Policy Issues for Pervasive Computing

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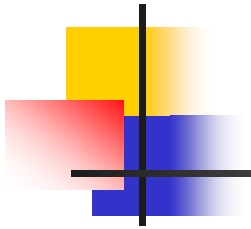
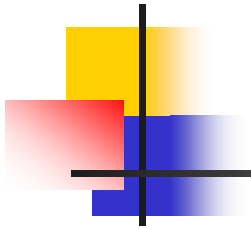


Contents

- What is pervasive computing
- Healthcare scenario
- Policy-based autonomic management
- Conflict Analysis
- Pervasive Computing Grand Challenges
- Conclusions

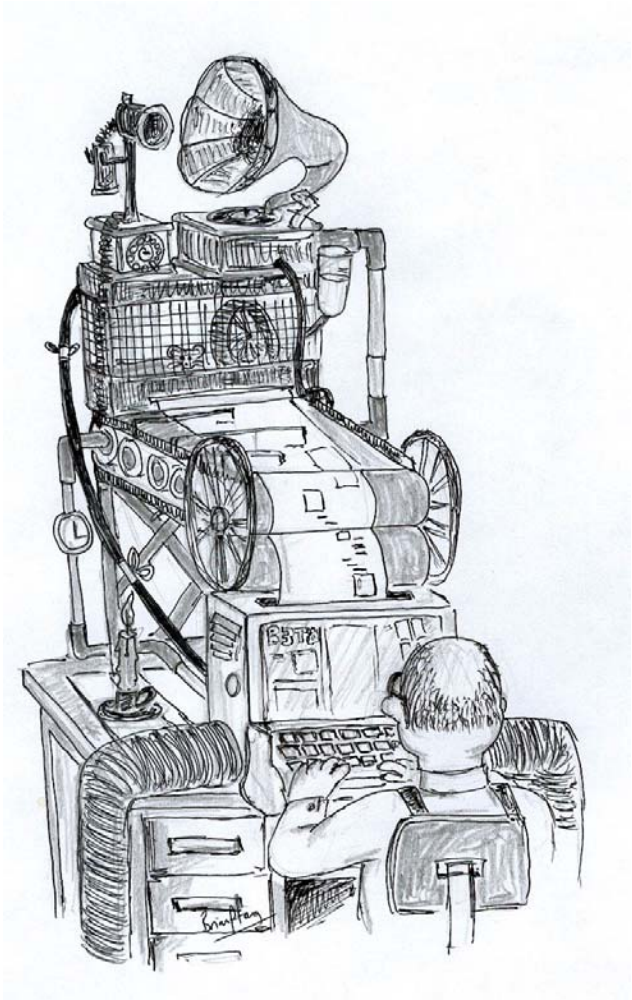


What is Pervasive Computing?

- Technology View
  - Pervasive, Ubiquitous, Sentient
  - Intelligent devices everywhere: home, office, street, car, trains, on-body, implanted, in appliances – 100K devices per person?
  - Mobility of people, environment, and programs
  - Battery powered
  - Capable of wireless communication
- User View
  - Devices mostly invisible – devices interact implicitly with each other and environment
  - Augment human abilities in performance of tasks

☞"The Computer of the 21st Century", Mark Weiser, 1991, Scientific American

The UbiComp Challenge!



- How to build the truly invisible intelligent environment?
- Designed rather than ad-hoc implementation
- Understandable
- Analysable based on underlying theory
- Manageable
- Dependable and secure
- Does not infringe privacy

Need both design and science

Healthcare Everywhere

Applications

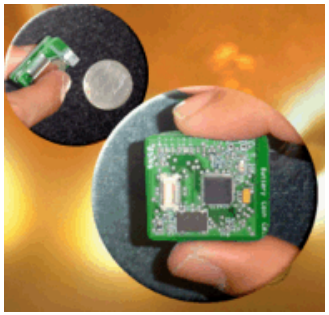
- Automated monitoring
  - Implanted devices
  - Smart clothing
  - Swallow/inject intelligent sensors and actuators
  - Reaction to complex drug regimes
- Health advisor

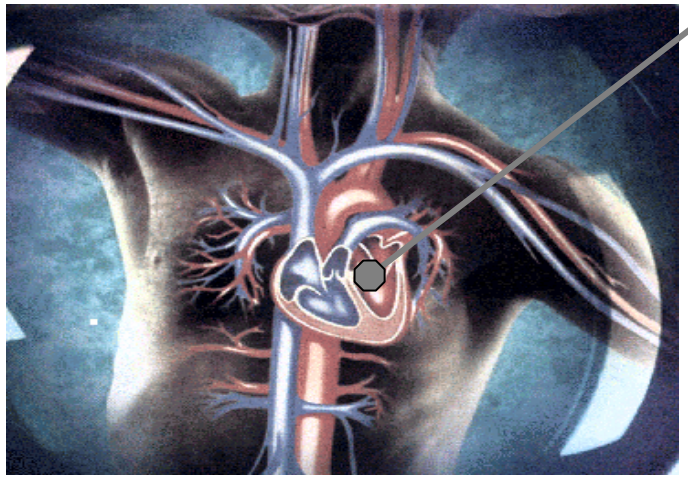
Benefits

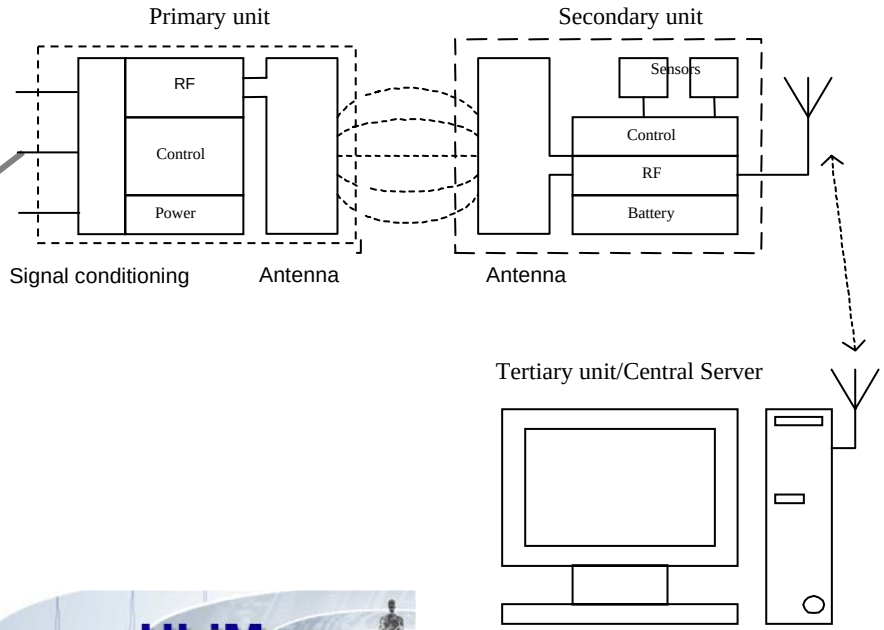
- High ➔lower risk monitoring
- Mobility for chronically ill
- Greater out-of-hospital patient management
- Mass data & analysis
- Emergency feedback or response

