# Pervasive Computing

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# Contents





# What is Pervasive Computing?

- Technology View
  - Computers everywhere – embedded into fridges, washing machines, door locks, cars, furniture, people
    - ➔ intelligent environment
  - Mobile portable computing devices
  - Wireless communication – seamless mobile/fixed
- User View
  - Invisible – implicit interaction with your environment
  - Augmenting human abilities in context of tasks
- Ubiquitous = mobile computing + intelligent environment



# Mobility

- Mobile computing
  - Computing & communication on the move
  - Mostly voice based or embedded?
- Nomadic computing
  - Intermittent connectivity
  - Usual environment available
- Mobile agents
  - Mobile code and data

# Contents

- What is pervasive computing
- **Current technology**
  - Current & near term gadgets
  - Wearable computing
- Mobile computing
- Context adaptation
- Intelligent environment
- Adaptive architecture
- Security, privacy and management



# Current Technology

PDA/mobile phone


Phone/camera

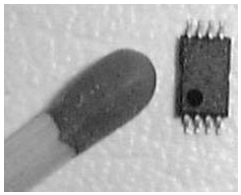
Softphone
www.eleksen.com

Bluetooth Handsfree



# Current Technology 2

Matchbox computer



Web Server

Best friend

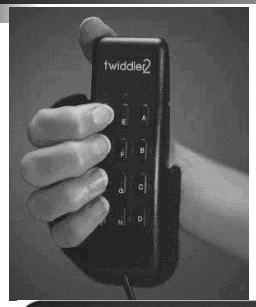


# Wearable Computers


Watch phone

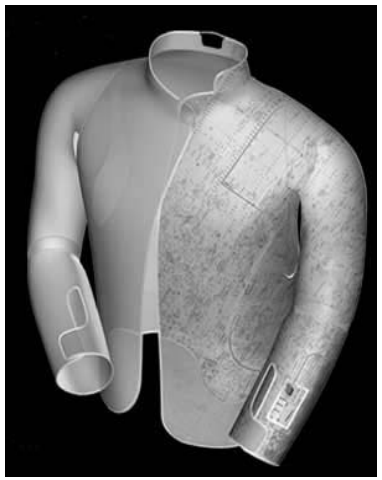

Watch camera

# Wearable I/O





LCD Jacket



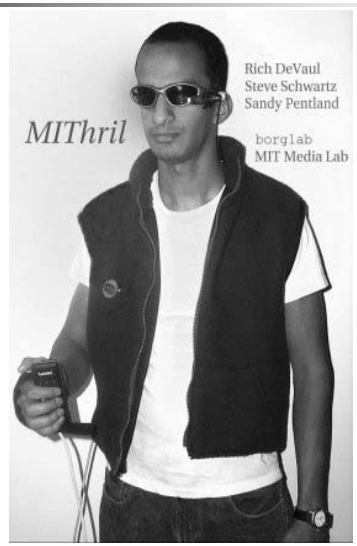


# Wearable I/O


Sony Glasstron

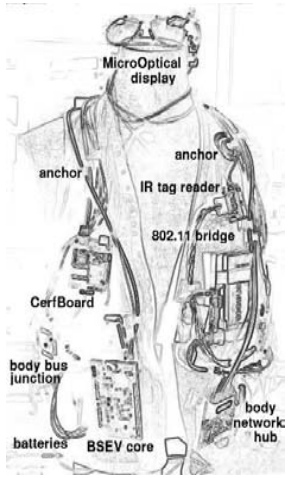


# Designer Gear






# Wearable or luggable?



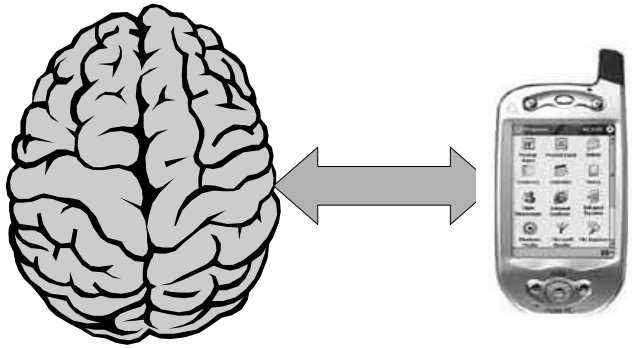

See http://wearables.www.media.mit.edu/projects/wearables/mithril/index.html

# Usability

- Common user interface for workstation and mobile device applications
  - Adaptive information display
- Replicate characteristics of paper-based notebooks for annotatablity, robustness, universality
- Flexible voice based input-output
  - Voice recognition + text to speech conversion
- Gesture recognition
- WAP phone is not a useable computing device!!
- Remove human from loop – intelligent agents?



