

Ubiquitous Computing

- What is ubiquitous computing
- Grand challenges
- UbiComp Engineering issues
- Policy-based autonomic management
- Self managed cells
- Discovery service



Ubiquitous Mobile Interaction and Sensing

Sensors: sound, video, accelerometer, location



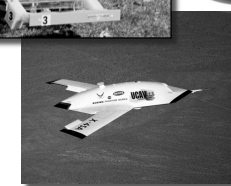
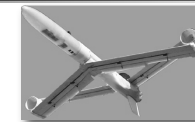
What is Ubiquitous Computing?

- Intelligent devices everywhere: home, office, street, car, trains, on-body, implanted, in appliances
- Mobility
- Battery Powered
- Wireless Communication
- Augment people in performing tasks
- Context aware

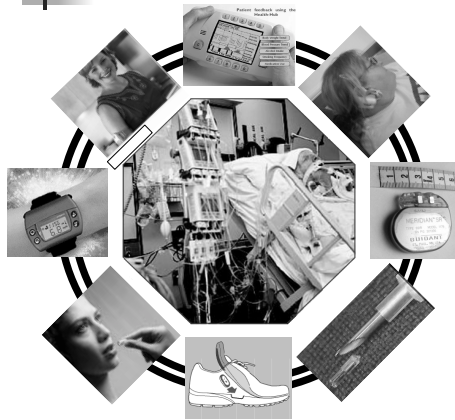
“The Computer of the 21st Century”, Mark Weiser, 1991, Scientific American

Autonomous Unmanned Vehicles

- Each vehicle is an autonomous collection of managed devices with different functional capabilities
- Must be extensible to different sensors and modules
- Can aggregate and collaborate in fleets of autonomous vehicles
- Must interact with external environment



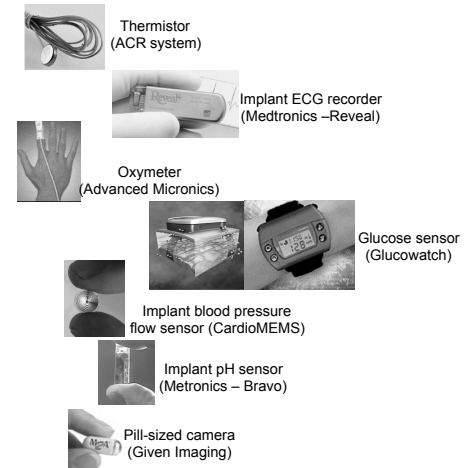
Ubiquitous Healthcare Monitoring



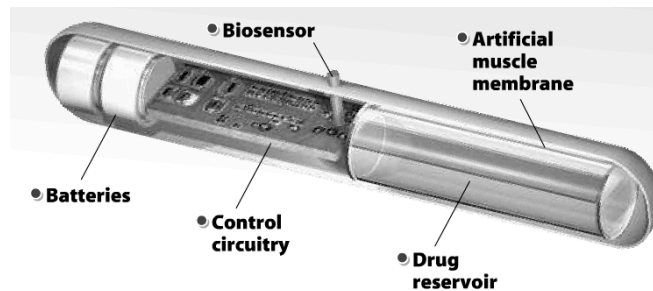
- Dynamic
- Home-based
- Continuous use 24/7
- Preventative
- Earlier diagnosis
- Unobtrusive
- Minimal interventions
- Improving Quality-of-Life
- Anytime
- Anywhere
- Anybody

Healthcare Biosensors

- Thermistor
- ECG
- SpO₂
- Glucose concentration
- Blood pressure
- pH measurement
- Capsule endoscopy



Bioactuators



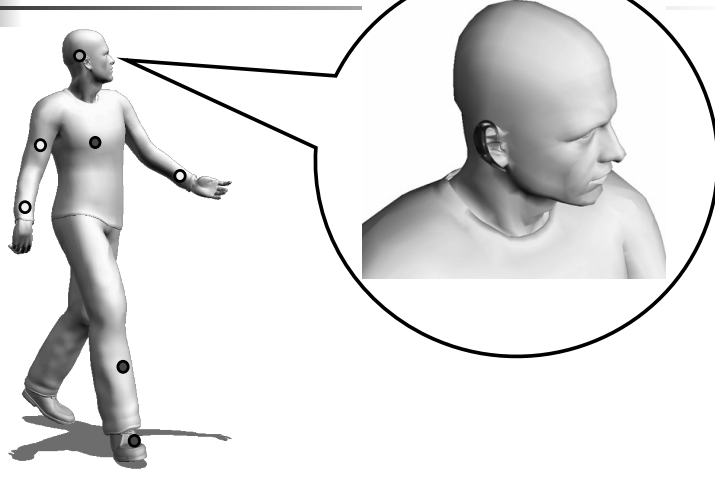
- Drug Delivery System
Smart Pill – Sun-Sentinel Co.

