Cooperating devices

(research perspective of SAN @ CS.TU/e)

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My motivation

- I like
  - computing machines, digital devices
  - programming
  - mathematics
- I am interested
  - in abstraction, getting to the essence, understanding the 'why', finding relationships
  - in generally applicable techniques
  - in making things work
- I am fascinated with and impressed by the electronics and the software I use today

Contents

- SAN status
- Technology trends
  - ‘laws’
  - networked systems evolution
  - roadmaps
- Plans
  - research topics, elements
  - cooperations

SAN, position

- One of eight research groups of Computer Science
  - Visualization, Algorithmics
  - Formal methods, Software construction
  - Architecture of Information Systems, Databases & Hypermedia
  - Design and analysis of systems, **System Architecture and networking**

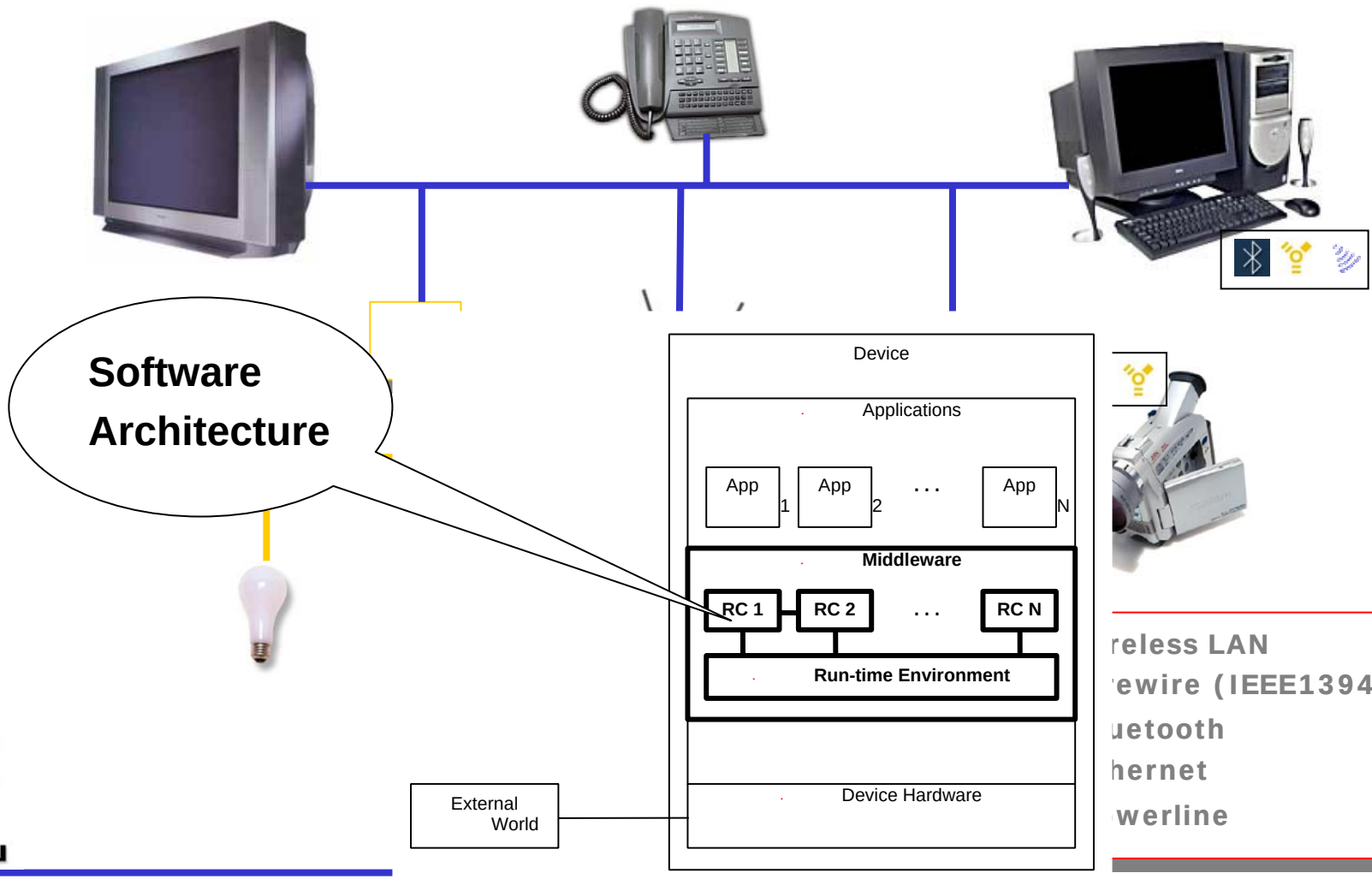
- Staff: 7 full-time, 4 part-time
- Temporary: 12

