Organic Computing

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Hardware-Software-Co-Design

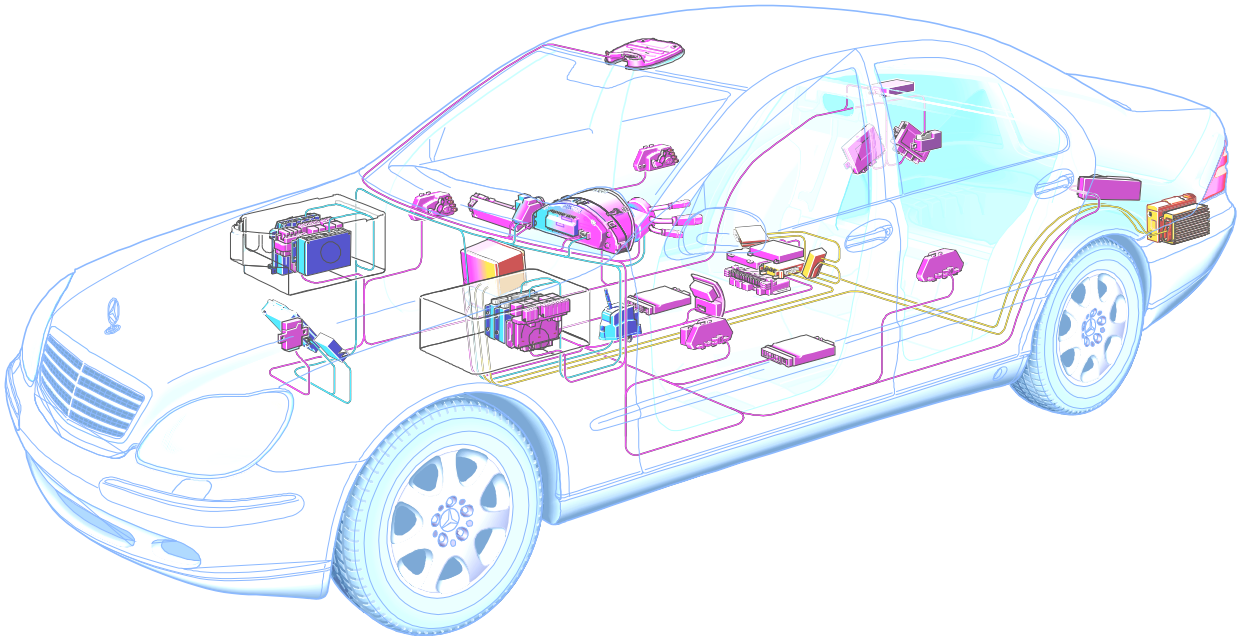
Introduction, Motivations, Overview

Smaller/Cheaper/Faster/Powerful/Connected

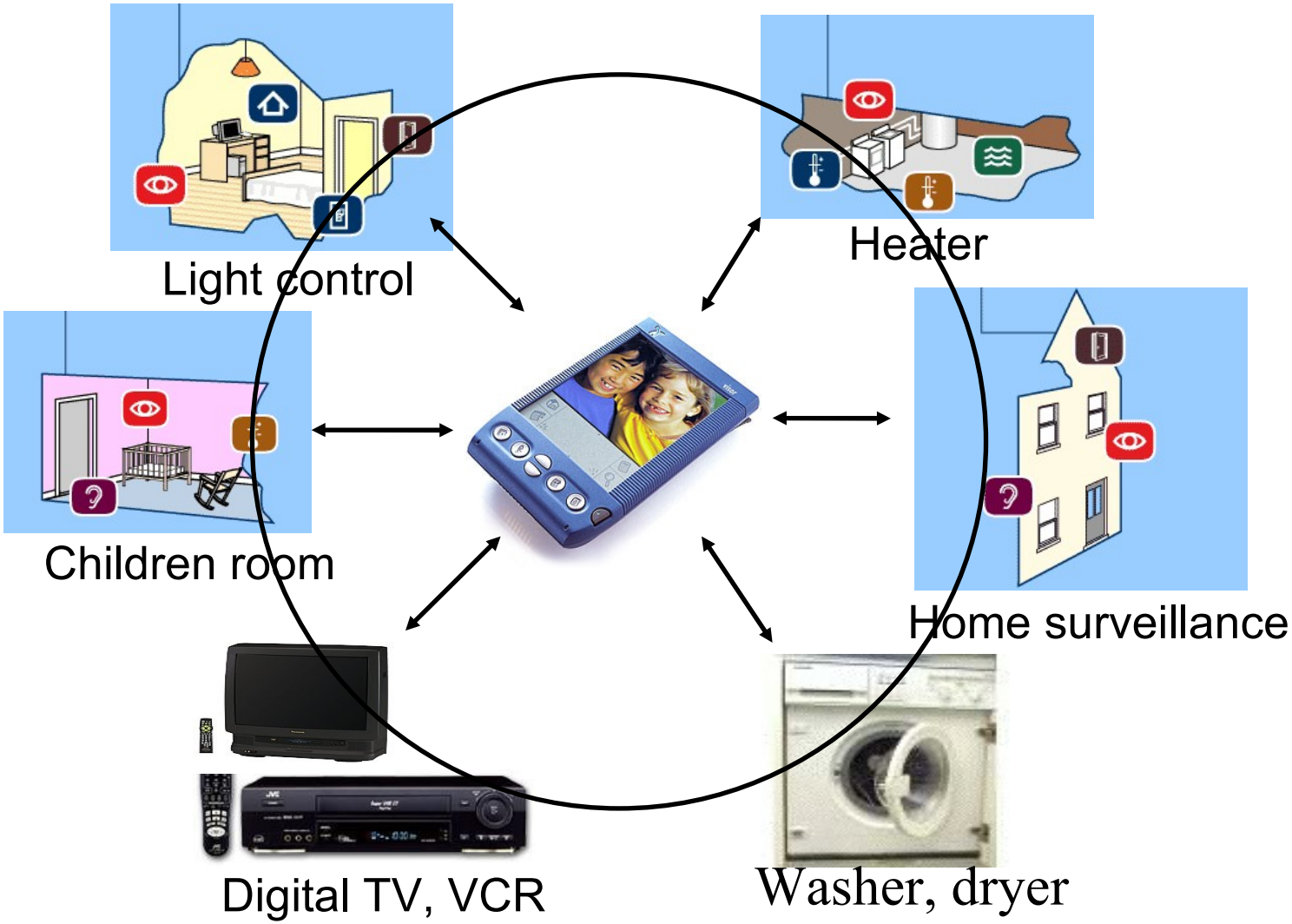
- Explosive growth in computation, communication, information and integration technologies
  - computing is ubiquitous, pervasive
  - communication is/will be
- Pervasive „anytime-anywhere“ access environments
  - ubiquitous access to information via PCs, PDAs, Cells, smart appliances, etc. (billions of devices, millions of users)
  - producing/consuming/processing information at different levels and granularities
  - phones, cars, traffic lights, lamp posts, refrigerators, medical instruments, clothes
- „On demand“ computational/storage resources, services