eAR Sensor



Guang-Zhong Yang and Benny Lo
Imperial College London

Optimal Sensor Placement



© GZ Yang and B Lo, Imperial College

Ubiquitous Computing Grand Challenge

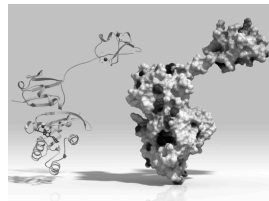
- Experience perspective: how people share world with ubicomp environments, interaction principles, effect on society etc.
- Engineering perspective: architecture & network challenges, dealing with emergent behaviour, engineering principles for designing systems
- Theoretical perspective: concepts and rigorous models to describe behaviour at various levels of abstraction, reason about behaviour, prediction of performance

UbiCompGC manifesto

www-dse.doc.ic.ac.uk/Projects/UbiNet/GC/index.html

Users + Engineering + Theory

- Users are part of the ubiquitous environment
- 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.



Power Management



- Require ultra-low power devices, transmitters etc. for body implants, sensor networks
- Light-weight communication protocols
- Sleep mode + low power modes for reduced QoS
- Energy scavenging..

Energy Scavenging

- **Photovoltaics (Solar cells)**
 - 15-20% efficiency (single crystal silicon solar cell)
 - 15mW/cm² (midday outdoor) to 10μW/cm² (indoors)
- **Temperature Gradients**
 - 1.6% efficiency (at 50C above room temperature)
 - 40 μW/cm² (50C differential, 0.5cm², and 1V output)
- **Human Power**
 - Human body burns 10.5MJ/day (average power dissipation of 121W)
 - 330 μW/cm² (piezoelectric shoe)
- **Wind/Air Flow**
 - 20-40% efficiency (windmills, with wind velocity 18mph)
- **Vibrations**
 - Electromagnetic, electrostatic, and piezoelectric devices
 - 200 μW (1cm³ power converter with vibration of 2.25 m/s² at 120Hz)
- **Nuclear microbatteries**
 - With 10 milligrams of polonium-210, it can produce 50mW for more than 4 months
 - It can safely be contained by simple plastic package, as Nickel-63 or tritium can penetrate no more than 25 mm



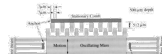
Panasonic BP-243318



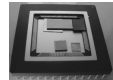
Applied Digital Solutions – thermoelectric generator



MIT Media Lab



MIT – MEMS piezoelectric generator



Cornell University - Nuclear micro-generator (with a processor and a photo sensor)
Distributed Systems © M. Sloman

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

Information Management

- Billions of sensors generating petabytes of (dynamic) data
- Need filtering, aggregation, collaborative sensing, new query techniques which cater for errors in source.
- Meta data description of information
- Provenance → audit trails, how and where modified etc.



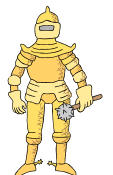
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Security Wish List



- 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

Privacy

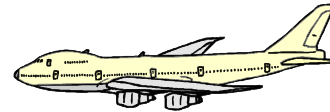


- You are now predictable
 - System can co-relate location, context and behaviour patterns
- Do you want employer, colleagues or insurance company to know you carry a medical monitor?
- Tension between authentication and anonymity – business want to authenticate you for financial transactions and to 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

The Business Model



- Who pays for the pervasive support infrastructure of processing, storage, wireless services everywhere: on the street, in planes, trains, shops, home?
- Accounting and billing
- Environmental issues



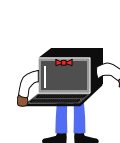
Management – the nightmare!