Wireless
video camera pill

Cardiac Monitoring

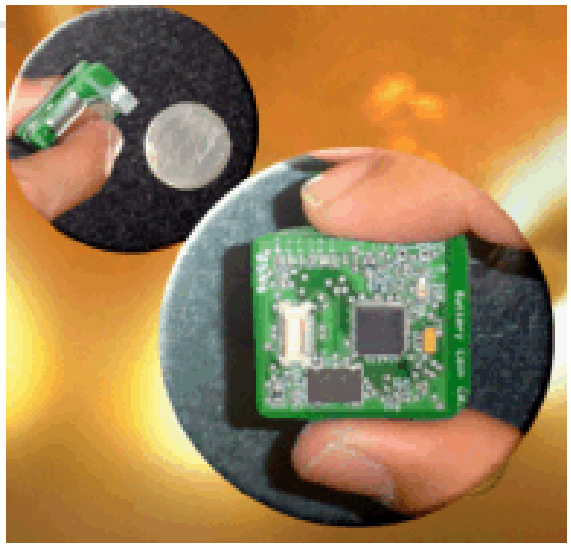




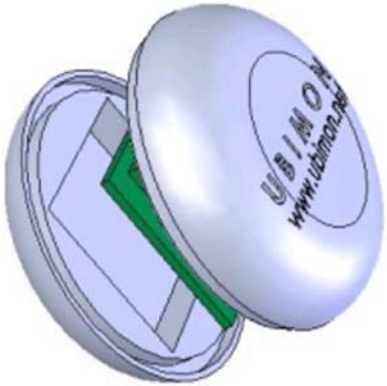


UbiMon
www.ubimon.net

Body Sensor Nodes



- TinyOS
- TI MSP430 ultra low power processor
  - 16 bits RISC processor
  - 64KB +256B Flash memory
  - 12-bit ADC
  - Very low power
- Chipcon CC2420 RF module
  - IEEE 802.15.4 (Zigbee) wireless link
  - 2.4GHz, 250kbps
  - Low current consumption (RX:19.7mA TX:17.4mA)
  - Hardware MAC encryption
  - Range 50m
- 6 analog channels (connect up to 6 sensors)
- 512kByte serial memory



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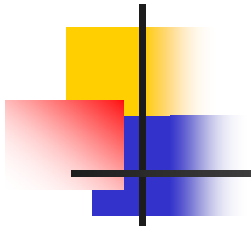
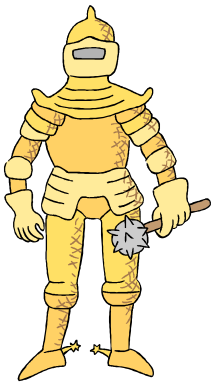


Context Awareness

- Context defined by:
  - Current location
    Need location detection eg GPS or base station
    Indoors – sonic or ultrawideband wireless tags ➔ 10cm
  - User activity
    Walking, driving a car, running for a bus – how to detect this?
  - Ambient environment
    In theatre, alone, in meeting
  - Device capabilities
    Screen, input, processing power, battery life ….
  - Current QoS availability – particularly for radio links
- Fusion of information from multiple sources

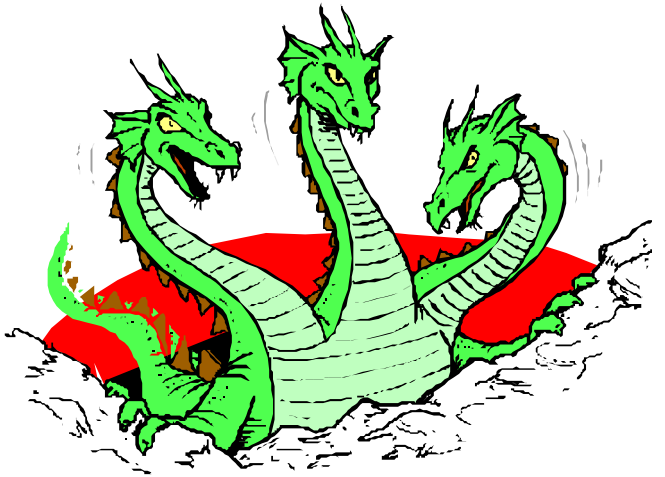
Security Wish List

- Lessons from history: everything worth hacking gets hacked
- SECURITY solutions that are proactive, minimally intrusive, easy to use
- Need for secure ‘out of the box’ set up
- Devices that recognise/respond to “owners” only
- Means of tracing stolen devices, proving transactions
- Ability to be invisible or anonymous when needed
- Protection from spam, viruses, denial of service, identity theft etc.....



☞ SECURITY solutions that are adaptive and context-aware

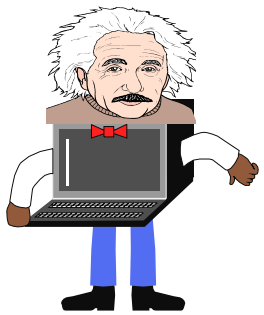
Management – the nightmare!

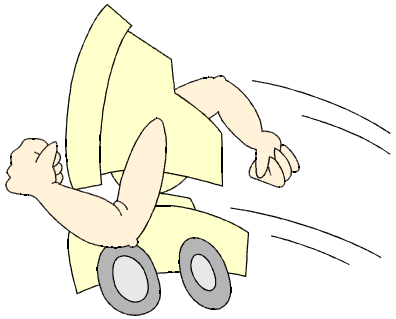


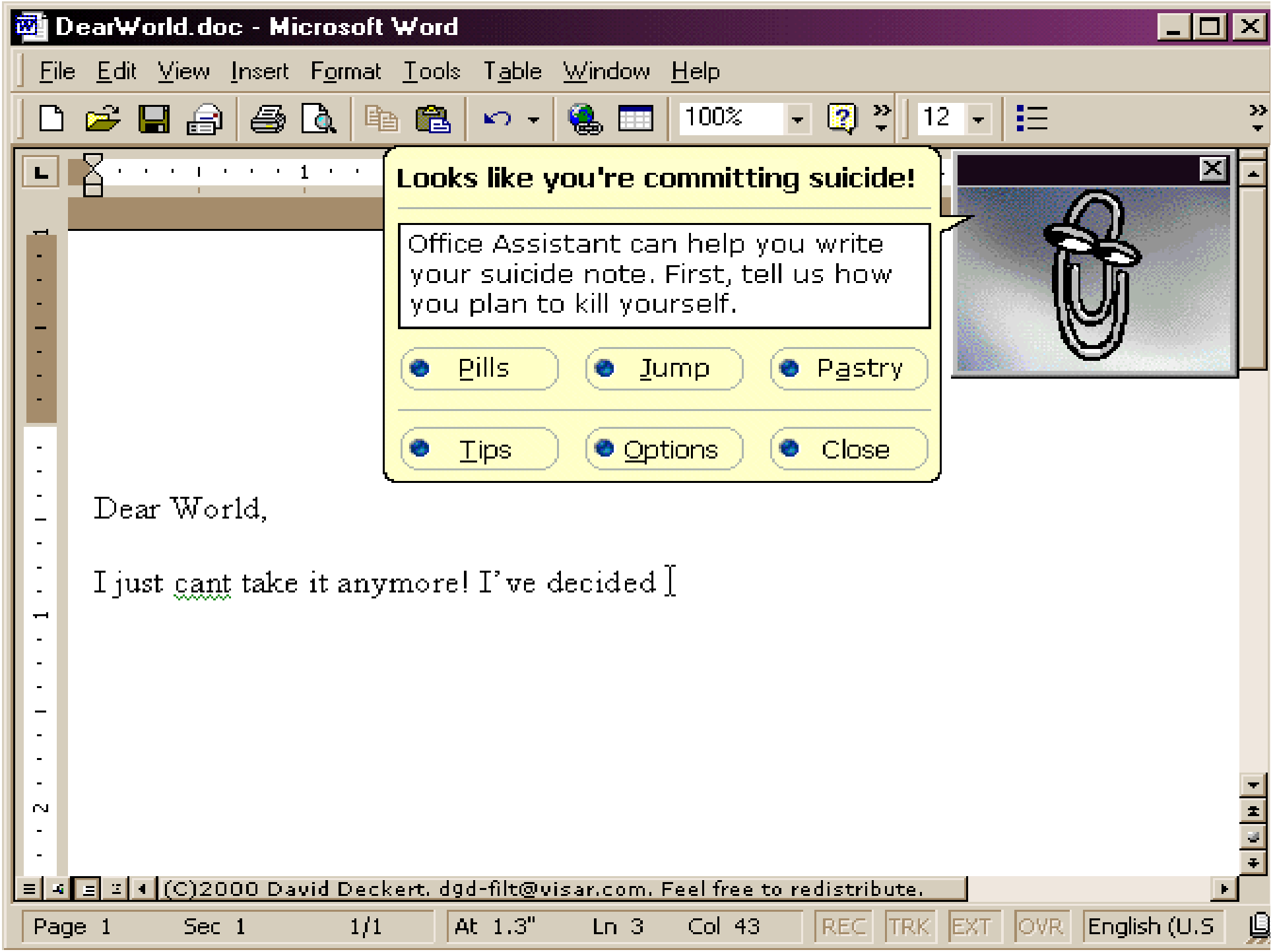
- Huge, complex systems
  - Billions of processors
  - Multiple organisations
  - Managing physical world, controlling sensors, actuators
  - Humans will be in the way
- Hacker and virus paradise
- System propagates false information about individuals or organisation
- Complexity of s/w installation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