  the Grid

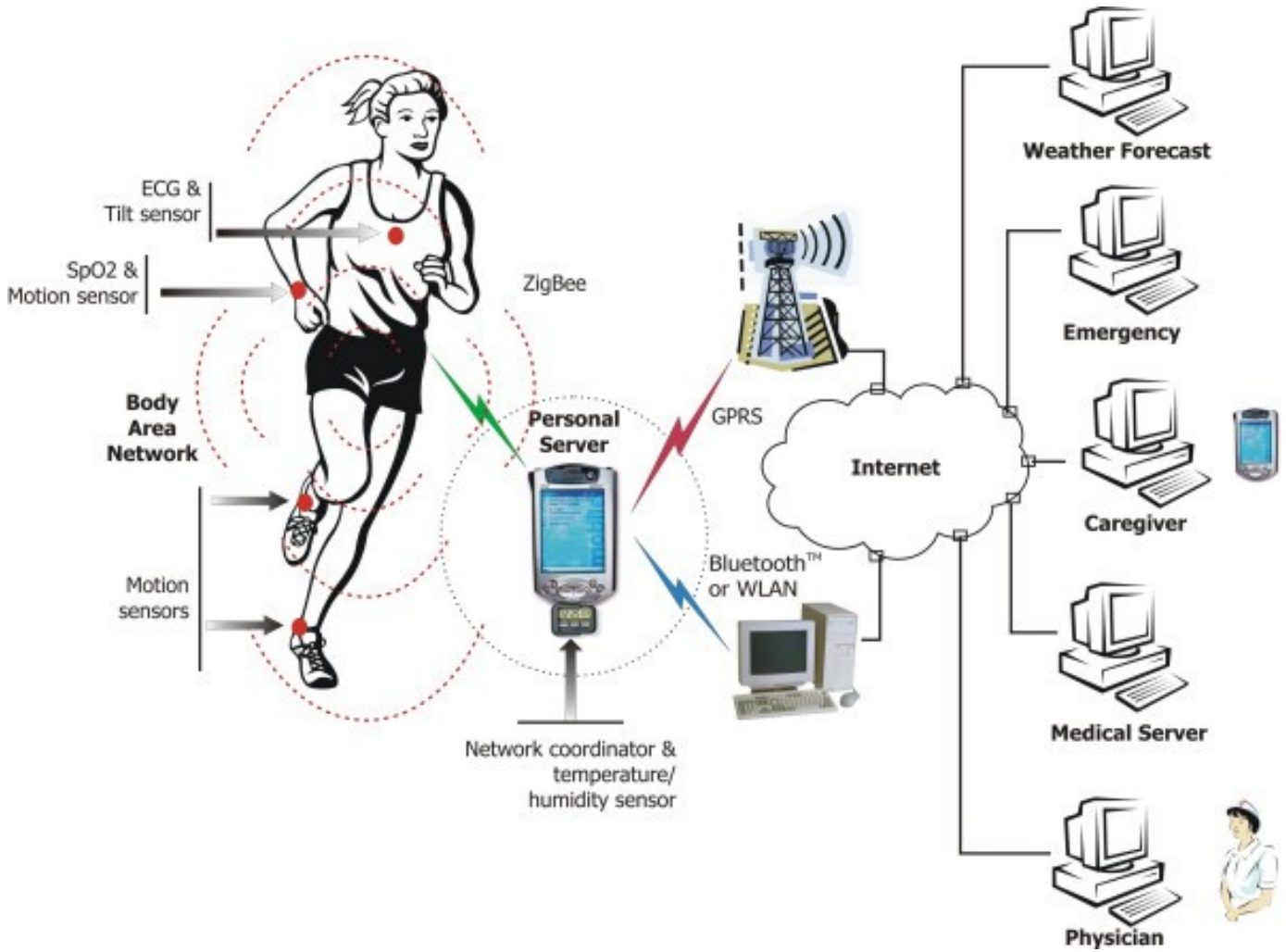
Example: Automobile



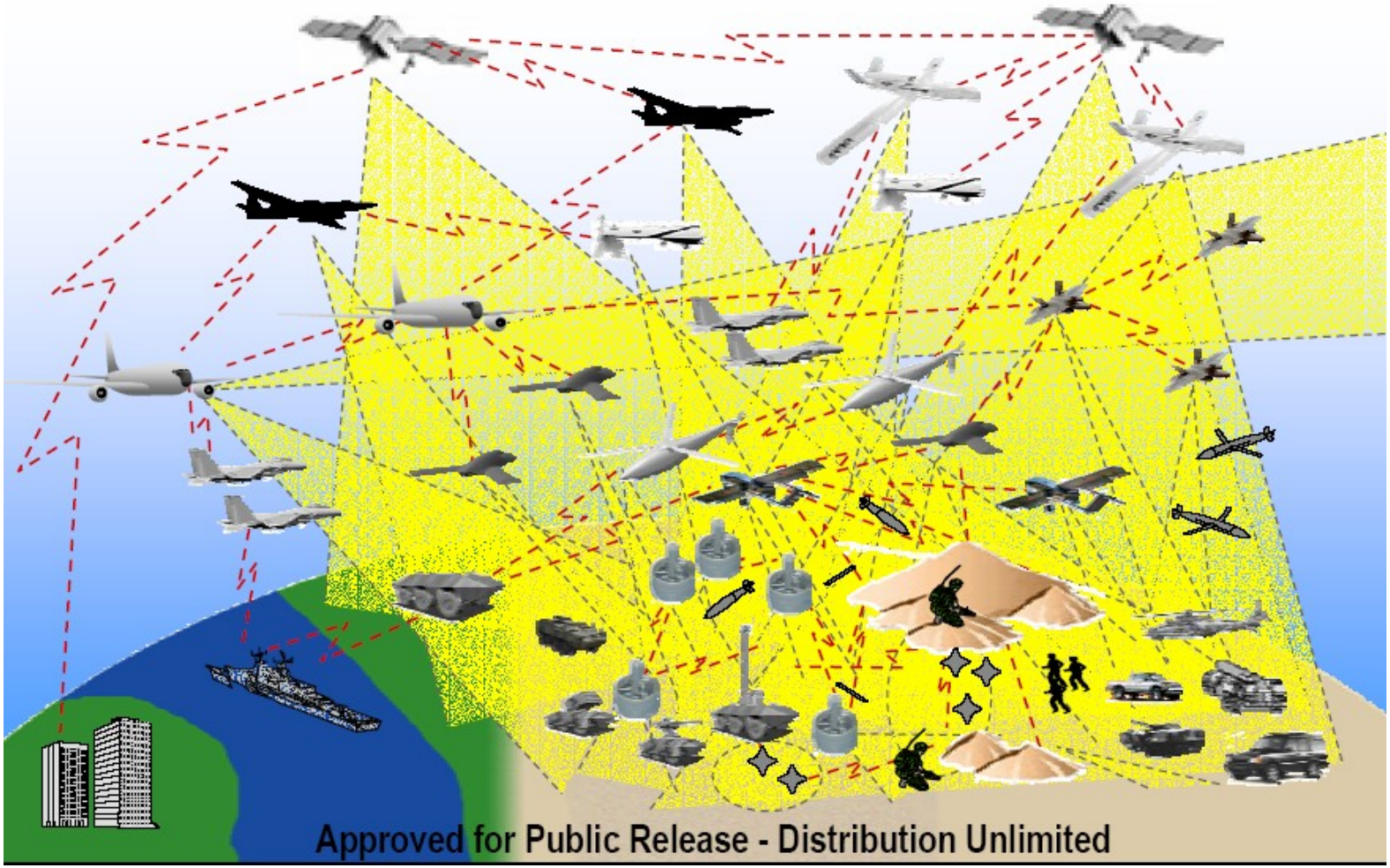
Example: Home Networking



Example: Body Area Network



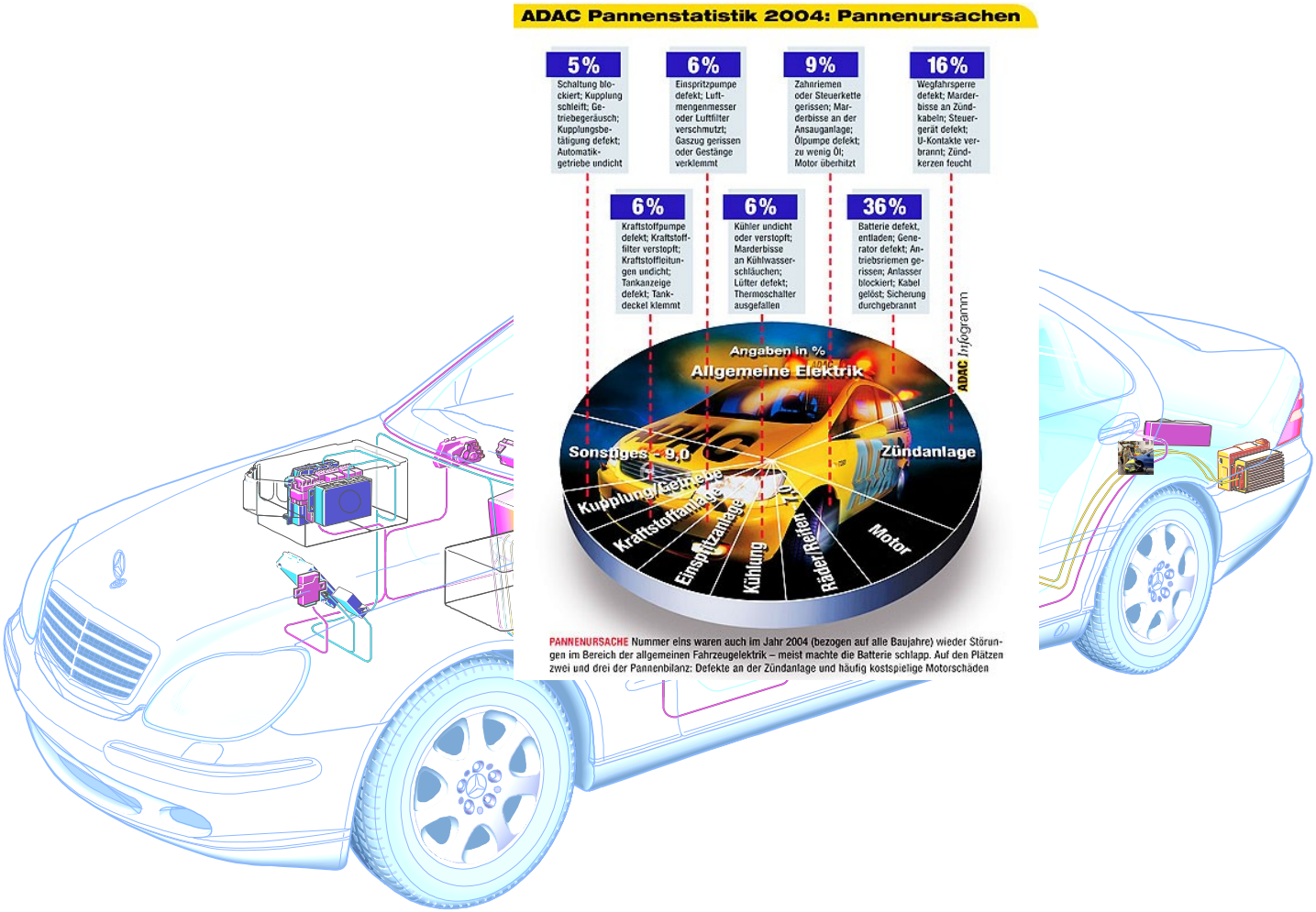
Example: DARPA IXO, A Rapidly Expanding Universe of Sensors, Weapons, and Platforms



Motivation: Complexity, the dark side

- Administration of individual systems is increasingly difficult
  - 100s of configuration, tuning parameters for DB2, WebSphere
- Heterogeneous systems are becoming increasingly connected
  - Integration becoming ever more difficult
- Architects can't intricately plan interactions among components
  - Increasingly dynamic; more frequently with unanticipated Components
- More of the burden must be assumed at run time
  - But human system administrators can't assume the burden; already
    - 6:1 cost ratio between storage admin and storage
    - 40% outages due to operator error