- Huge, complex systems
 - Billions of processors
 - Multiple organisations
 - Managing physical world, controlling sensors, actuators
 - Humans will be in the way
- Hacker and virus paradise
- 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

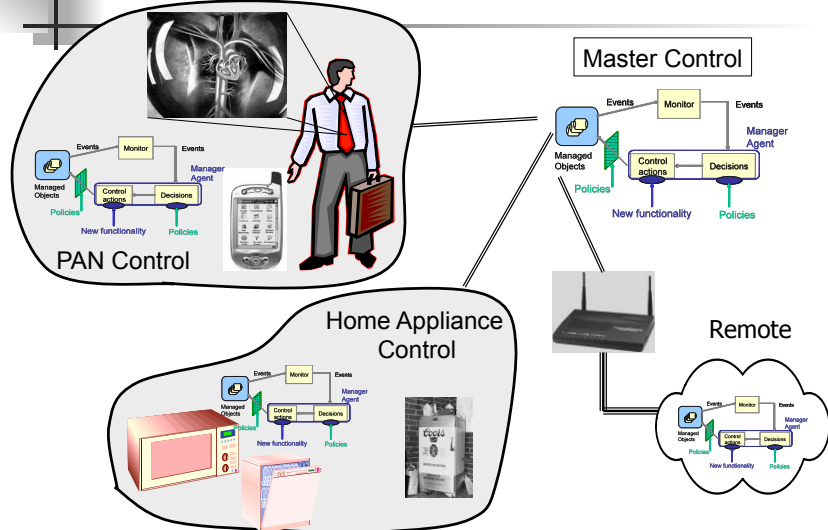


Autonomic Management

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



Policy-Based Control Loops

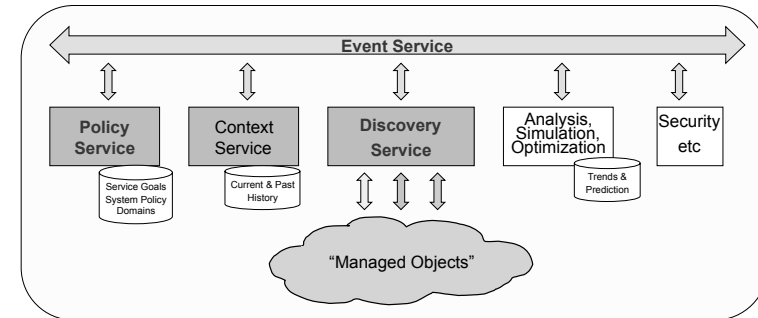


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Self-Managed Cell (SMC)



UbiComp

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What is a Self-Managed Cell?

- A set of extensible hardware and software components forming an administrative domain that is able to function autonomously and thus capable of self-management.
- Management services interact with each other through asynchronous event bus. Permits the use of different service implementations when used at different levels of scale
- Policies provide local closed-loop adaptation.
- Modularization building block with clearly defined interface
- Able to **interact** with other SMCs and able to **aggregate** in larger scales SMCs.
- Scope for design, reasoning and analysis

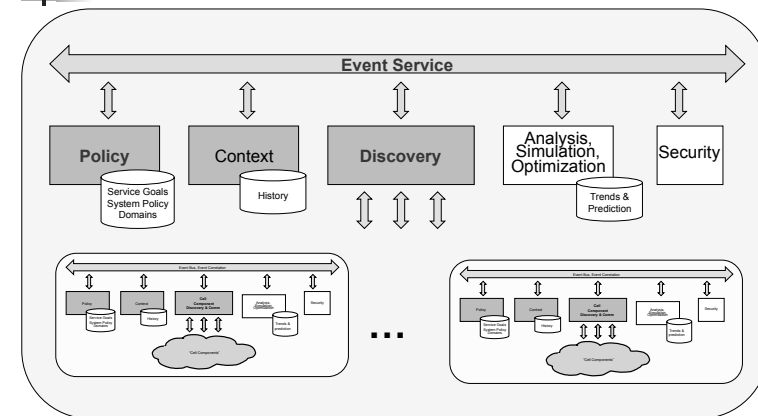
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SMC Composition