# Brainwaves!





# Contents

- What is pervasive computing
- Current technology
- **Mobile computing**
  - Issues
  - Wireless communication
  - Ad-hoc networking
- Context adaptation
- Intelligent environment
- Adaptive architecture
- Security, privacy and management



# Mobile Computing Vision

- Universal connectivity – anywhere, anytime
- Accommodate heterogeneity of networks and communicators
- Ubiquitous intelligent environment – embedded computers everywhere
- Easy user interaction
- Context independent access to services + context dependent information

# Mobility Issues

- How to integrate mobile communicators into complex information infrastructures?
- What effect will they have on work and leisure?
- Privacy
- How to develop and manage adaptable, context-aware software systems?
- What support is needed within the network?
- Power supplies




# Wireless Communication

- GSM phone 9.6 Kbps,
- GPRS typical 28Kbps, theoretical 172Kbps max
- Wireless LAN IEEE 802.11b 200 m range
  2.4 Ghz band: 11 Mbps
- Bluetooth 10 m range
  2.4 Ghz band: 1 data (700 kbps) & 3 voice channels
- UMTS – 3G mobile
  114 kbps (vehicle), 384 Kbps (pedestrian),
  2 Mbps (stationary)
- HIPERLAN & IEEE 802.11a
  5 Ghz band: currently 20 Mbps eventually 54 Mbps
- InfraRed – direct line of sight: 4Mbs

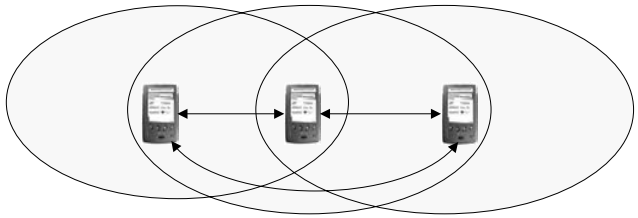


# Wireless Problems

- Too many similar standards
- Shortage of spectrum
  Use low power + multiple base stations with intelligent antenna.
- Overlapping spectrum usage can cause interference eg Bluetooth and IEEE 802.11
- Unregulated bands lead to chaos
- Health risks?



# Ad-hoc networking



- Networking with no fixed infrastructure
- Use other devices as routers
- But, security concerns and usage of scarce battery power for relaying – possibly more suited to sensor than user networks
- See http://tonnant.itd.nrl.navy.mil/manet/manet_home.html

# Ad-hoc Network Applications

- Sensor networks
- Disaster teams
- Autonomous robots eg searching buildings, mapping toxic spills
- Meetings – exchange visiting cards and information
- Car trains on motorways – 100 KmPH, 2m apart automatic steering and braking



# Ad-hoc Collaborative Working

- Support for cooperative working
- Group management protocols
  - Public and private groups
- Service discovery
- Dynamic adaptation to other device interfaces



# Integration of Mobile Systems

- Not stand alone devices.
  - Need to interact with complex legacy information systems eg large databases – merging updates, displaying tables etc.
- Systems development
  - Requirements specification for adaptable systems
  - Component composition to meet global QoS, security, reliability & performance requirements.
- Mobility models
  - Behaviour specification and analysis
  - Modelling context aware systems
- Interaction paradigms
  - Event-based not object invocation or RPC



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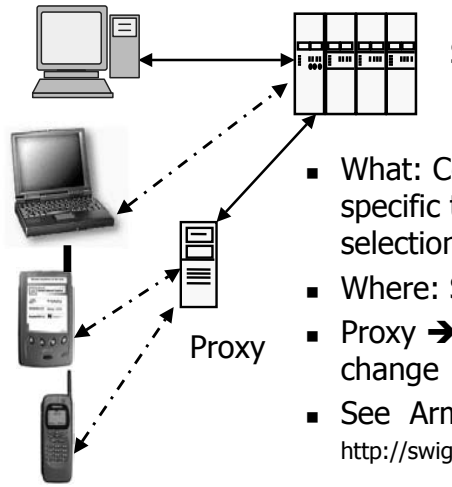
# Context Awareness