Motivation: Complexity, the dark side



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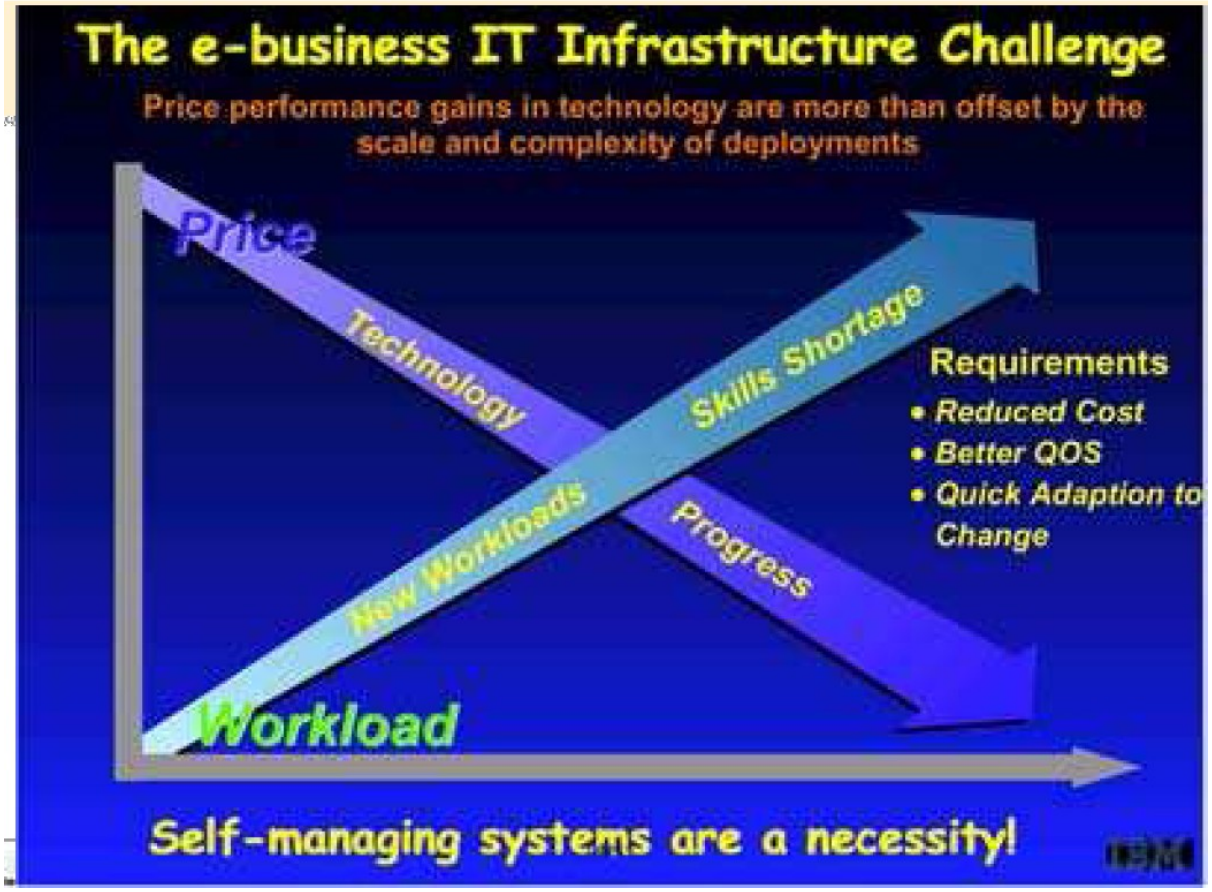