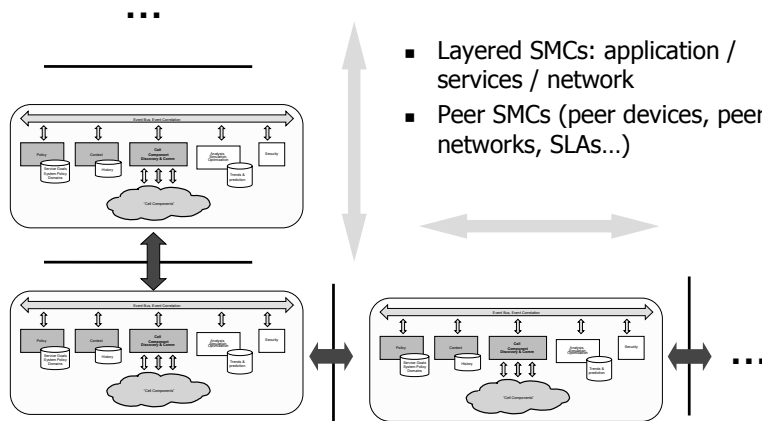
- Enclosing SMC controls the nested SMCs

UbiComp

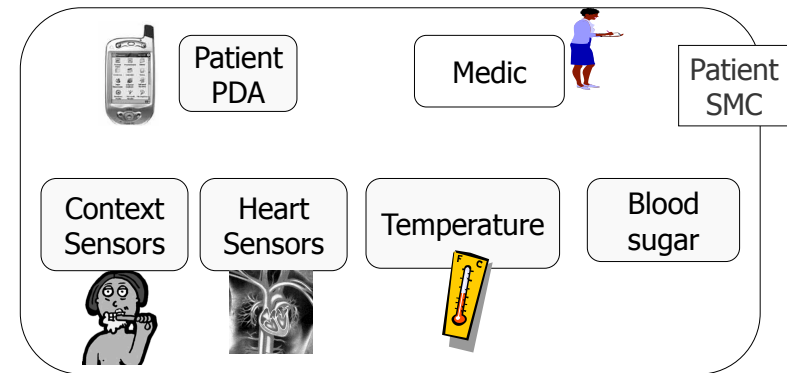
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Layered and Federated SMCs



SMC: Application Roles

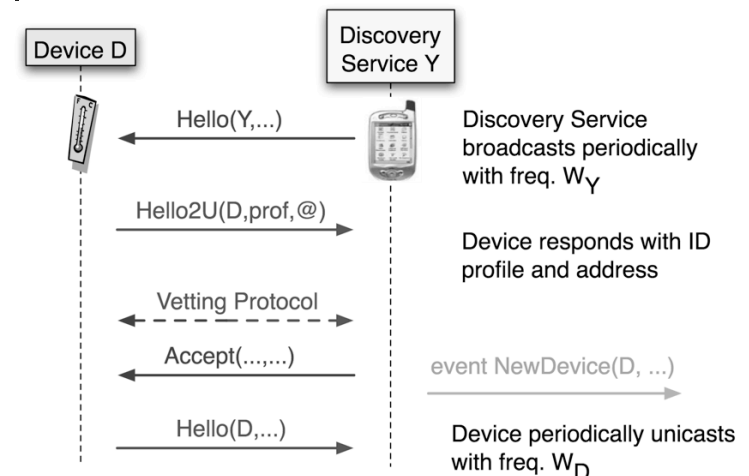


- SMC defines role assignment policies and roles include policies for inter-SMC management behaviour.

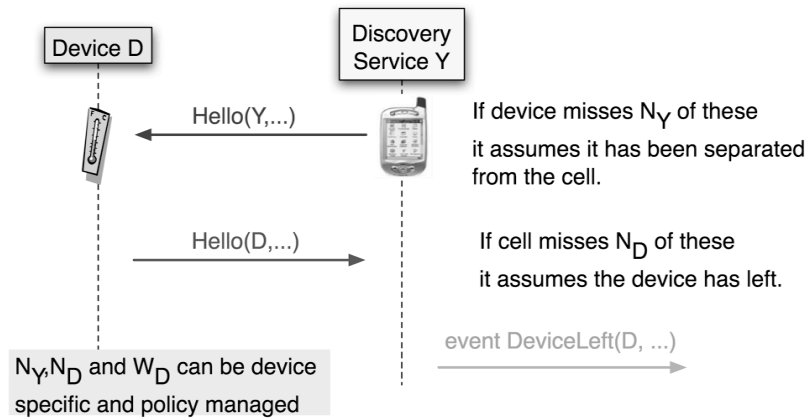
Cell Discovery Service

- Discovers new devices and maintains membership to detect failures and departures from cell.
- Queries device for its profile and services;
- Performs vetting functions e.g. authentication, admission control.
- Listens for new service offers and service removals from the devices
- Generates events to signal new/disconnected devices or software components. Interested services can subscribe, receive and react to these events.
- Own implementation developed to cater for BSN nodes and policy configurable parameters but other protocols e.g., SDP, SLP, ... could be used in other environments.