Autonomic Management

- **Autonomic** – self-organising, self-configuring, self-healing, self-optimising, adaptive management
- Remove human from the loop
- Intelligent agents, mobile agents, policy, genetic algorithms?






DearWorld.doc - Microsoft Word
File Edit View Insert Format Tools Table Window Help
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Looks like you're committing suicide!
Office Assistant can help you write your suicide note. First, tell us how you plan to kill yourself.
Pills
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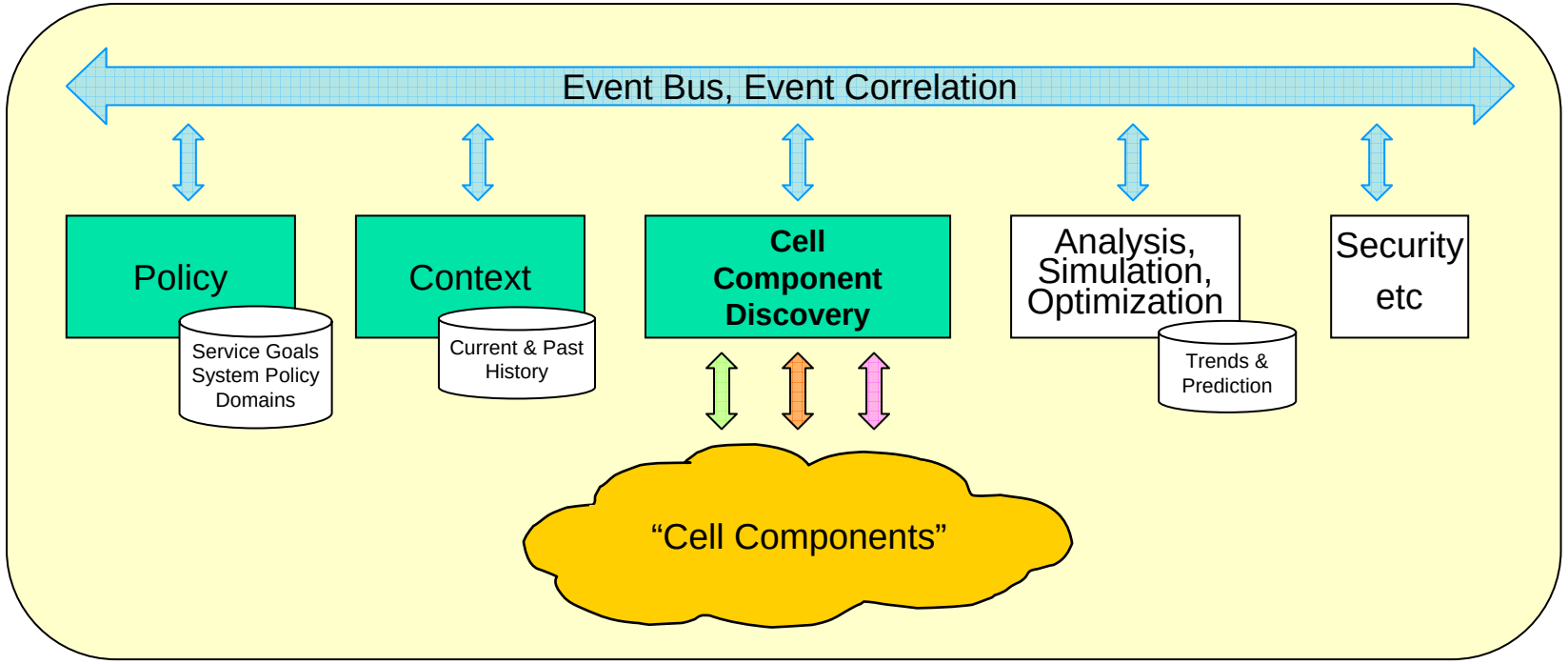
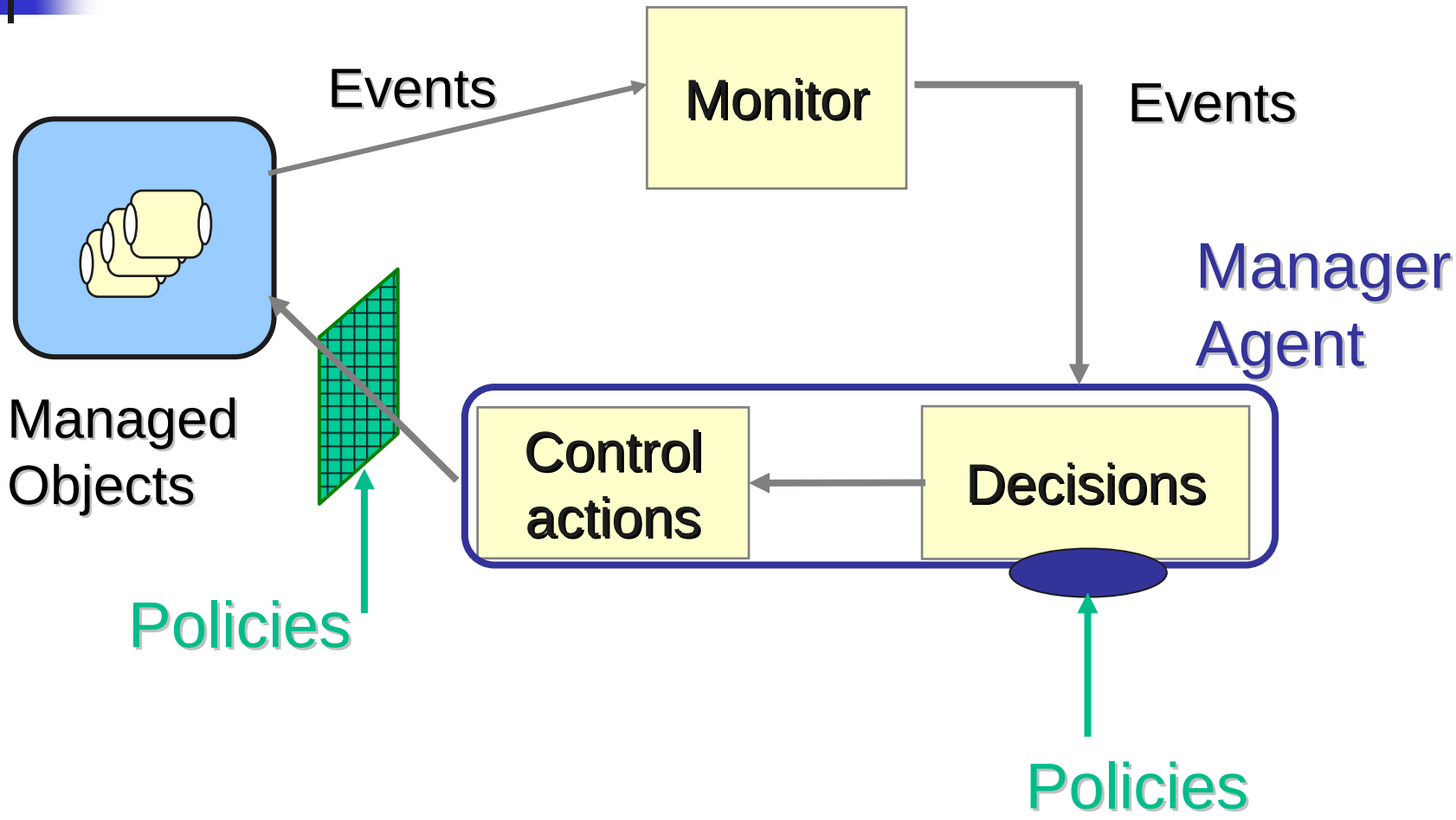
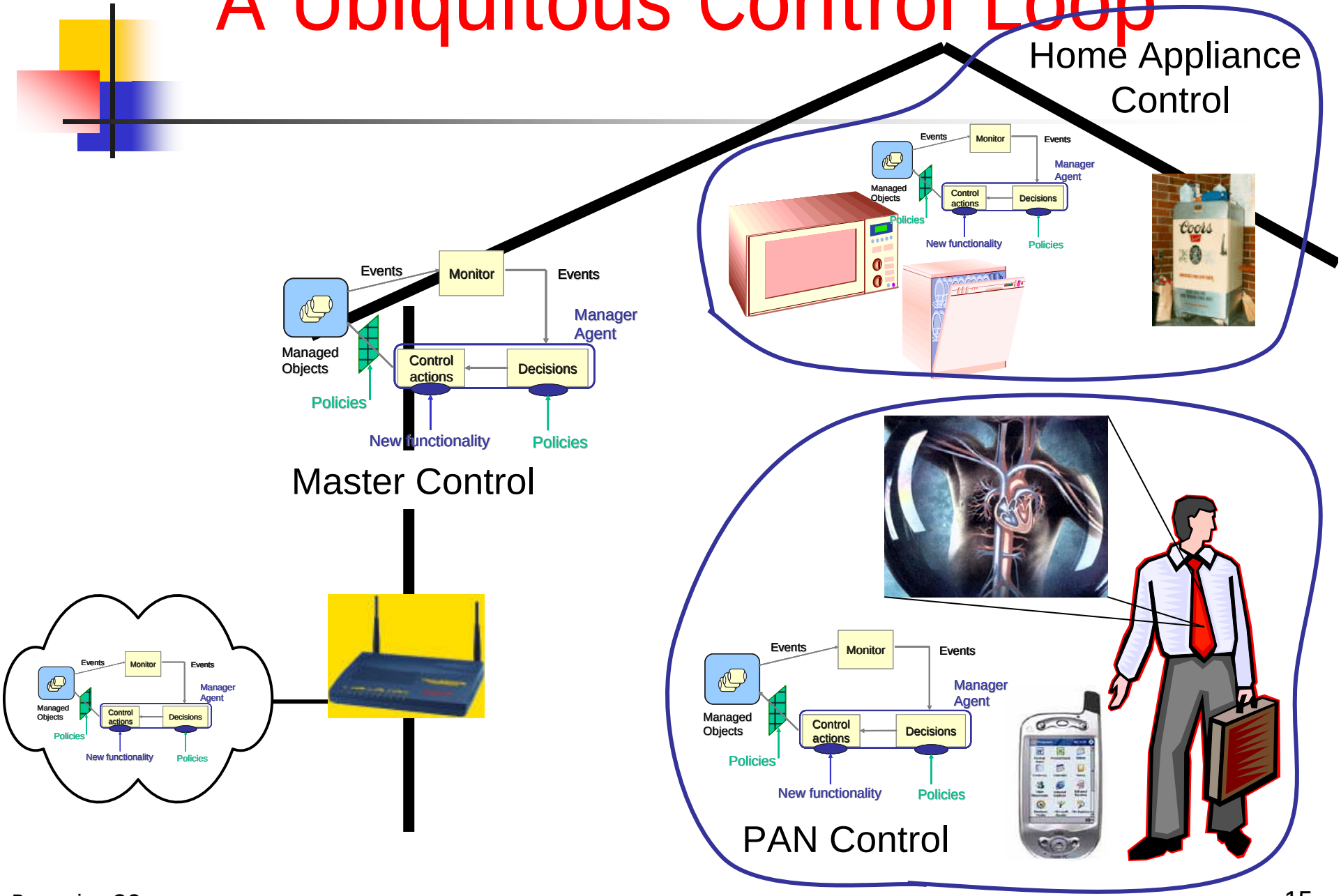
Self-Managed Cell (SMC)