- Context defined by:
  - Current location
    Need location detection eg GPS or base station
    Indoors – radio beacon, IR
  - User activity
    Walking, driving a car, running for a bus – how to detect this?
  - Ambient environment
    In theatre, alone, in meeting
    Local resources or services available
  - Device capabilities
    Screen, input, processing power, battery life ….
  - Current QoS availability – particularly for radio links



# Context Adaptation




- What: Compression, filtering, device-specific transformations, information selection …..
- Where: Server, proxy or client?
- Proxy ➔ client and server do not change
- See Armando Fox work at Stanford
  http://swig.stanford.edu/~fox/



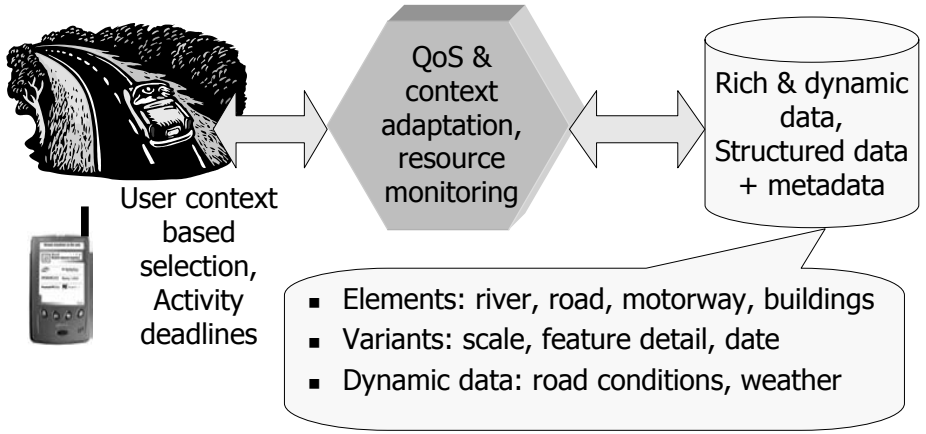
# User Selection

- Ultimately, users know best
  - proxy transforms as best as it can, but gives users a way to "force" proxy to deliver original content
  - here, a simple client-side UI enhancement is coupled with proxy-side refinement intelligence


From presentation by Armando Fox, Stanford



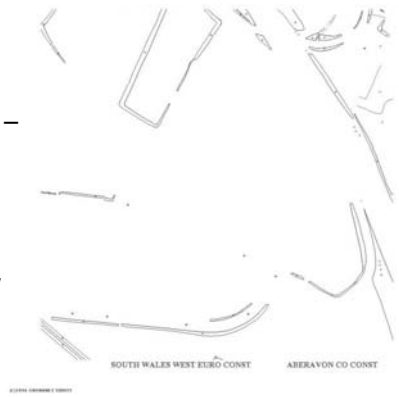
# Map Adaptation



# Adapting Vector Maps

- Maps can be…
  - Split into features and presented in part
  - Encoded at different scales – different feature detail
  - Selective adaptation can consider content being degraded

See http://www.doc.ic.ac.uk/~dc/






# UbiCare: Ubiquitous computing for community care

**Applications**

- Automated monitoring
  - Implanted devices
  - Smart clothing
  - Swallow/inject intelligent sensors and actuators
- Accident and emergency support
- Patient record access and integration

**Benefits**

- High ➔lower risk monitoring
- Mobility for chronically ill
- Greater out-of-hospital patient management
- Predictive care from mass data analysis

Wireless video Camera Pill



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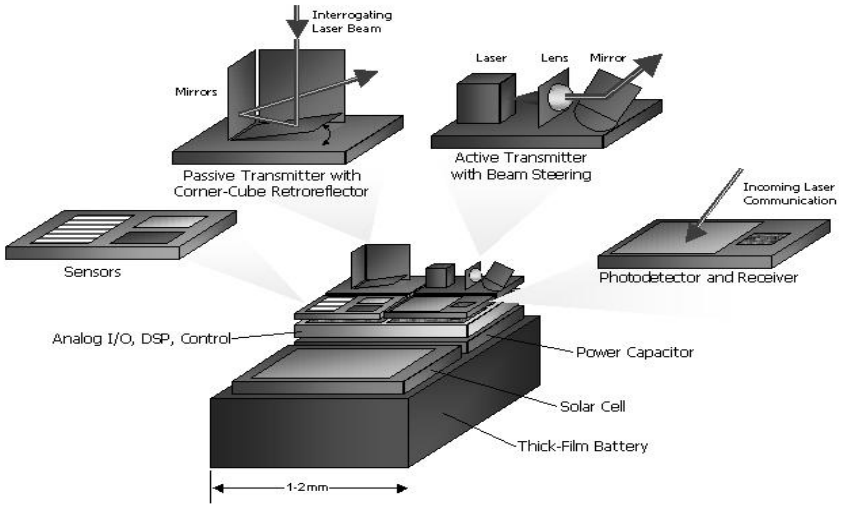
# Smart Dust