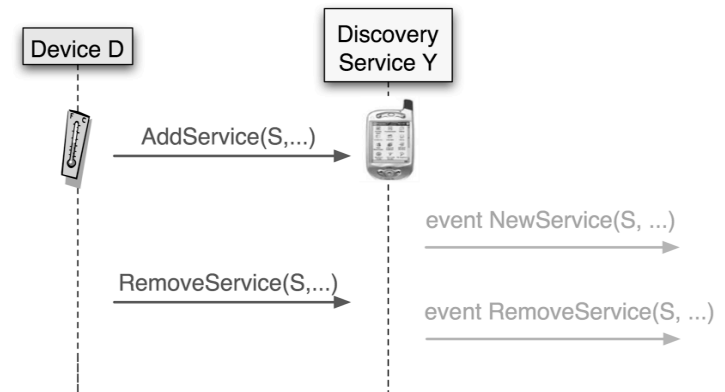
Discovery Service I



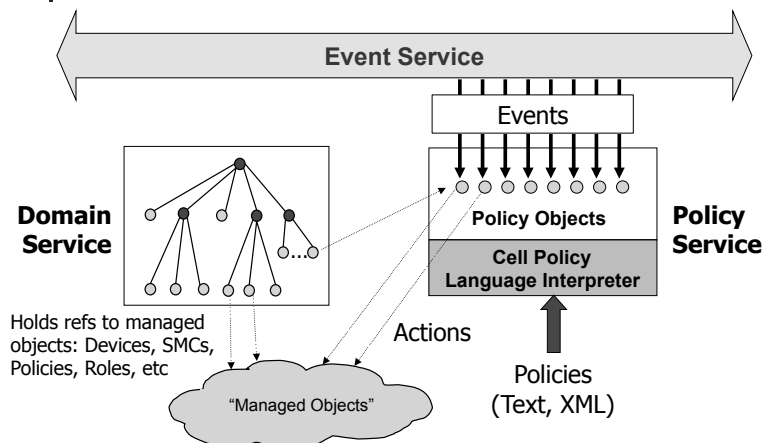
Device Discovery - Separation



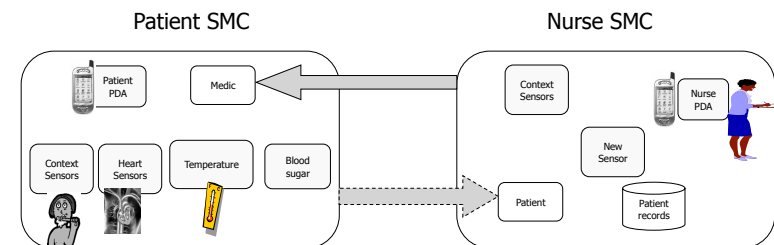
Service/Component Discovery



Cell Policy Service



Peer-to-Peer SMC Discovery



- On SMC discovery, each SMC assigns discovered SMC to pre-defined local Roles.
- Policies for roles apply to assigned SMC.
- SMC Discovery can also result in policy-exchange and sharing of events and services.

Role Assignment Policies

```
on compDetect (X) do if X.profile.type = nurseT &
    signed (X.profile.certificate, nursingCouncil_PK ) then
    /roles/medicRole.add (X)
```

```
on compDetect (X) do if X.profile.type = tempSensorT then
    /roles/temperatureRole.add(X)
```

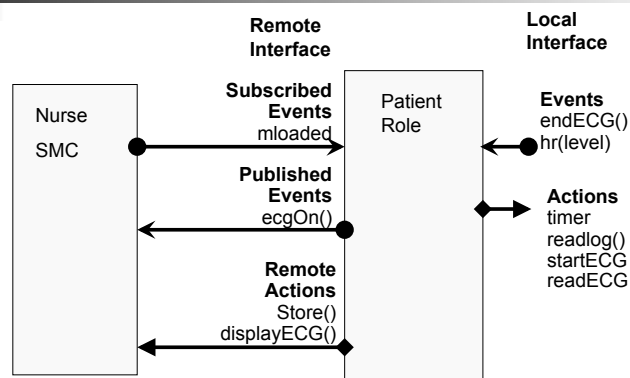
```
every mins (polltime) do
    /roles/temperatureRole/*.poll()
    /roles/medicRole/*.poll()
```

.....
poll all members of a role and remove any which have not responded
after max tries.
.....