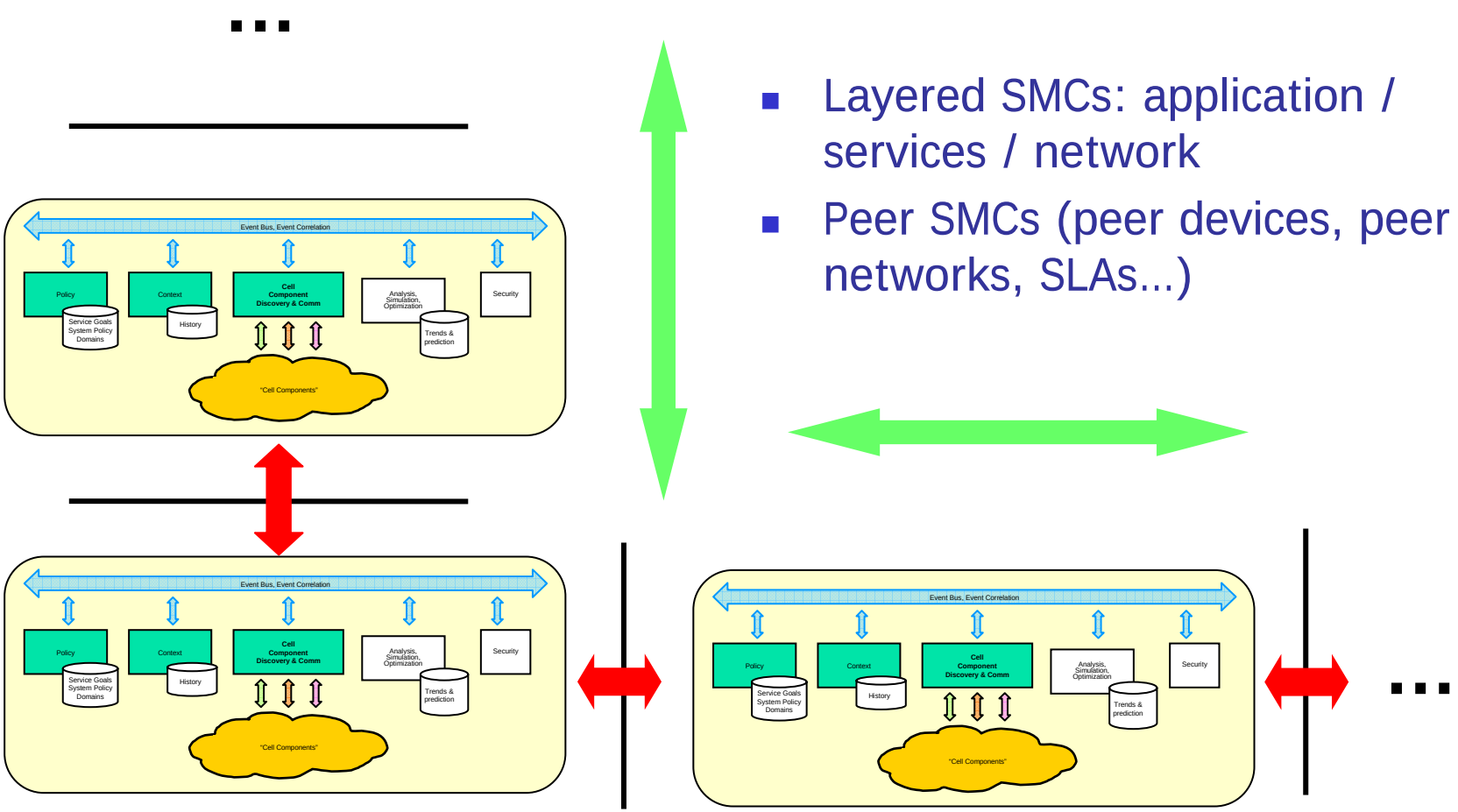
Policy-Based Management



A Ubiquitous Control Loop

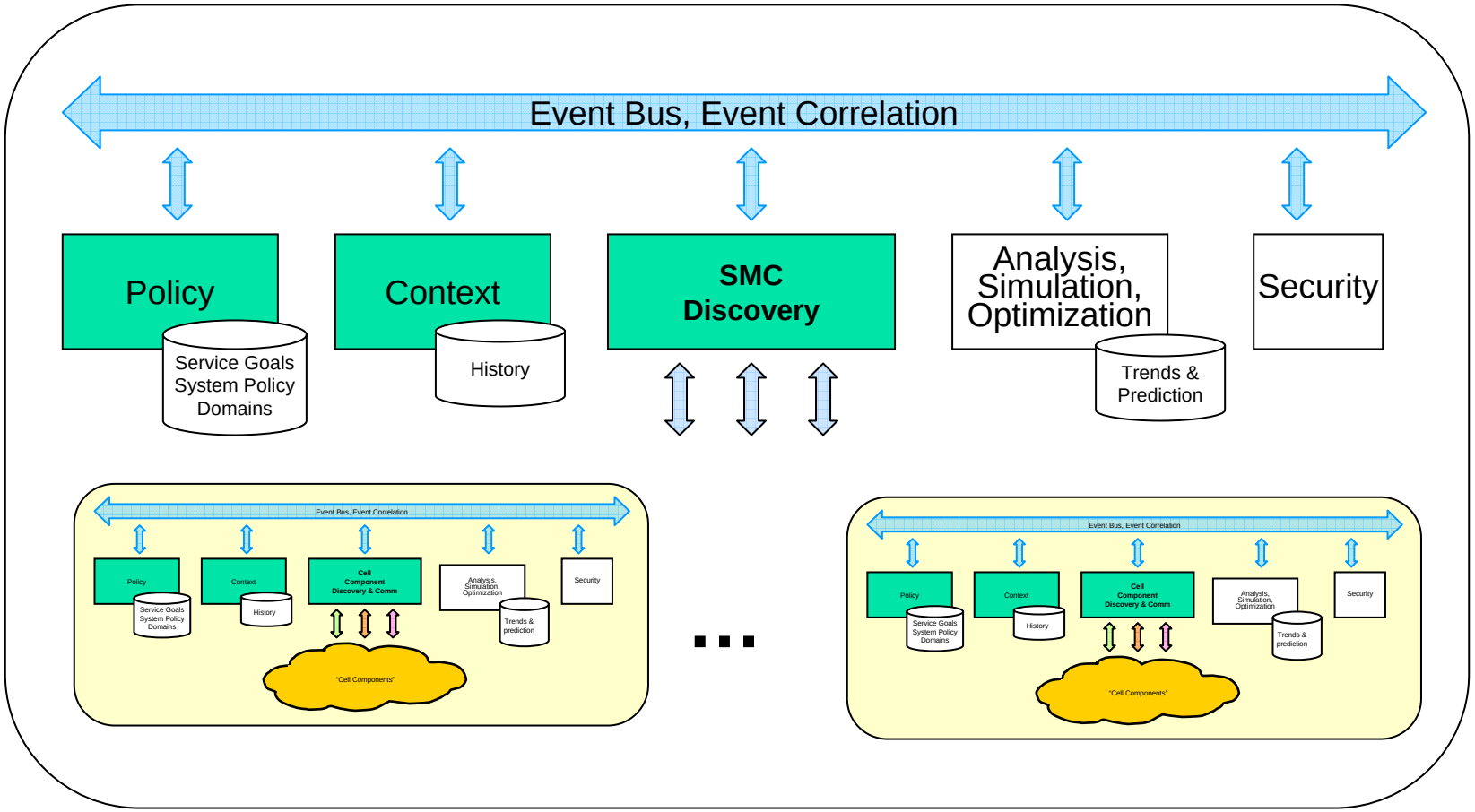


Layered and Federated SMCs



