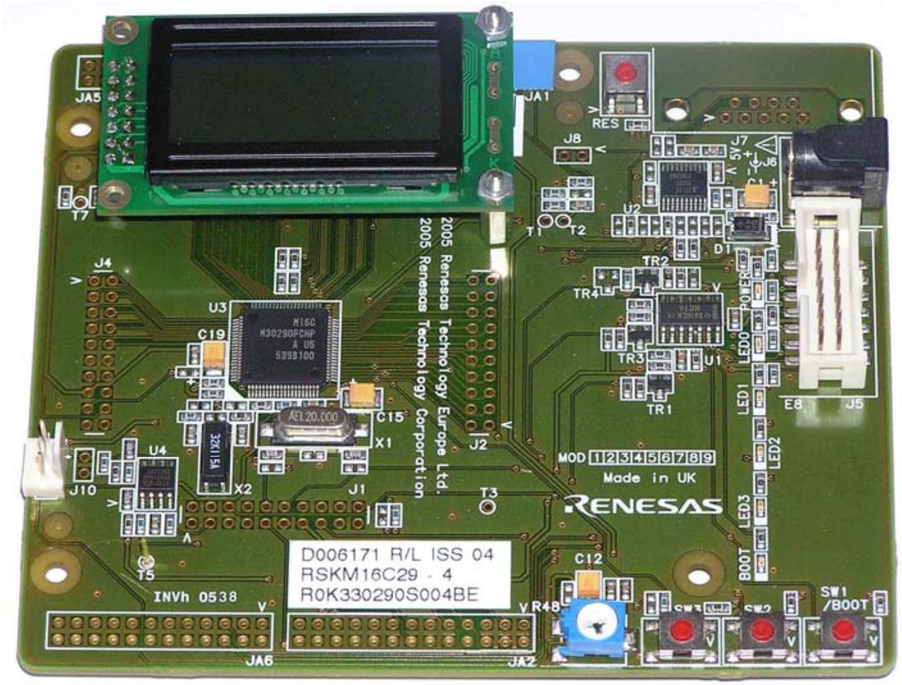
Building ZigBee compatible devices
For
Ambient Intelligence

ZigBee Device



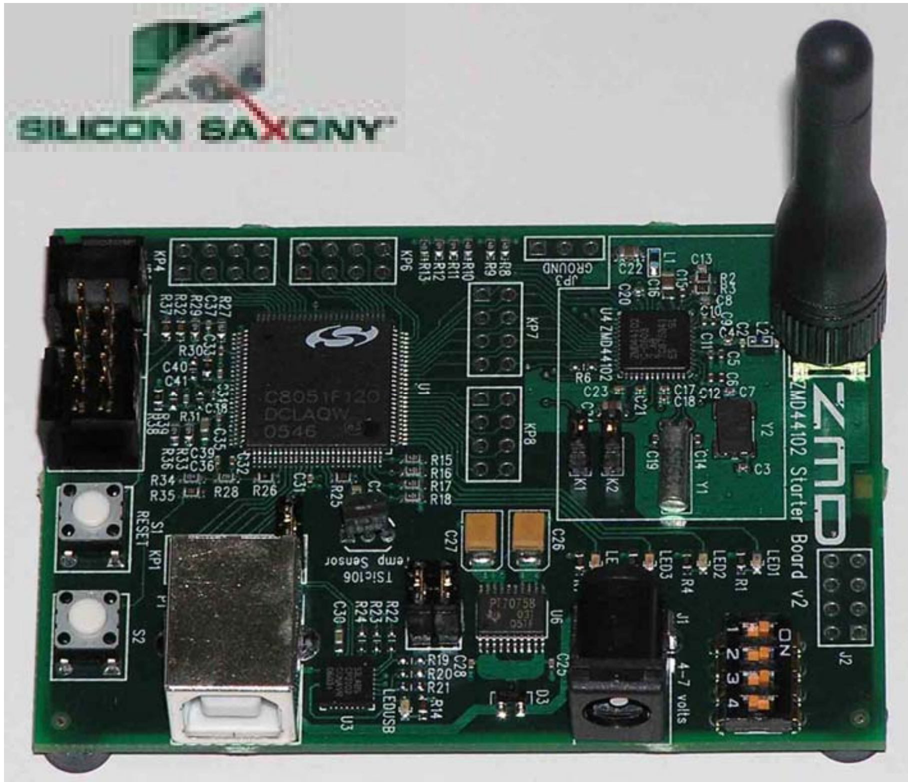
Typical ZigBee device:
- Microcontroller
- RF IC
- Interface to sensors or actuators

ZigBee related components, chip sets, products, etc.



Renesas
Development Kit
Microcontroller: M16C

ZigBee related components, chip sets, products, etc.