Roles

- Role-Domain = placeholder
 - Assign discovered SMCs to Role domain
- Role-Interface = scope for specifying policies
 - Local events & actions
 - Remote events & actions
- Role Mission
 - Set of policies specified in terms of role interface
 - Loaded into SMC assigned to Role domain
 - Unit of configuration – loading, enabling etc.
- Authorisation policies
 - Who can load policies, notify remote events, invoke operations on exported actions

Role Interface

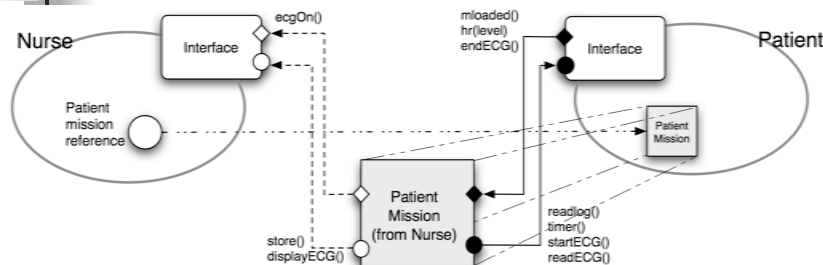


Patient Role Mission from Nurse SMC

```
mission patientT(nurse, patient, ECGlevel, ECGTime) do
    on patient.mloaded() do nurse.store(patient.readlog())
    on patient.hr(level) do
        if level > ECGlevel then
            patient.startECG()
            patient.timer(ECGTime, endECG())
            nurse.ecgOn()

    on patient.endECG() do nurse.display(PatientI.readECG())
}
```

SMCMissions: Policy Exchange



```

auth+ /nurse → /patient.loadMission    // at the Patient
auth+ /patient → /nurse.store           // at the Nurse
auth+ /patient → /nurse.displayECG
on newPatient(p) do
  ref = p.loadMission(/patients.interface, p.interface, 82, 40);
  /roles[p].add(ref)
  
```

Policies to Protect PDA



```

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

```

pda/policies/selfprotect
every minutes (5) do
  sendSMS (07957341, "Stolen PDA", "ownerID", currentLocation)
  
```

```

on shutdown do
  if pda.locked then
    pda.switchoff
  
```

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

Context aware policies

```

on enterhome do
  pda/policies/trusted.enable
  pda/policies/untrusted.disable
  
```

```

on leavehome do
  pda/policies/untrusted.enable
  pda/policies/trusted.disable
  
```

Policy Analysis

- Policy specifications are complex and conflicts may arise due to: **different sources** for the policy specifications or **conflicting goals** e.g., availability vs. maintenance, emergency vs. security, etc.
- Policy Analysis seeks to provide the means to:
 - Review the specification to check expected behaviour in specific circumstances.
 - Ensure consistency of the policy specification i.e. absence of conflicts.
 - Ensure correctness of the policy specification w.r.t desired properties.
 - Ensure minimality of the specification w.r.t achieving a higher-level goal or property.

Policy Refinement

- Seeks to provide the means to derive concrete operational policies from higher-level goals and requirements.
- The set of derived policies must entail the higher level goal/requirement. It further needs to be correct, consistent, minimal and amenable to review. Also, needs to be consistent with other co-existing policies.

Goal: *Protect troop location information from unauthorised disclosure*

Policies regarding:

Who can access location information?

Granularity of the information location provided.

Protection of Information in communications system.

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Summary

- Many research projects but little commercial deployment
- Some component technologies are available
- Key properties – mobility, wireless comms, context awareness
- SMC – policy-based adaptive self management, modularity, scope for implementation and analysis
- Little theory to underpin understanding, analysis & design

References

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