SAN: application and research domains

- Application domain: networked, resource-constrained embedded systems
  - techniques, concepts, approaches, results

- Calls for a *diverse collection* of research domains
  - distributed systems, networking, parallel computing
  - architecture, software and hardware
    - compositional systems
    - non-functional requirements
    - specialized embedded hardware for special functions
  - real-time techniques
    - resource sharing (QoS), resource allocation (budgets), performance analysis

Research context and topics



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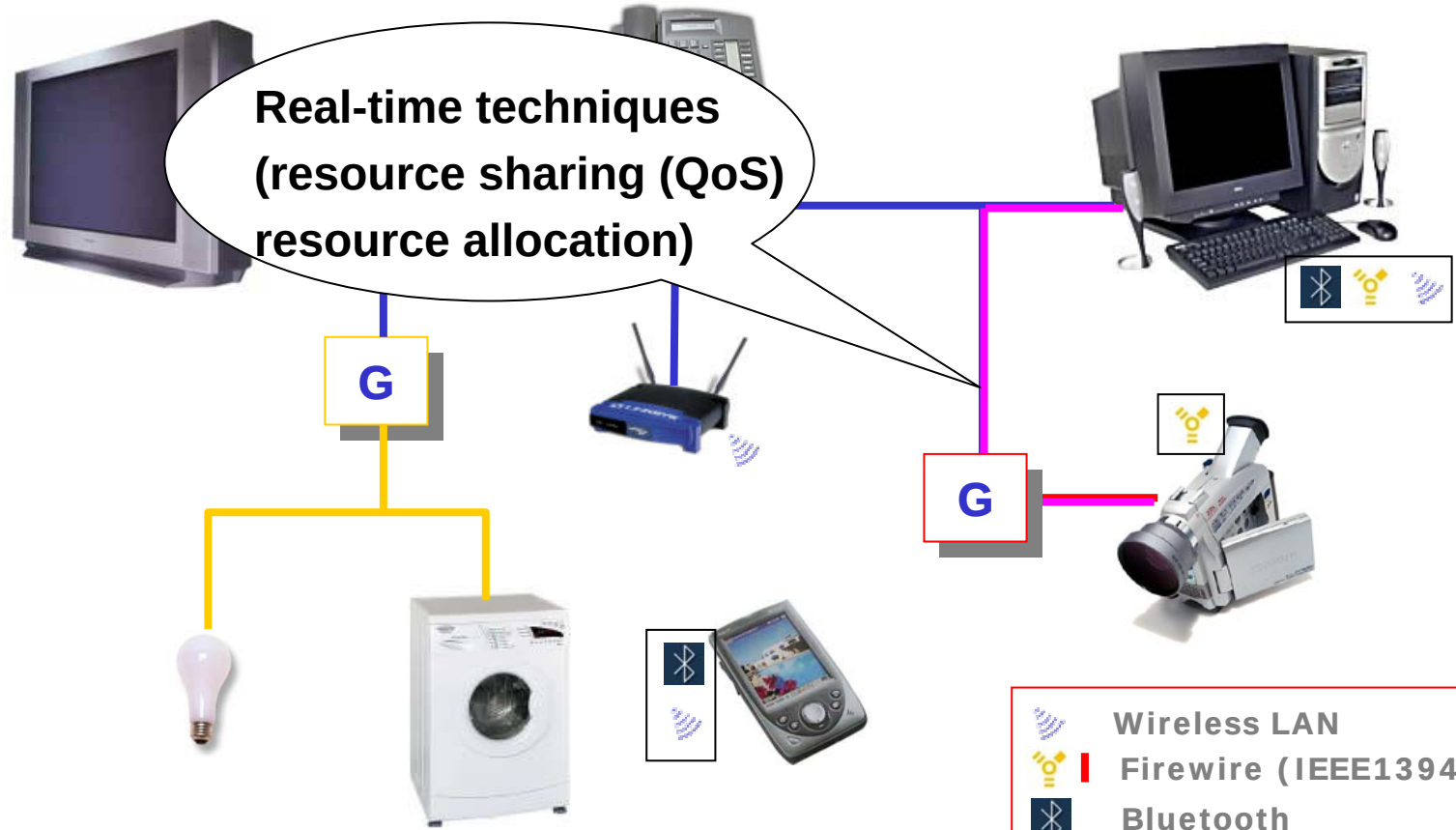