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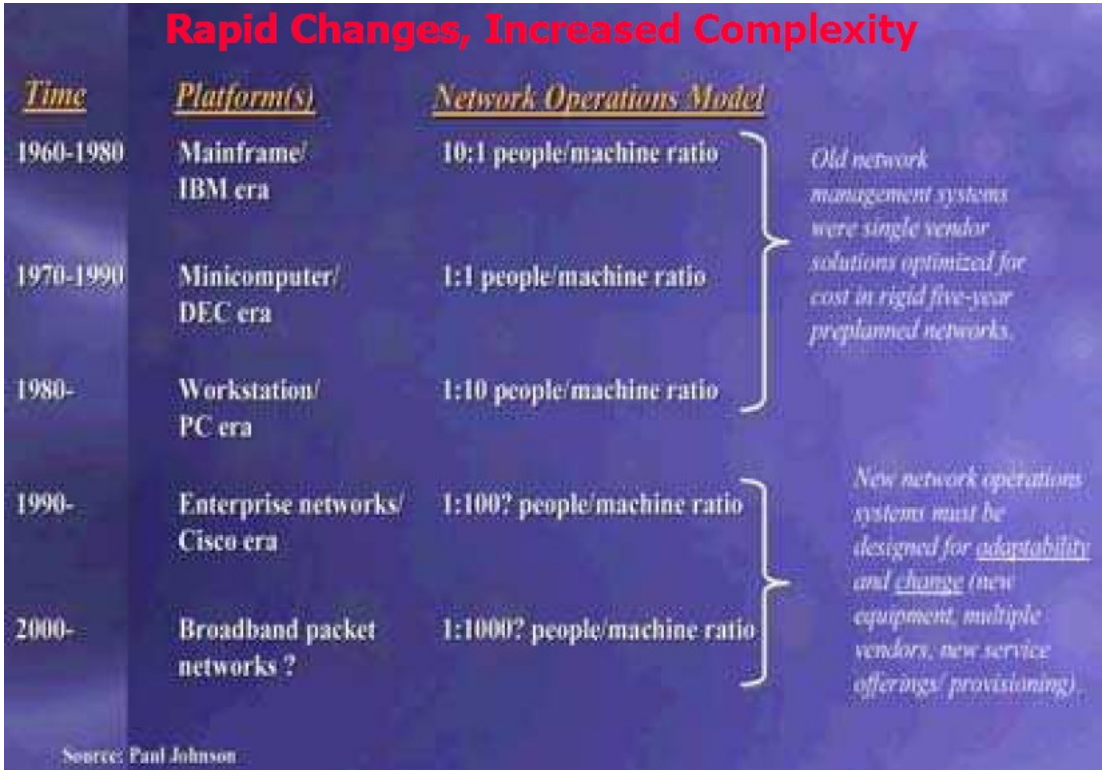
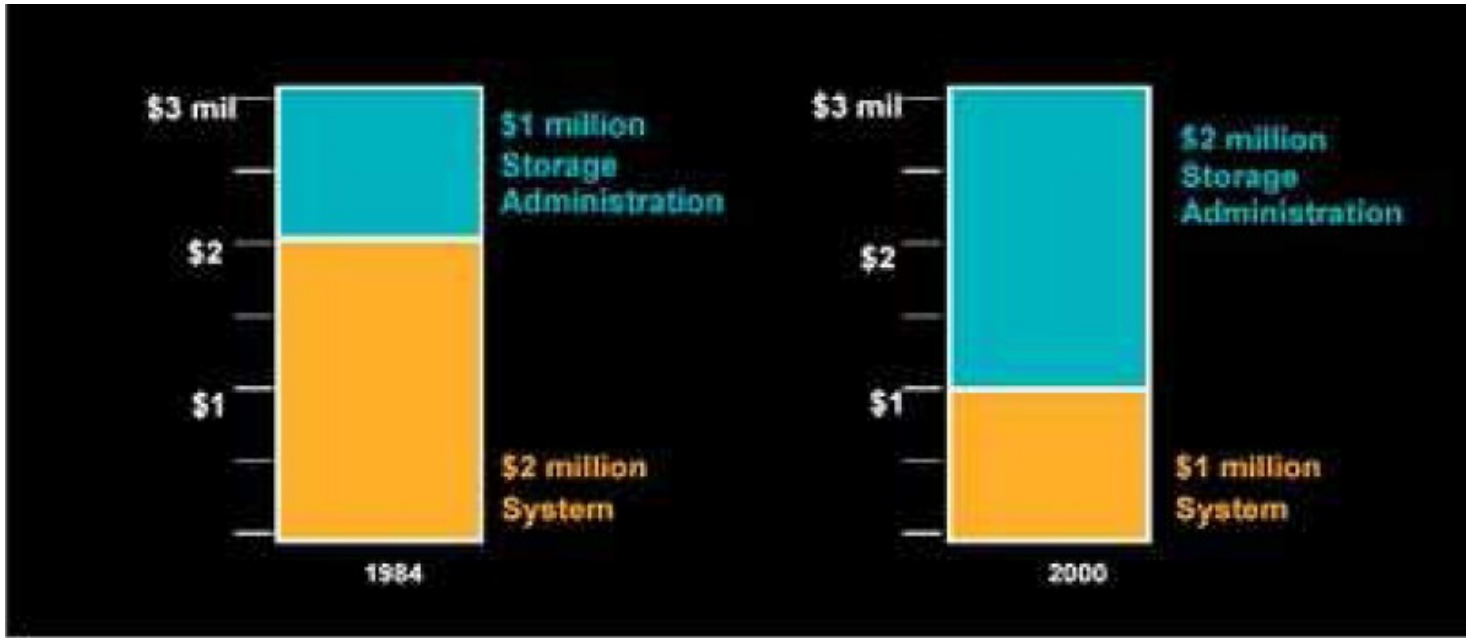