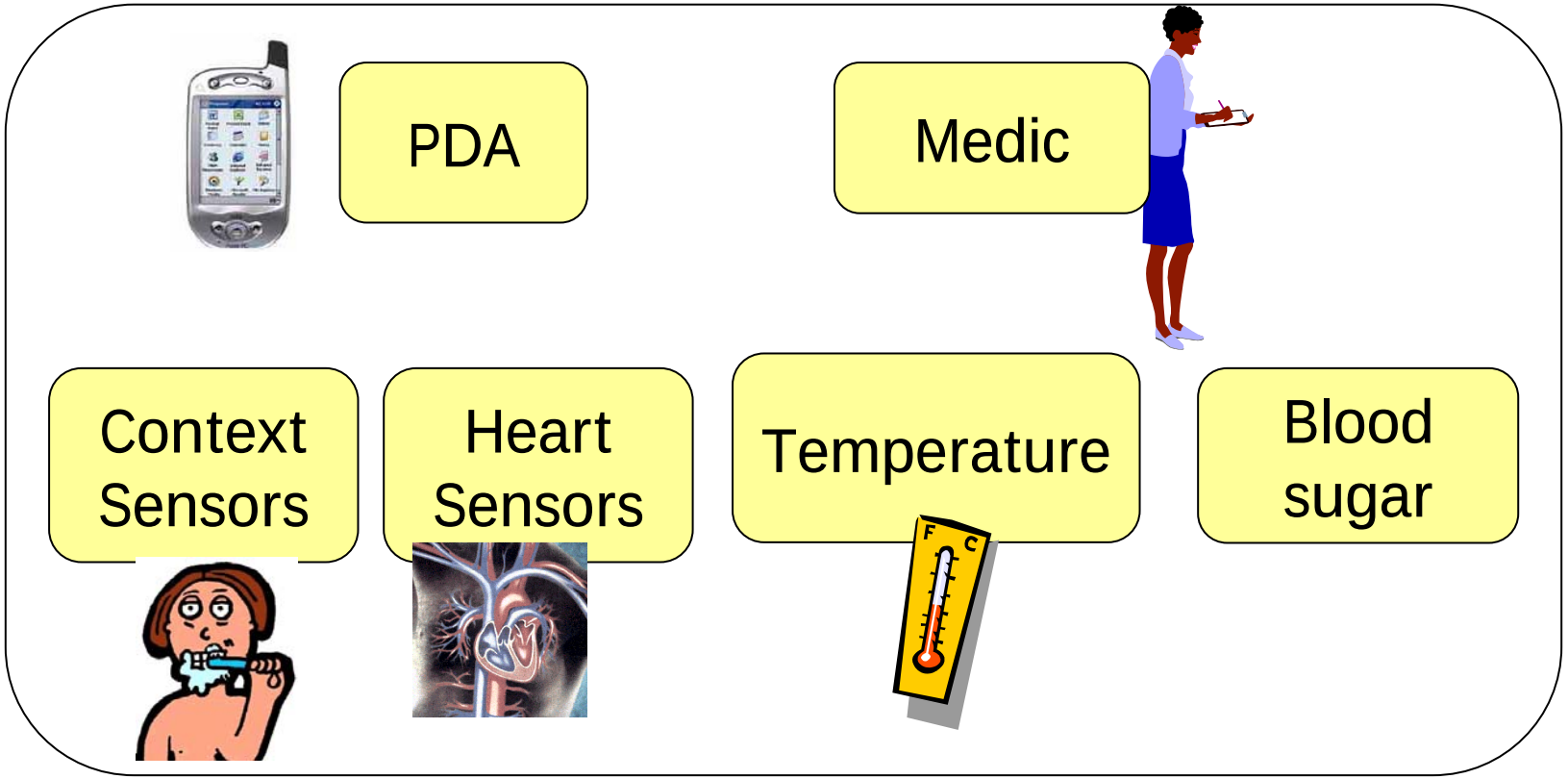
- Layered SMCs: application / services / network
- Peer SMCs (peer devices, peer networks, SLAs...)