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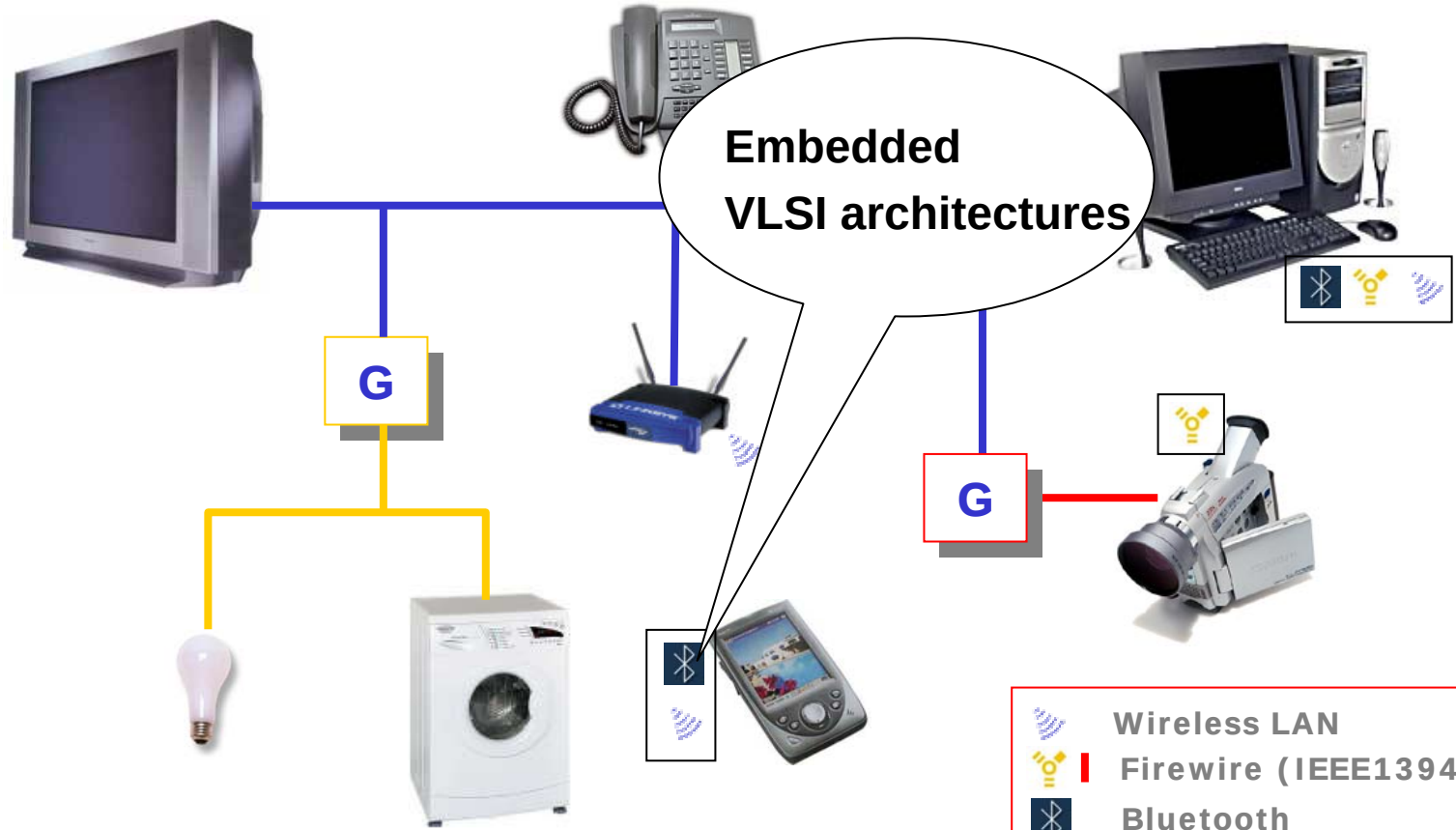
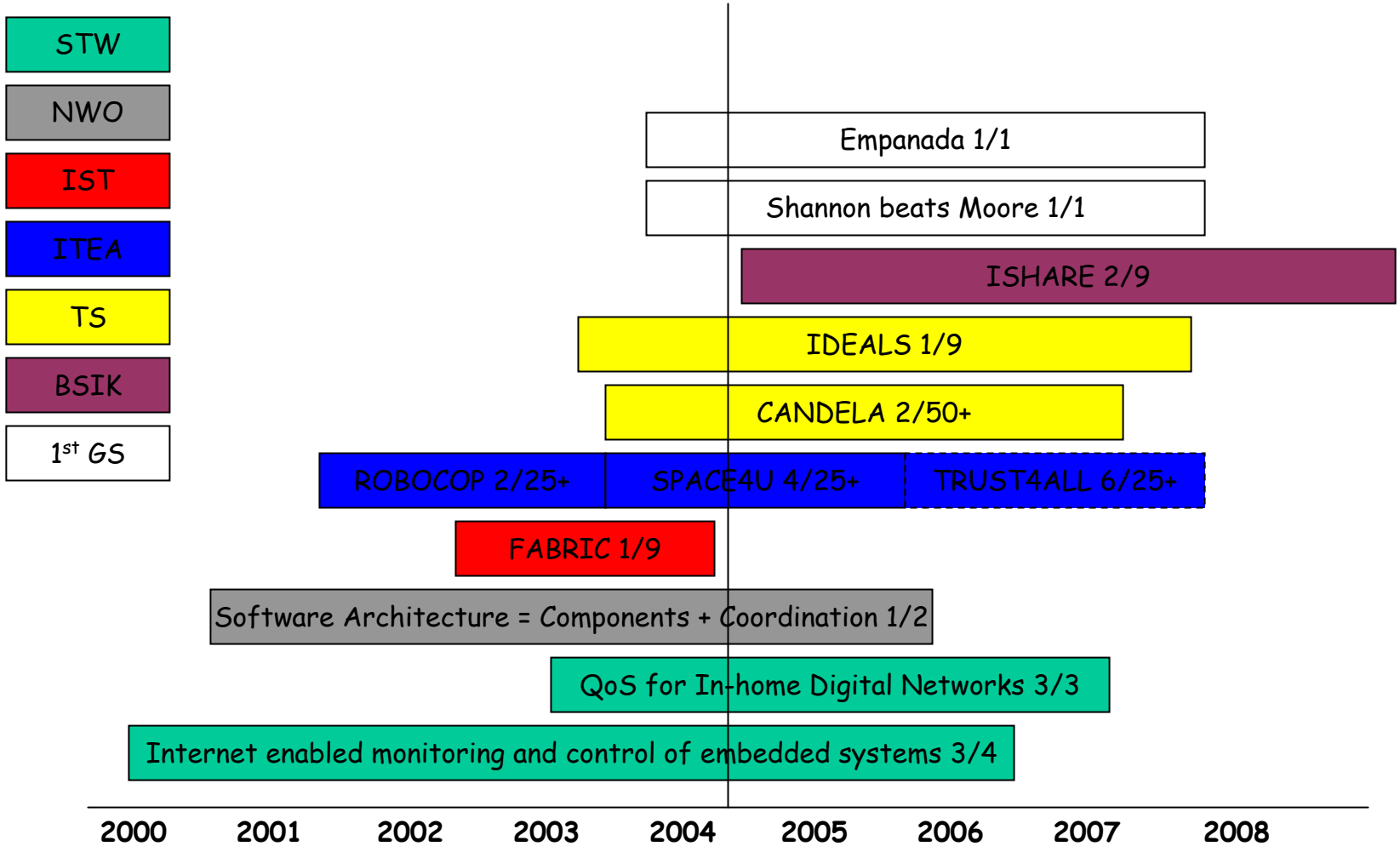