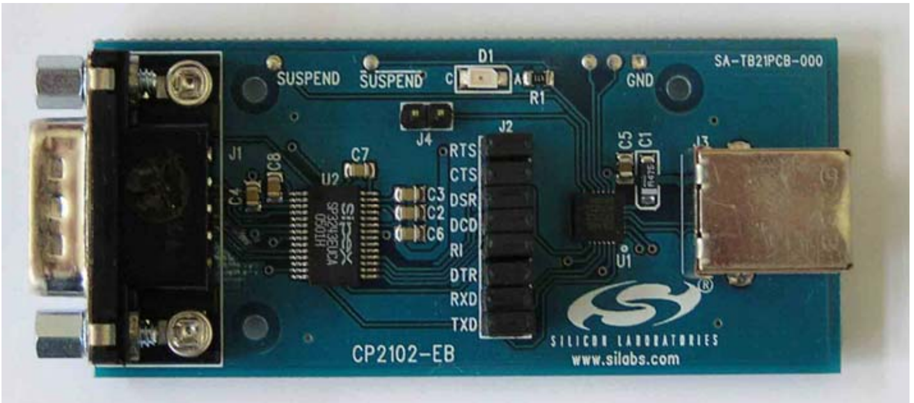


ZMD
Development Kit

http://www.zmd.de

IEEE 802.15.4 Summary

ZigBee related components, chip sets, products, etc.



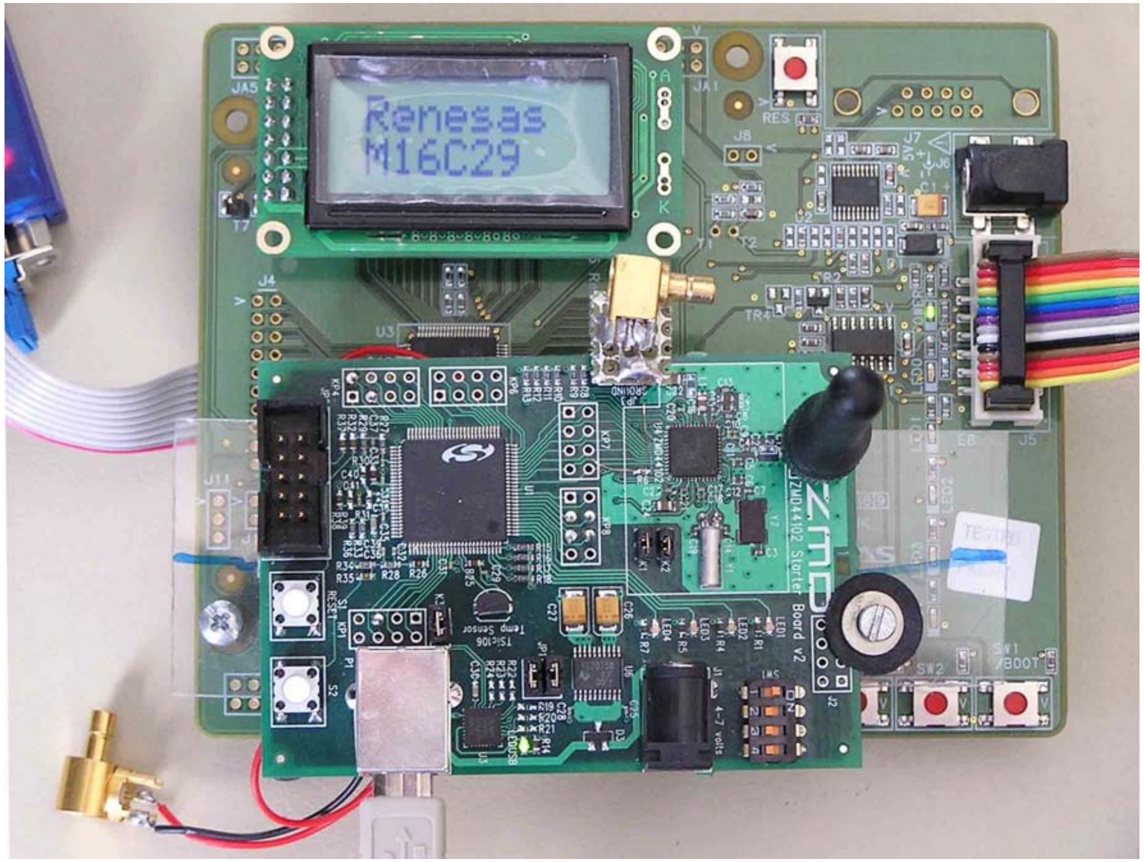
Silicon Labs
Development Kit

SILICON LABORATORIES

http://www.silabs.com

IEEE 802.15.4 Summary

ZigBee related components, chip sets, products, etc.



The end

Thank you!

The End

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