SMC Composition

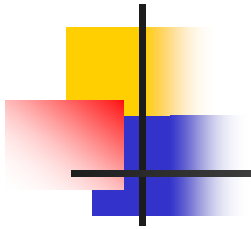


- Enclosing SMC “programs” the nested SMCs

Body Sensor SMC ‘Roles’



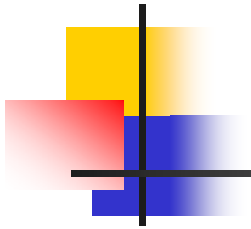
- SMC defines role assignment policies
  + role interaction relationship policies



Discovery Policies

oblig on compDetect (compName, compRef, compType) **->**
medicRole.assign (compName, compRef)
when compType = nurseT &
signed (compRef.getCertificate, nursingCouncil_PK)
oblig on compDetect (compName, compRef, compType) **->**
temperatureRole.assign (compName, compRef)
when compType = tempSensorT
.....

oblig every mins (1) **->** discoveryService.findNewMembers()
oblig every mins(2) **->** discoveryService.pollMembers()
.....
poll all members of a role and remove any which have not responded after max tries.



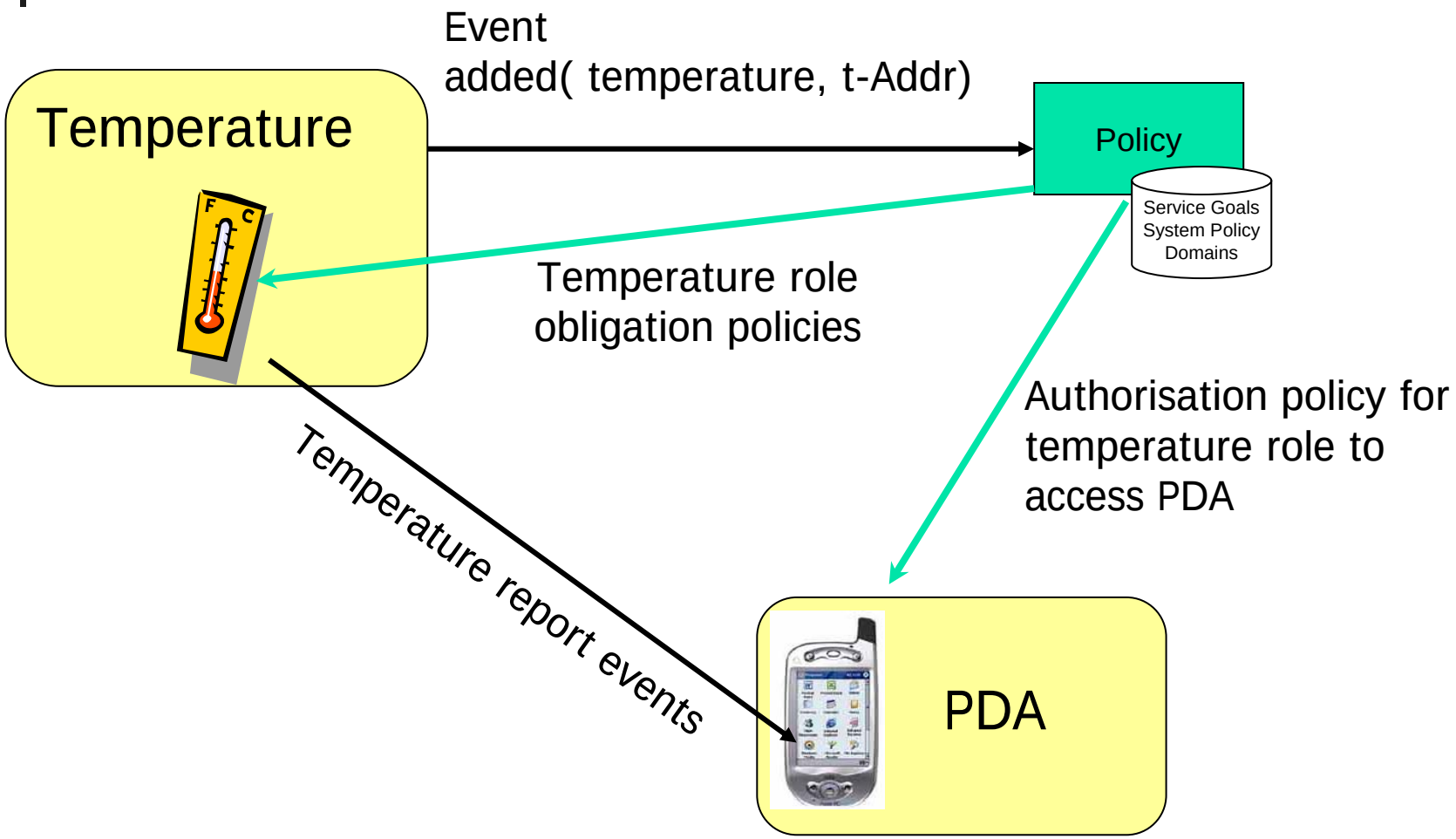
Example Policies

```
tempSensorPolicies {
    oblig every mins (2) ->
        tempSensor.read (tempValue) ->
        tempSensor.tempEvent (tempValue)
            // trigger local event

    oblig on tempEvent (tempValue) ->
        pda.reportTemp (tempValue)
        when (tempValue > maxtemp)
}

SMCAuthPolicies {
    auth+  tempSensor -> pda.reportTemp
}
```

Deploying Policies



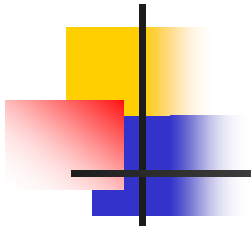
Policies to Protect PDA

oblig on 3* fingerprintfail ->
    pda/policies/bodymonitor.disable ->
    pda/policies/selfprotect.enable ->
    timerEvents.trigger (shutdown, currentTime + 60)

pda/policies/selfprotect
oblig every minutes (5) ->
    sendSMS (07957341, “Stolen PDA”, “ownerID”, currentLocation)

oblig on shutdown ->
    pda.locked ->
    pda.switchoff

Assume this prevents pda from being rebooted or reset without an owner card.