Motivation: Increasing cost



Motivation: Complexity, the dark side

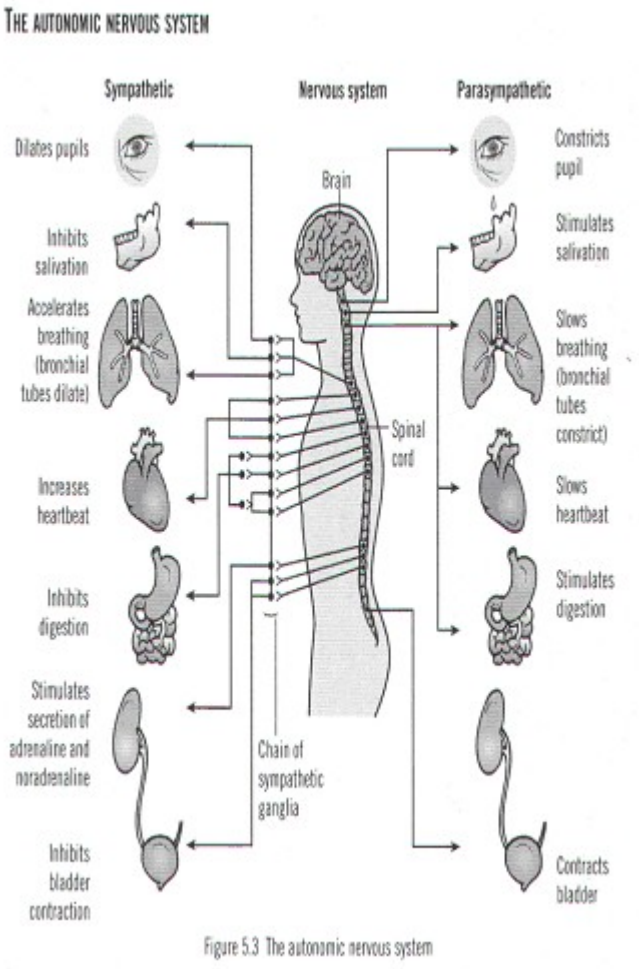
- Bottom line
  - the increasing system complexity is reaching a level beyond human ability to manage and secure
  - programming environments and infrastructure are becoming unmanageable, brittle and insecure
- A fundamental change is required in how applications are formulated, composed and managed
  - autonomic components, dynamic compositions, opportunistic interactions, virtual runtime.