- Autonomous sensing and communication in a cubic millimeter – "dust motes"
- Sensors for temperature, humidity, light, motion …. With bidirectional radio or laser + battery
- Costs soon < $1
- Typical Applications
  - Defense related battlefield sensors, motion detectors etc.
  - Inventry control on boxes which communicate with crates, trucks, plane etc to tell you where they are
  - Product quality monitoring – vibration, humidity, overheating
  - Car component monitoring
- See http://robotics.eecs.berkeley.edu/~pister/SmartDust/

# Smart Dust Technology






# Commercial Motes

- Manufactured by Crossbow http://www.xbow.com
- Processor: 4MHz
- RAM Memory: 128 Kbytes
- On-Board Flash: 512 K bytes
- Radio: 916 Mhz, 52K bps
- Antenna: On-board, optional external
- TinyOS from Berkeley



# Future Smart Dust

- Intelligent paper with integrated radio ➔ replace current displays
- Smart paint monitors vibrations and detect intruders or changes colour to react to temperature, lighting etc.
- Intelligent glass can filter sunlight, become opaque ➔ no need for curtains
- Smart garments or injectable sensors for people monitoring
- Download design and printable motes for < 1c mote www.media.mit.edu/nanomedia
- Printable batteries http://www.usatoday.com/life/cyber/tech/review/2001-02-12-batteries.htm



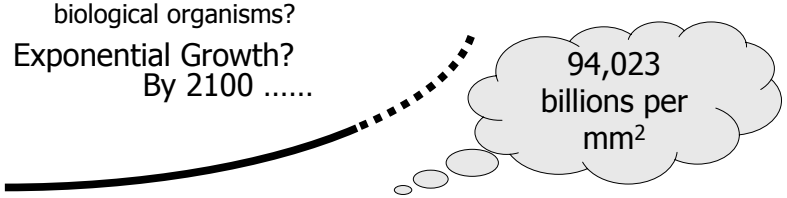
# Pervasive Computer Problems

- What means of communication?
  - Radio – spectrum shortage
  - Light based – very directional
- Batteries would be impractical power source for 100K processors per person.
  Solar cells are not suitable for all environments.
- Solar cells, fuel cells, body heat power?
- Power not speed is the key issue for future processor designs.

SRI Shoe power: 0.5 W

# Scaling factors

- > 100K computers per person
  - Self organising and self configuring
  - Coherent behaviour from vast numbers of unreliable sensors, actuators and comms. devices
  - Need new techniques for interaction maybe based on biological organisms?
- Exponential Growth?
  By 2100 ……




425,352,958,651, 200,000,000,000,000,000,000,000
Billions of computers

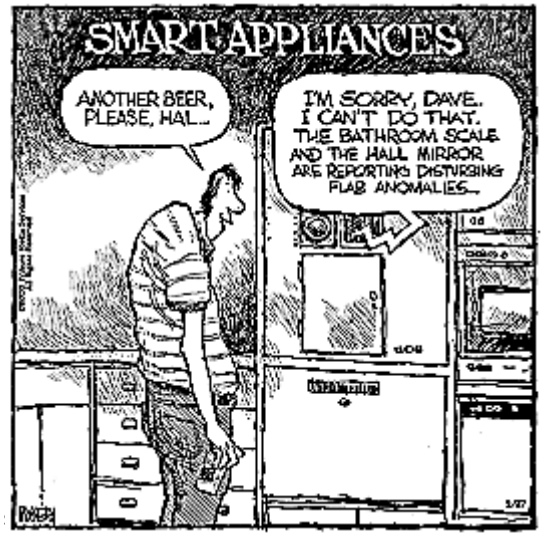


# Intelligent Environment

- Lights, air conditioning, TV automatically switch on and off when you enter or leave rooms
- Sit on your favourite chair and TV switches on to the program you usually watch at this time of the day
- Use communicator/pda for phone, remote control, keys payments, passport, health records, authenticator.
- Route input from 'virtual' keyboard to nearest suitable display.
- Automatic detection of new items to control and physical layout in a room or office, using computer vision.