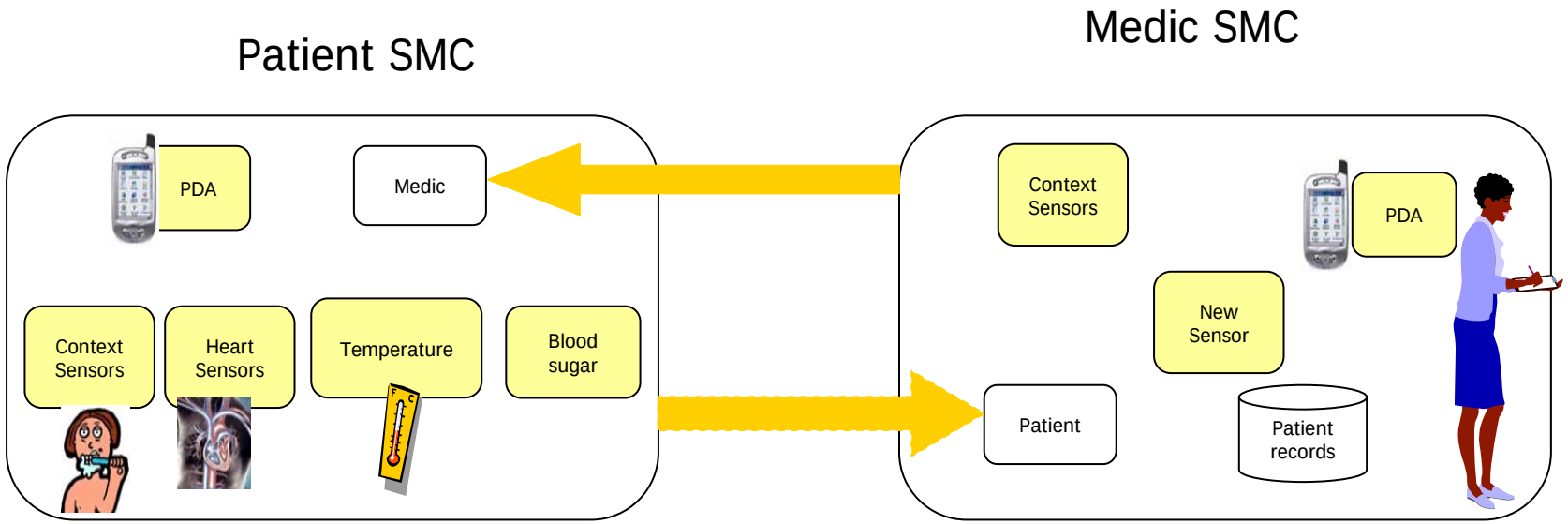


Context aware policies

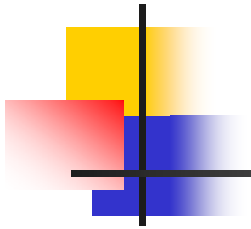
oblig on enterhome ->
pda/policies/trusted.enable ->
pda/policies/untrusted.disable

Oblig on leavehome ->
pda/policies/untrusted.enable ->
pda/policies/trusted.disable

Peer-to-Peer Interactions

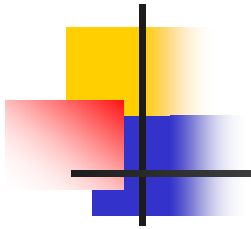


- Assign peer SMC to pre-defined roles within each SMC
- Predefined policies specify obligations and authorisation for entity assigned to role
- Default entity(PDA) interprets obligation policies provided to it.



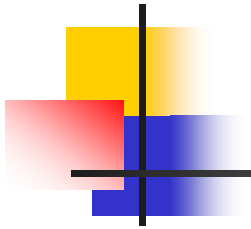
Other forms of cell interactions

- SMCs define implementable policies
- What about overall management strategy or goals?
- Requires goal refinement
  - Use *refinement patterns* in order to refine goals
    - Domain independent refinement patterns
    - Domain specific refinement patterns
  - Strategy defines how the goals are achieved. Note, there can be multiple strategies to achieve the same goals.
  - Derive strategy from goals and system description through abduction
- Very hard, not implementable on PDAs
- A Goal-based Approach to Policy Refinement by A Bandara et.al http://www.doc.ic.ac.uk/~bandara/publications.shtml



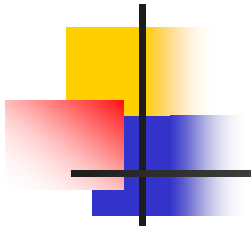
Policy Consistency

- Policies specify adaptive behaviour
- Multiple policies may apply to object within SMC
- Policies may be imposed by an external SMS – peer or parent
- Need to ensure consistency and coherance



Policy Conflicts

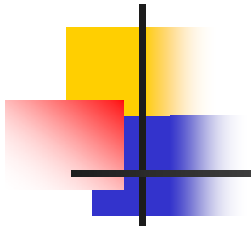
- Policy Analysis – Is the policy specification consistent (i.e., absence of conflicts)? Is it deterministic (i.e., conflicts can be resolved)? What properties does a set of policies satisfy?
- Two categories of conflicts
  - Modality conflicts – occur because the policies are inherently incompatible e.g., auth+ and auth-
  - Semantic conflicts – occur because the actions are incompatible or the policies violate desired properties of the system.
- Potential modality conflicts can be detected by looking at overlaps of subject, actions, target.
  - Does not take into account constraints
  - Can define precedence?



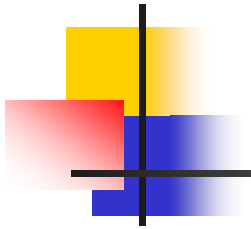
Conflict Resolution

- Negative policies override
  - Does not permit positive exceptions to negative policies.
- Specified Priorities
  - Hard to define priority
  - Several managers may specify inconsistent priority
- Evaluating a ‘distance’ between a policy and the object to which it refers
  - Refinement level – more concrete overrides?
  - Time of last update – more recent overrides?
  - Policy relevance – policies specified for roles take precedence over policies for SMC.

Semantic (Application Specific) Conflicts



- Types of conflict:
  - Separation of duty e.g., the same person is not allowed to authorise prescription and issue drugs
  - Inconsistency eg
    2 policies for triggering temperature event with different maxtemp values
    Multiple policies performing mutually exclusive actions, triggered by same event
- Need to specify the conditions which result in conflict
- Constraints on a set of policies (Meta-Policies).



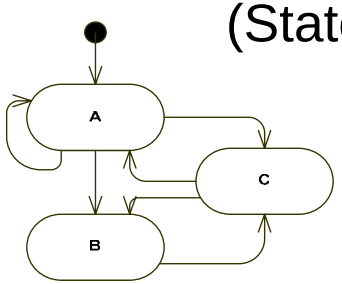
Formal Analysis

- Most conflict analysis does not take into account policy constraints.
- Need to analyse the “behaviour” of the system under a given set of policies.
- Need to identify:
  - Which sequence of events leads to a policy conflict.
  - What consequences policies have when applied to the system
  - Check that under a set of policies the system satisfies desirable properties.
- Requires: a behavioural model of managed objects e.g. statecharts, logic reasoning (complexity?, decidability?, etc.)