Wireless LAN
Firewire (IEEE1394)
Bluetooth
Ethernet
Powerline

SAN Projects



SAN education

- 2IC10 Computer Networks
- 2IN10 Design of Parallel Programs
- 2IN20 Real-time Architectures
- 2IN30 VLSI programming
- 2L490 Neural Networks
- 2L550 Heuristic Search
- 2Q341 Concepts of Disitrbuted Systems
- 2R800 Software Architecting of Distributed Systems
- 5KK20 Multiprocessors
- t.b.d. Components 2
- Parallel computations and applications
- Seminar Transport protocols
- Operating Systems

Some thoughts

- We do have a diverse portfolio
  - which does not lead to a strong cohesion
  - but this is to be expected from the domain

- We can benefit from
  - a shared vision on developments and consequences (or at least a *known* vision)
  - perhaps: the definition of a complex system of which most projects develop parts
    - e.g. a component-based, distributed, real-time middleware supporting routine changes which are predictably correct, exposing networked services running on dedicated hardware
  - organize staffing overlap in projects
  - assist in each others courses

Education, towards the future

- **General focus**: the engineering *practice* in systems and system software
  - Operating systems!, processor architectures?
- Courses preferably combined with practical
- Practicals based on software that we know or developed
- Involve students
  - preparing software for courses
  - testing ideas
  - developing systems

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‘Laws’

- Moore
  - # transistors/mm^2 doubles per 18 months
- Metcalfe
  - value of a network proportional to (# nodes)^2
- Gilder
  - internet bandwidth triples every 18 months
    - better radix than Moore
  - the principle seems to apply to communication technology in general
    - Shannon is beating Moore ?
- Bell
  - computing paradigm shift per 10 years

Points of view

- Moore:
  - don't mind performance, just wait
    - a 'clumsy-looking' but human time-saving approach may turn out to be useful later
    - a performance hole may be filled later
  - electronic devices becomes *cheap*, *small* and *self-contained (systems on chip)*
  - inventions of applications do not rely on ingenuity
    - just be the first to observe that something comes within reach
  - how do we get these transistors to work? and what for?
    - 200 Mtransistor on a chip right now
    - 100 Gneuron in the brain
      - **notice**: I can store a byte per neuron on my HD

Points of view

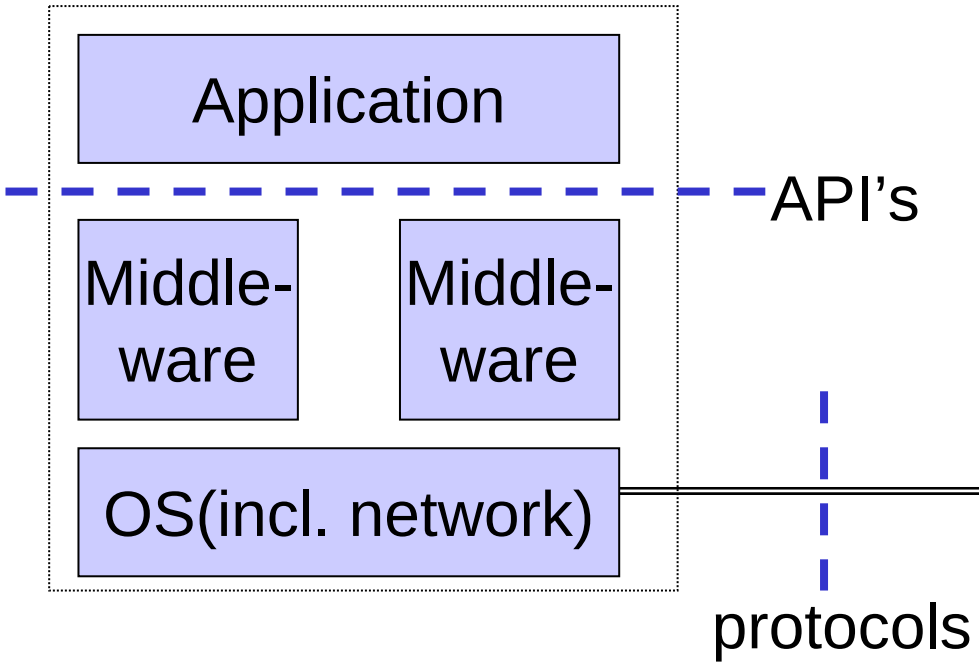
- Metcalfe:
  - connect everything with everything
- Gilder:
  - everything connected to the internet (cf. Metcalfe)
  - how to process all that information?
    - particularly with all that increasing communication
- Bell:
  - well... what's a paradigm anyway?
    - and what were these shifts then in the past?
  - perhaps:
    - a shift to embedded *control*
    - service oriented architectures – taking a networked context for granted
    - network as system bus