Motivation: Natural systems as solution

- Nature has evolved to cope with scale, complexity, heterogeneity, dynamism and unpredictability, lack of guarantees
  - self configuring, self adapting, self optimizing, self healing, self protecting, highly decentralized, heterogeneous architectures that work!!!
  - Biological system: e.g. the human body. The autonomic nervous system
  - Social society: insects, birds and human swarm
  - Can these strategies inspire solutions?
  - Of course, there is a cost.
    - lack of controllability, precision, guarantees, comprehensibility,

Motivation: Natural systems as solution

- Biological systems
  - The autonomic nervous system monitors and regulates without requiring our conscious
  - The system defends it self from foreign (viruses, etc...) attacks
  - The system optimizes it self (when we run it increases our breath and heart
  - The system is self healing: When we are hurt, the system produce new cells to heal the hurt.
  - The system is self reconfigurable. It modifies it self to adapt the environment.



Motivation: Natural systems as solution

- Social life
  - Limited local information

    Each individual in the group has access only to limited local information and has no global knowledge of the structure which it is engaged in constructing together with the other members of the group
  - A set of simple individual rules

    Each individual obeys a collection of a few simple behavioral rules. This rule set permits the group collectively to coordinate its activities and to build a global structure or configuration.
  - The global structures which emerge accomplish some function

    These structures often allow the group to solve problems. They are flexible (adapting easily to a novel environment), and they are robust, (if one or several individuals fail in their behaviour or make a simple mistake, the structures spontaneously re-form).

Motivation: Natural systems as solution

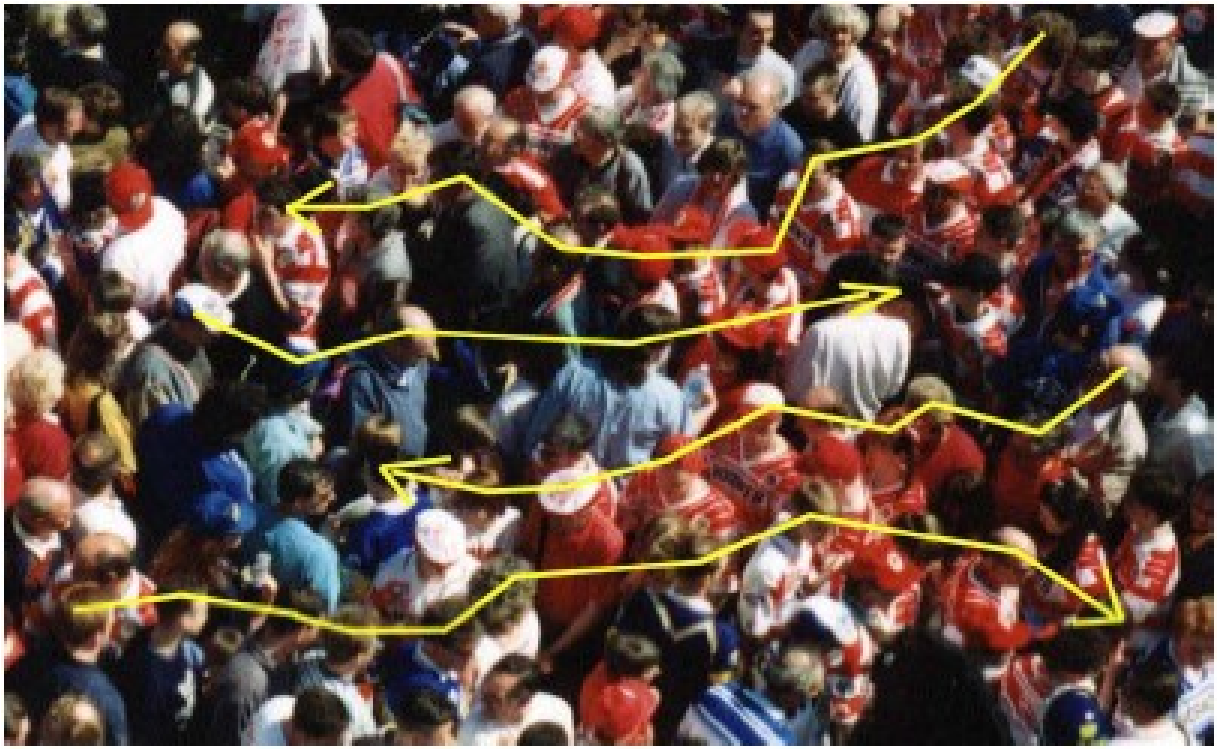
- A natural model of distributed problem solving
  - Collective systems capable of accomplishing difficult tasks, in dynamic and varied environments, without any external guidance or control and with no central coordination
  - Achieving a collective performance which could not normally be achieved by any individual acting alone
  - Constituting a natural model particularly suited to distributed problem solving
  - Many studies have taken inspiration from the mode of operation of social insects to solve various problems in the artificial domain

Motivation: Natural systems as solution

- Collective complexity out of individual simplicity
  - The behavioral repertoire of the insects is limited
  - Their cognitive systems are not sufficiently powerful to allow a single individual with access to all the necessary information about the state of the colony to guarantee the appropriate division of labor and the advantageous progress of the colony
  - The colony as a whole is the seat of a stable and self-regulated organization of individual behavior which adapts itself very easily to the unpredictable characteristics of the environment within which it evolved

Motivation: Natural systems as solution

- Collective behavior



Motivation: Natural systems as solution

- Collective behavior

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- Collective behavior

Motivation: Natural systems as solution

- Division of labor

Motivation: Natural systems as solution

- Division of labour



Motivation: Natural systems as solution

- **Some questions arise ...**
  - How do animal societies manage to perform difficult tasks, in dynamic and varied environments, without any external guidance or control, and without central coordination?
  - How can a large number of entities with only partial information about their environment solve problems?
  - How can collective cognitive capacities emerge from individuals with limited cognitive capacities?