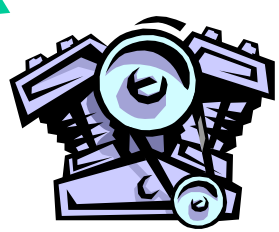
Approach

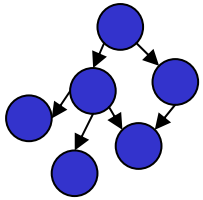
Policy specification
(Ponder)

Behavioural model
of managed objects
(State charts)



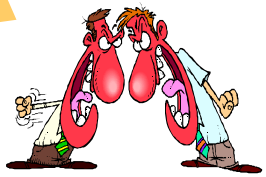
Event
Calculus





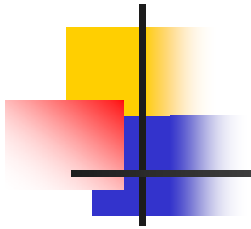
Organisational
Model
(SMC/Role hierarchy)

Property checks
(Logic rules)



Errors, Conflicts
Explanations

Using Event Calculus to Formalise Policy Specification and Analysis
http://www.doc.ic.ac.uk/~bandara/publications.shtml



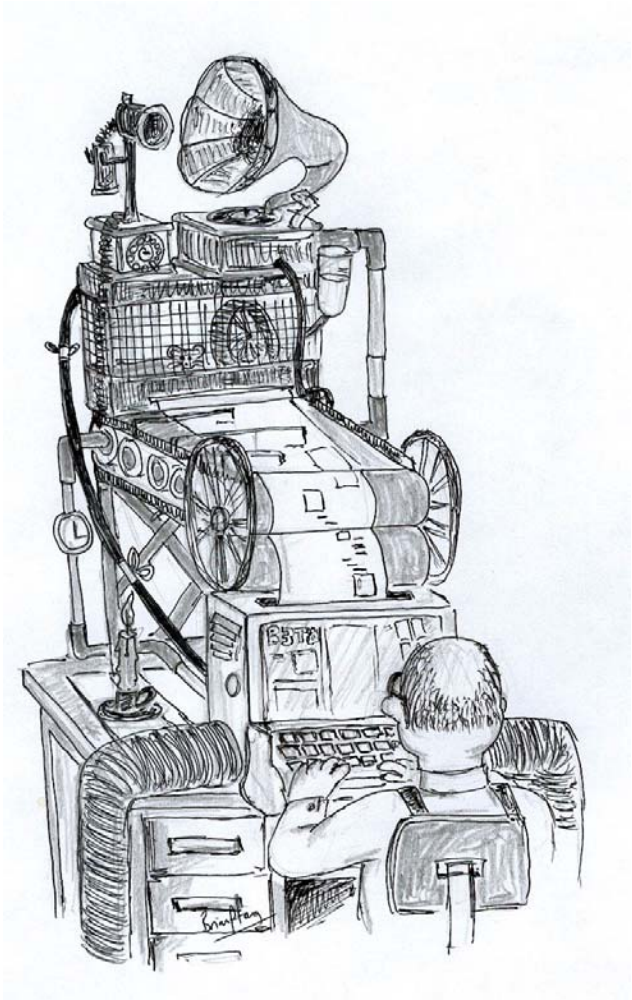
Policy Analysis

- Specification errors
  - Empty subject/target domain.
  - Unsupported operations in action specification.
  - Unsupported attributes in constraint specification.
- Modality conflicts
  - Authorisation modality conflict (auth+ / auth-).
  - Unauthorised obligation modality conflict (oblig / auth-)
- Semantic conflicts
  - Separation of duty / interest conflict.
  - Application specific consistency conflicts.

Deductive reasoning over system organisation model and policy specification.

Abductive reasoning over system behaviour model and policy specification.

The UbiComp Challenge!



- How to build the truly invisible intelligent environment?
- Designed rather than ad-hoc implementation
- Understandable
- Analysable based on underlying theory
- Manageable
- Dependable and secure
- Does not infringe privacy

Need both design and science

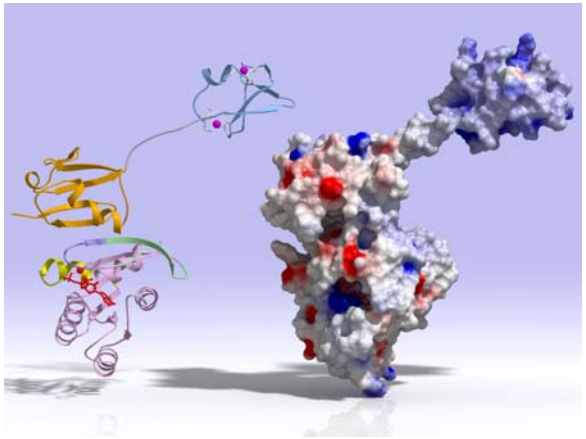
Privacy

- 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
- Users should be aware of being monitored
- Ability to control who/what has access to “my” data (stored, communicated, inferred), ability to define levels of privacy, trust etc

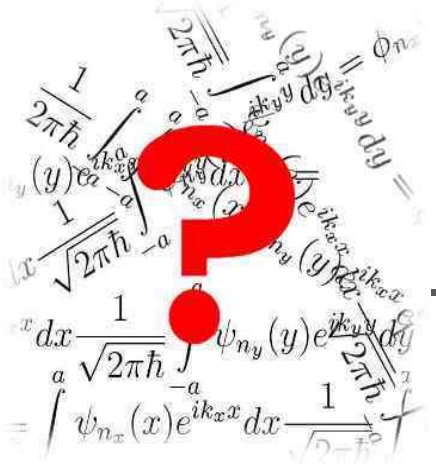
Theory for Pervasive Systems

- We have theory for design and analysis of complex buildings, bridges, electronic circuits

- We need the theory to understand and model complex interactions of pervasive systems

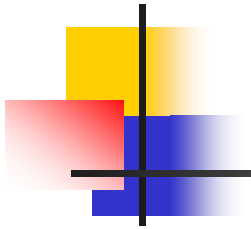


- Currently use ad-hoc implementation, relying on skill of programmers.



Theory Challenges

- Large Scale, complex, dynamically self-modifying system, unplanned interactions ...
- To develop a coherant informatic science whose ***concepts***, ***calculi***, ***theories*** and automated tools allow descriptive and predictive analysis of a pervasive system at many levels of ***abstraction***
- To employ these theories to derive all ubiquitous systems and software, including languages;
- To validate all constructions by these theories and tools.

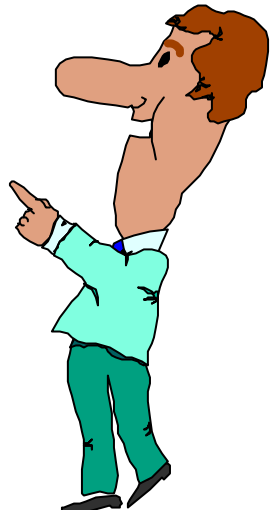


Theoretical Foundations

- **Basic notions** Automata; Relational databases; Program logics; Verication; Mathematical semantics; Type theories; . . .
- **Concurrent systems** Petri nets; Process calculi; Logics of action; . . .
- **Ubiquity** Mobility (ambients, pi calculus); Security and privacy; Boundaries, resources and trust; Distributed data; Game-theoretic models; Hybrid systems; Stochastics; Model-checking; . . .

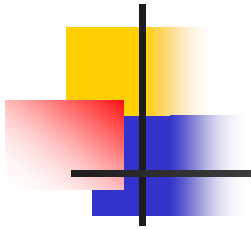
www.cl.cam.ac.uk/users/rm135/plat.pdf

Current UK Activities



- Equator IRC http://www.equator.ac.uk/
- DTI Next Wave Technologies http://www.nextwave.org.uk/index.htm
- EPSRC WINES Program
- Mostly engineering
- Need to develop scientific theory and engineering principles in a tight experimental loop
- UK-UbiNet + Grand Challenges

http://www-dse.doc.ic.ac.uk/Projects/UbiNet/



Conclusion

- Currently pervasive systems are more hype than reality
- Some component technologies are available
- Technology problems - seamless communications, power
- Management problems - adaptive self management
- Security and privacy are major issues.
- Most research focuses on Engineering aspects
- No theory to underpin understanding, analysis & design
- SMC provides a scope for theoretical analysis and implementation
- Adaptive behaviour specified by policies
- Policy analysis and refinement are still difficult problems