Some observations

- Practice goes slower than the hype predicts
  - e.g., break-through of Internet, use of BlueTooth, in-home digital networks and devices, broad-band for everyone, ...
  - .... but the developments do continue
- Compositionality will be vital
  - impossible to repeat building systems from scratch
- More and more control (decision making) must be – and is – handed to systems
  - need to extend the *basis* for decisions

Composition

- Usual approaches
  - layering
  - composing *known* objects
- NFR going up the stack and between objects
  - awareness at the interface
- Internal and external boundaries
- Partners not known at design time
- Cooperation beyond communication



Questions for the coffee-table

- What is the *goal* of all this increase in technology?
  - what do we want to build with unlimited ....
    - performance
    - connectivity
    - memory & storage
  - ... perhaps run next-gen windows?

- What would we do when we had to live with today's technology for a longer time?
  - use it better? more effectively?

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Embedded systems characteristics

- Heterogeneous
  - both in design as in product, platform
- Resource limited
  - cheap, small, minimal, low power, ...
  - limited user interface
- Cost effective
  - balance hardware and software, optimal hardware use
- In itself not visible
  - platform invisible to user
  - serves device core function

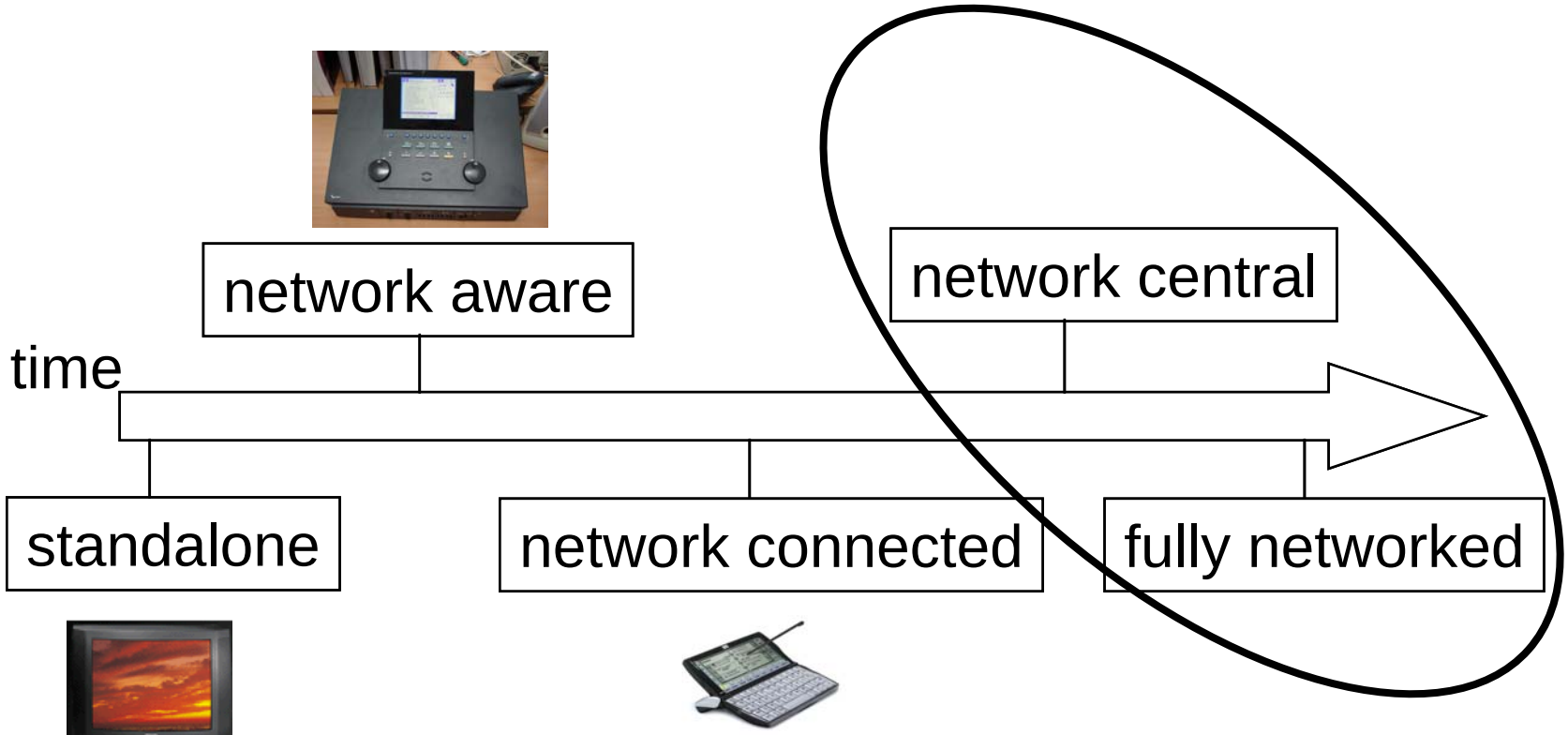
Embedded systems evolution

- Software replaces hardware
  - initial and most important application of real-time systems
- Product competition on features
  - features easier to realize with software
  - more and more it is software that determines *what* a product is
  - increasing diversity of functions
- Signals becomes digital
  - telephony, audio, video
- System becomes open
  - programmable, replacement of software [flash firmware, download new applications, remote update]
- Fully networked system
  - cooperation with other embedded systems

Evolution of networked embedded systems

- network unaware
  - embedded hardware inaccessible
- network aware
  - simple, proprietary connection to outside world
- network connected
  - network is add-on, remote access, standards
- network central
  - network(s) gets into the system design
- fully networked
  - network connectivity essential for core functionality (single device rather useless)

Evolution of embedded networking



Network central

- Devices have a stand-alone function
  - PDA, TV set
- In addition, they serve as ‘platform’ for networked applications
  - specific device capabilities available on the network
    - display, internal hardware (e.g. codecs), internal memory