Autonomic Computing: The IBM Initiative

- Computer Systems that can regulate themselves much in the same way as our autonomic nervous system regulates and protects our bodies..

(by Paul Horn, IBM)

Autonomic Computing: The IBM Initiative

- "increasing productivity while minimizing complexity for users."

- "to design and build computing systems capable of running themselves, adjusting to varying circumstances, and preparing their resources to handle most efficiently the workloads we put upon them.
- Does not require the duplication of conscious human thought as an ultimate goal.
- Does require system to take over certain functions previously performed by humans"

Organic Computing: The German Initiative

- Ein „organischer Computer“ ist definiert als ein selbstorganisierendes System, das sich den jeweiligen Umgebungsbedürfnissen dynamisch anpasst. Organische Computer sind selbst-konfigurierend, selbst-optimierend, selbst-heilend und selbst-schützend.

Organic/Autonomic Computing: The goal

- Self organizing
  System designed to manage it self without external intervention
- Self optimizing
  system design to automatically manage the resource to allow the system to meet the user's need in the most efficient fashion
- Self protecting
  System design to protect it self from any unauthorized access from anywhere
- Self healing
  autonomic problem determination and resolution
- self reconfiguring
  system design to define itself on the fly

Organic/Autonomic Computing: Scenarios

- Smart Factory:
  Autonomous robots can be connected in a federation in order to collectively solve problem that a single robot cannot solve. The system recognizes which part is overloaded and tries to balance the load. self-configurable, self-healing and self-optimizing.
- Smart warehouse
  Single articles can be observed in a an intelligent warehouse. In some warehouse it is already possible to use a portable device to communicate with article through a transponder with etiquette. In few years, this can be use to check the status of shelves, reserve, goods, caddy and electronic shopping list. This can then be used to automatically check the missing goods. This also allows good to be better controlled.
- Smart network: The grid
  Internet builds a worldwide heterogeneous parallel computer: the Grid. With the use of an intelligent network, the system has moved to a self-organizing, self-configurable, self-healing and self-optimizing entity.

Organic/Autonomic Computing: Scenarios

- Anthropomatic
  Computers will be tailored in the future to the individual need of single people. The goal of this discipline is to compensate individual decrease in the human functions as it could happen through illness or ageing. Organic computers will be the basis of this science.
- Robots in the household:
  According to a VDE study, 39% of women and 25% of men in Germany wish for robot help primarily in their household. Actual robots are not totally efficient due to the technology which is not yet mature. In the future, robots should be autonomous and low costs.
  Properties like self configurability, self-healing and self-optimizing are necessary.

Organic/Autonomic Computing: Program

- The landscape
  - Survey of existing systems
- System architecture
  - Autonomic component
  - Intelligence
  - Components interconnection
- Autonomic component development
- Brief tour in machine learning
- SelfX properties realization
  - Self organization
  - Self optimization
  - Self configuration
  - Self protection
- Example of system: Sensor networks

Literature

http://www.organic-computing.de
Autonomic computing and Grid., P. Pattnaik, K. Ekanadham, and J. Jann, Thomas J. Watson Research Center, Yorktown Heights, New York
Autonomic Computing: IBM.s Perspective on the State of Information Technology, P. Horn, IBM, (2001).
Autonomic Computing: The Evolution Continues, Data Management Strategies, (July 2002).
Autonomic Personal Computing, D. F. Bantz, C. Bisdikian, C. Challener, J. P. Karidis, S. Mastrianni, A. Mohindra, D. G. Shea, and M. Vanover, IBM Systems Journal 42, No. 1, 165.176 (2003).
Back to the Future: Time to Return to Some Long-Standing Problems in Computer Science., J. Hennessy, Almaden Institute 2002, IBM Almaden Research Center, San Jose, CA (April, 2002).
Helping Computers Help Themselves., D. Pescovitz, Contributing Editor, Special R&D Report.
NASA Challenges in Autonomic Computing., D. J. Clancy, Almaden Institute 2002, IBM Almaden Research Center, San Jose, CA (April, 2002).
The Dawning of the Autonomic Computing Era., A. G. Ganek and T. A. Corbi, IBM Systems Journal 42, No. 1, 5.18 (2003).
The Design and Implementation of Network Service., H. Morikawa, Platform for Pervasive Computing, Department of Frontier Informatics, Tokyo University.
The Vision of Autonomic Computing, J. O. Kephart and D. M. Chess, IEEE Computer 35 (1): 41-50 (2003)