# Intelligent Environment?

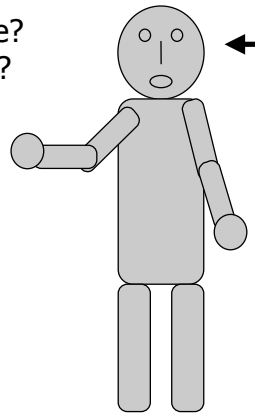





# Vision Based Interaction

Presence: Is anyone there?
Location: Where are they?
Identity: Who are they?
Activity: What are they doing?

Hand tracking
Hand gestures
Arm gestures



Head tracking
Gaze tracking
Lip reading
Face recognition
Facial expression

From http://research.microsoft.com/easyliving/

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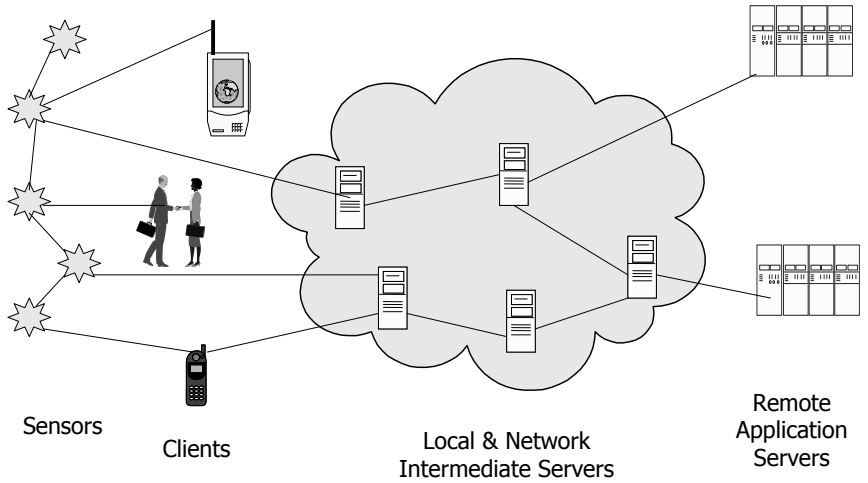
# Adaptive Application Architecure






# Policy

Rule governing choices in behaviour of the system

- Derived from trust relationships, enterprise goals and Service level agreements
- Need to specify and modify policies without coding into automated agents
- Policies are persistent
- But can be dynamically modified

  ➔Change system behaviour without modifying implementation – not new functionality



# Policy Based Adaptive Systems

- Authorisation policies
  Derived from trust relationships to define what resources or services clients can access, what proxylets or code can be loaded into servers, or what code loaded into the client can do.
- Obligation Policies
  Event-condition-action rules to trigger when to perform actions, what alarms to generate etc
- Ponder – declarative object-oriented language for specifying policies.
  See http://www-dse.doc.ic.ac.uk/Research/policies/

# Example Authorisation Policy

```
inst auth+ facilities {
   subject guests;
   target gym + pool;
   action enter;
   when time.between ("0900", "2100");
}
```



# Obligation Policy

- Defines what actions a subject must do
- Subject based ➔ subject interprets policy and performs actions on targets
- Event triggered obligation
- Actions can be remote invocations or local scripts
- Can specify sequencing or concurrency of actions



# Example Obligation Policy

```
inst oblig heartmonitor {
   subject s = medicAgent;
   on heartanomaly (symptom);
   action s.display (messages [symptom]) ->
                    send(alarm, symptom);
   target cardiacCentre;
}
```



# Roles

- Group of policies with a common subject
- Defines rights (authorisations) and duties (obligation)
- Position in organisation – nurse, surgeon
- Mobile 'visitor' roles in hotel or shopping mall – policies which apply to mobile user in an environment
- Paramedic attending an accident