  - support for hosting (networked) applications
    - components that can be down- and re-loaded routinely

Consequence

- Highly distributed applications
  - composed of the cooperation of small services
- Highly mobile code
  - services and applications realized in independent components that can be down- and re-loaded routinely
- Embedded knowledge
  - decisions taken without direct user involvement
    - at most some steering
  - need a reference that separates good from bad decisions
    - model, learning, feedback-control loops
  - intelligence at many levels
    - protocols, algorithms, system

Fully networked

- No stand-alone function
  - dedicated, single function components
    - e.g. networked storage, internet radio
  - cheap devices, elementary behavior
    - sensing, actuating, computing, communicating (sensor networks)
- Applications arise from cooperation

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Roadmaps

- ITEA
  - handling of multimedia, increasing the semantic level (content)
  - include (physical) environment inside the system – sensing and actuating in all forms
- PROGRESS
  - increase in heterogeneity, networking
  - standards on sensing, actuating with varying sources
- SENTER (ESI)
  - adaptive, self-organizing networks
    - embedded intelligence
    - micro electro mechanical systems
  - resource aware software (architecture)
  - methods: reuse, predictability, reliability
- NOAG-I by NWO

De zeven NOAG-i-thema's

- Parallel and Distributed Computing (PDC)
- Embedded Systems (ES)
- Software Engineering (SE)
- Multimedia (MM)
- Modelling, Simulation and Visualization (MSV)
- Intelligent Systems (IS)
- Algorithms and Formal Methods (AFM)

NOAG-i: Embedded systems

- communicatieprotocollen.
- koppeling van theorie aan toepassingen (verificatie, validatie, testen).
- communicatie van stand-alone-systemen door middel van draadloze communicatie (“wireless”).
- mobiele (draadloze) communicatie; alomtegenwoordige (“ubiquitous”) communicatie;
- "ambient intelligence".
- hardware/software co-design, hybride systemen (discrete en continue componenten).
- randvoorwaarden ("constraints") zoals temporeel gedrag, foutentolerantie, geheugengebruik, vermogensdissipatie, bestendigheid tegen onvriendelijke milieus enz.

NOAG-i: relevant disciplines

- Bijdragende informaticabasisdisciplines:
- Architectuur
- Beeld- en sensorverwerking
- Constructiemethoden
- Dependability
- Formele methoden
- Gedistribueerde systemen
- Interoperabiliteit
- Ontwikkeltools
- Parallelle systemen
- Specificatiemethoden
- Testmethoden

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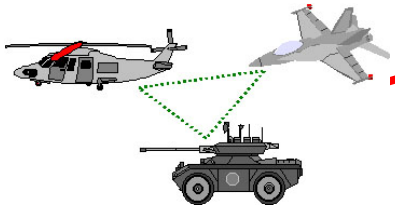
Key Aspects



Self organizing networks

Advanced interaction

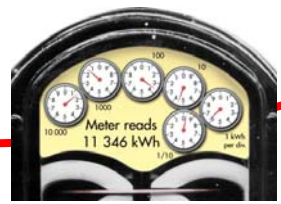
Minimal (zero) ration

- addressed within the architecture
- integrated in design methodologies, programming languages

Privacy, security

Open protocols

Embedded intelligence (resource awareness)



Transparent control

Automatic

- Devices cooperate to support user goals & applications
  - partners not known at design time
  - applications not known at design time
- Cooperation goes beyond electrical standards and protocols, e.g.
  - agreements on sharing of resources
    - network, processing, storage
  - *derivation* of behavior from general goals
    - rather than explicit programming by a user
  - resilience against service mobility

- *"Auto-configuration towards the application level"*

Feedback and Reference model

- Current programs, typically
  - specify behavior – action sequences
  - derived through a design process from a specification
    - that includes *assumptions*
  - total specifications are difficult
    - and don't cover non-functional requirements

- Challenge
  - include *goals* of actions inside the system
  - let system *reflect* on effect of actions
  - integrated, methodological approach, including language support

- Example:
  - environment model, updated through observation
  - reference model, giving the desired situation

Privacy

- Privacy is **not** security
  - though security mechanisms help
- Privacy pertains to information being
  - non-existent
  - non-recorded
- Communication based on ‘what is needed’ principle
- Aggregation and processing close to information source

Models

- In our research field, what are good models for
  - storage
    - awareness of mobility?
  - processing
    - e.g. grid computing
  - (sharing) communities?
    - e.g. competitive, cooperative
  - security and privacy?
    - e.g. trust?
- ... and what are the supporting mechanisms?

Cooperations and neighbors

- Internal
  - TU/e research directions
    - SEES: science and engineering of ES – CS focus
      - FM, OAS, group Otten (EE), group Rooda (ME), ESI
    - Ambient Intelligence
      - IS, ID (Feijs), TM, ...
  - EE: Peter de With (Broadband TT)
  - ESI: renewed – CS focus
    - I will take over Baeten's tasks
    - involved in IDEALS
  - DTI: request from E to setup programme
    - very low profile; currently, exchange student
  - LaQuSo: all CS
    - opportunity!

LaQuSo

- We have much of the searched expertise
- Through LaQuSo we can build on this
  - staff extension & location
  - access to advanced example systems in companies
- Contacts
  - place to learn from each other (CS)
  - to have more effect of research output
- Quickly growing – 6+fte appointed
  - has the opportunity of ‘discontinuous growth’

Cooperations and Neighbors

- External
  - VU Amsterdam – van Steen
  - TUD – Lagendijk, Sips
  - TUT – Hartel

  - Philips Research, many groups
  - Bosch Security
  - OCE
  - ASML

  - ... perhaps more that I overlook now

SAN Systems

- Cluster of 16 nodes
  - Distributed and parallel computing
  - Real-time networks and scheduling
- Heterogeneous network
  - Wireless LAN, Bluetooth, Firewire
  - PCs, laptops, PDAs
  - sensors (wireless)
- LANs
  - Shared data spaces
  - Real-time networks
  - UPnP & JXTA, Test & Development

Visibility

- The website is important
  - visibility is vital
    - students
    - interested outsiders
    - .... hence, please update project pages
  - communication
    - content sharing, maintaining project status
    - students again
    - ....hence, update output and project descriptions
- Use –at least– the SAN icon on any relevant output
  - we'll make it available

Some conclusions

- Ambient intelligence requires open, flexible systems
  - cooperation beyond the protocol level
- New perspectives in design
  - service orientation
  - component based
- Embedded intelligence plays at multiple levels
  - intelligence ‘stack’
- Embedded intelligence raises strong issues of privacy

User observations

- My 2.6 GHz, 512MB, 390GB computer
  - misses frames from a stream when I start IE
  - disrupts mp3 playback in that case
  - needs *device support* (buffering) to avoid CD-write underrun
  - stops functioning when it needs virtual memory
  - sometimes locks for an indefinite amount of time or is just very slow
- Playing video across my 100Mbit/sec network of a 5Mbit/sec stream does not work very well
  - though lower quality streaming across the internet works reasonably
    - but that is not P2P
- Connecting my IRDA enabled PDA to anything is painful
  - need to setup strange settings
  - no idea about what is going where and where problems are
- I have no clue how to configure my system software
  - new versions
  - effect of updates