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# Security

- Interactions cross multiple organisational boundaries
- Specification, analysis and integration for heterogeneous OS, databases, firewalls, routers
- Lessons from history:
  - Cell phones, IR garage doors, CATV decoders
  - Everything worth hacking gets hacked
- Need for secure 'out of the box' set up
- Identify friend or foe ➔ level of trust
- Small communicators, with confidential data, are easily lost or stolen – biometric authentication
- Necessary security technology exists

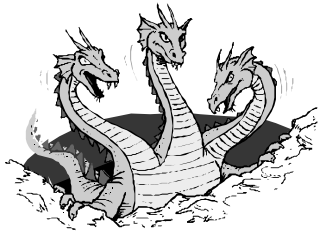


# Privacy

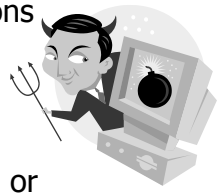
- Location service tracks movement to within metres (cf mobile phones but pay-as-you-go can be anonymous).
- Clearly indicate you are being sensed or recorded + user control to stop recording or control distribution of information
- You are now predictable
  - System can co-relate location, context and behaviour patterns
- Do you want employer, colleagues or insurance company to know you carry a medical monitor?
- Tension between authentication and anonymity – business want to authenticate you for financial transactions and to provide 'personalized' service cf web sites
- Constant spam of context dependent advertising



# Management – the nightmare!



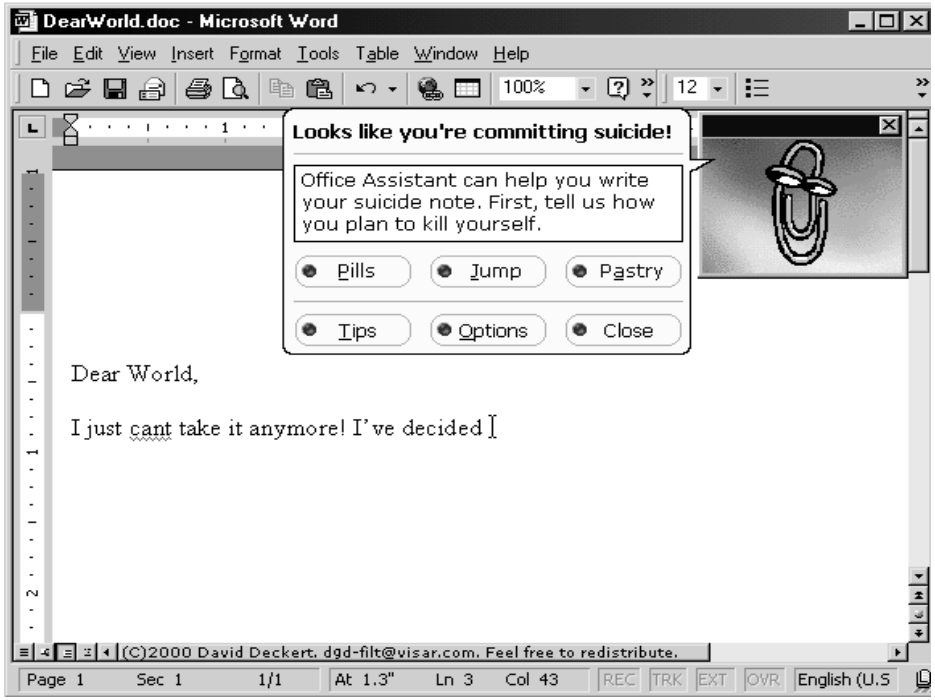
- Huge, complex systems
  - Billions of processors
  - Multiple organisations
  - Managing physical world, controlling sensors, actuators
  - Humans will be in the way
- Errors propagate to bring down complete regions
- Hacker and virus paradise
- System propagates false information about individuals or organisation
- Complexity of s/w installation on a workstation or server – how do you cope with billions?



# Management Solutions


- Intelligent agents, mobile agents, policy
- QoS Management
  - Fat pipes and large storage can convert media streams to short traffic bursts in core network but still needed for wireless links
- Adaptive self-management is the only answer
  - Partitioned domains of responsibility
  - Genetic algorithms may be suitable for long-term strategy but need more deterministic solutions for short term decision making
- Remove human from the loop






# Conclusions

- Universal PDA/communicator
- Explosion in embedded sensors/actuators
- Context-aware intelligent environment
- Privacy will be a major issue
- Out of the box security
- Adaptive self-management is needed – biological paradigms?



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